Interaction of Participant Characteristics and Type of AAC with Individuals with ASD: A Meta-Analysis

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Abstract

Individuals with autism spectrum disorders (ASD) and complex communication needs often rely on augmentative and alternative communication (AAC) as a means of functional communication. This meta-analysis investigated how individual characteristics moderate effectiveness of three types of aided AAC: the Picture Exchange Communication System (PECS), speech-generating devices (SGDs), and other picture-based AAC. Effectiveness was measured via the Improvement Rate Difference. Results indicated that AAC has small to moderate effects on speech outcomes, SGDs appear to be most effective when considering any outcome measure with individuals with ASD without comorbid intellectual/developmental disorders (IDD). PECS appears to be most effective when considering any outcome measure with individuals with ASD and IDD. SGDs and PECS were the most effective type of AAC for preschoolers, when aggregating across outcome measures. No difference was found between systems for elementary-aged and older individuals.

Keywords: AAC, augmentative and alternative communication, ASD, autism spectrum disorders, meta-analysis, PECS, speech, SGDs

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Currently, nation-wide, schools are under increasing pressure to incorporate evidence-based practice (EBP) in educational settings (Kratochwill & Stoiber, 2002). One key criterion necessary for qualification of an intervention as an EBP is a clear delineation of the contexts in which the practice yields desired results (Horner et al., 2005; McDonald, Kessler, Kauffman, & Schneider, 2006). For example, it is crucial to determine common characteristics of participants for whom the intervention is most likely to yield practically significant changes (Odom, 2009). This is particularly challenging for the determination of EBPs for individuals with autism spectrum disorders (ASD) given the large degree of variability found for identified individuals. In addition to the broad range of skill levels for core deficit areas (e.g., social, communication), other factors such as age and comorbid disability, will likely moderate overall outcomes of the interventions.

Augmentative and Alternative Communication and ASD

Augmentative and alternative communication (AAC) includes systems designed to supplement or replace spoken or written communication for individuals with temporary or permanent communicative impairments (Cafiero, 2011). AAC is implemented to supplement speech and non-verbal communication (e.g., body language, facial expression) or serve as the main modality of communication when speech is absent. AAC is often implemented with individuals with ASD due to the significant challenges exhibited in terms of receptive and expressive communication (American Psychiatric Association [DSM-5], 2013).

AAC can be divided into two types: aided and unaided. AAC may be implemented without supplemental aids through the use of gestures and sign language (i.e., unaided AAC) or through the use of other instruments, such as pictures, writing, or speech generating devices (i.e., aided AAC; Ganz, Earles-Vollrath, et al., 2012; National Research Council, 2001). One aided AAC intervention, the Picture Exchange Communication System (PECS; Bondy & Frost, 2011) uses pictures as a means for the user to communicate with others by handing a picture or pictures to another individual (Ganz, Davis, Lund, Goodwyn, & Simpson, 2012). Other aided AAC devices, called speech-generating devices (SGDs) may produce prerecorded or computer-generated speech upon the user's command (Millar, Light, & Schlosser, 2006). While PECS and SGDs are the most researched types of aided AAC, additional aided AAC systems, which are referred to here as "other picture-based AAC," are in use and include picture boards and pointing systems (Ganz, Earles-Vollrath, et al., 2012).

Current empirical research supports the use of aided AAC systems (e.g. PECS, SGD) as an evidence-based practice for enhancing communication (Ganz et al., 2011; Ganz, Earles-Vollrath, et al., 2012; Millar et al., 2006). However, given the variability in both the type of AAC interventions as well as the heterogeneity of skills and characteristics among individuals with ASD, it is difficult to establish that a particular type of AAC system will be effective for a given individual. While the use of AAC meets evidence-based standards due to sufficient rigor and number of studies, the broad range of systems and participant characteristics suggest a lack of specificity necessary for practitioners to make informed decisions. Given this variability, more information is needed to guide educational and therapeutic decision-making. Additionally, information regarding pre-intervention characteristics that will likely moderate increased speech production is an area in need of exploration. Parameters for choosing which AAC intervention to implement when given a particular set of participant characteristics are currently unavailable (Flippin, Reszka, & Watson, 2010).

Meta-analysis of Single-Case Experimental Design

Recently, meta-analyses have been used more frequently to provide aggregated results of multiple single-case research studies to determine the overall effectiveness of interventions for individuals with disabilities (Parker, Vannest, & Brown, 2009). Meta-analysis of single-case research involves the use of effect size measures. Such techniques allow for the aggregation of numerous small-scale studies, such that results are able to be viewed with more confidence than when considering studies individually or via literature reviews. Although meta-analysis is not without controversy (Schlosser & Pennington, 2005) in the fields of special education, speech-language pathology, and applied behavior analysis in general, and augmentative and alternative communication in particular, these fields have not dismissed the potential for statistical methods to synthesize single-case research. Instead, it has been noted that there is not one method of meta-analysis agreed upon by statisticians, primarily due to difficulties meeting the assumptions inherent in many of the statistical methods proposed (Kratochwill et al., 2013). Indeed, statistical analysis of single-case research is noted in a paper written by national experts for the major federal funder of education research grants, the Institute of Education Sciences (Kratochwill et al., 2010), and meta-analyses of single-case research are becoming prominent in the special education literature (Bowman-Perrott, Davis, Vannest, Greenwood, & Parker, 2013; Mason, Davis, Boles, & Goodwyn, 2013). More specifically, effect sizes may be computed to summarize across cases if a common metric is used or over classes of outcomes (Burns, 2012; Kratochwill et al., 2010). These issues will continue to be examined as newer effect sizes are tested via meta-analysis of single-case research (Horner & Kratochwill, 2012).

To date, Percent of Non-overlapping Data (PND) is the most published measure of effect in single-case research (Parker et al., 2009; Scruggs & Mastropieri, 1998). Despite its popularity, its 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. Further, PND relies on a single data point in phase A, which may be an outlier; thus, skewing the score. These shortcomings have resulted in recent investigations of new, more robust effect size measures, such as Improvement Rate Difference (IRD) (Parker et al., 2009). “Risk difference,” the model from which IRD was developed, is frequently used for research in the medical field (Altman, 1999; Sackett, Richardson, Rosenberg & Haynes, 1997). The Cochrane Collaboration (2006) deems risk difference to be a legitimate measure of treatment efficacy in evidence based medicine (http://www.cochrane.org/).

IRD has a number of benefits. These include the ability to conduct simple hand calculation of the effect size, the usefulness of IRD as a complement to traditional visual analysis of data, the ability to calculate confidence intervals that enable comparisons between scores, and the freedom from most distribution assumptions (Parker et al., 2009). IRD has recently been used in a number of meta-analyses of single-case research (Ganz et al., 2011; Ganz, Davis, et al., 2012; Ganz, Earles-Vollrath, et al., 2012; Mason, Ganz, Parker, Burke, & Camargo, 2012, Vannest, Davis, Davis, Mason, & Burke, 2010). Further, because IRD is a “bottom-up” approach to synthesizing single-case research, it may be more appealing and useful because it more accurately matches the visual analysis approach that is the tradition in single-case research compared to other statistical analyses that require top-down approaches (Parker & Vannest, 2012).

IRD, as used in single-case research, is the difference or change in percent of high scores from baseline to intervention phases (Parker et al., 2009). For example, if baseline has 20% high scores, and the treatment phase has 90% high scores, IRD will be 90%-20%=70%. Thorough instructions for calculating IRD are provided by Parker et al. (2009). Briefly, an “improved” data point in baseline (A) is one that is higher than (or lower than if the dependent variable is intended to be decreased) some intervention (B) data points, and a “not improved” data point in B is one that is below some phase A data points. Parker et al. suggest this interpretation of IRD scores: IRD scores below .50 suggest small effects, IRD scores from.50 to .70 suggest moderate effects, and IRD scores that are .70 or .75 or higher suggest large or very large effects.

Elaboration on pre-intervention skill levels that moderate effects, via meta-analytic techniques, would assist in narrowing practitioners’ options for intervention. There has been a reluctance to implement AAC interventions with some individuals with ASD (Millar et al., 2006) due to the concern that a secondary communication system would discourage speech production (Flippin et al., 2010; Romski & Sevcik, 2005). However, analysis of differential effects in speech production that occur when pre-intervention levels are considered has not been previously assessed via a meta-analysis of available studies to a level that would allow for the identification of moderating factors. That is, previously, there was not a large enough number of single-case studies that reported participants’ prior level of speech and results related to speech outcomes to allow for fine-grained analyses using meta-analytic techniques.

Millar et al. (2006) conducted a meta-analysis that used Percentage of Nonoverlapping Data (PND) to measure the increase in speech production for individuals with developmental disabilities and speech impairments after the implementation of AAC devices. The review of 27 studies published between 1975 and 2003 indicated increases in speech production for the majority of participants and no evidence of decreases in speech. Hart and Banda (2010) used PND to meta-analyze research on PECS. However, PND analyses do not allow for analysis of differential effects that might occur, due to the lack of calculable confidence intervals, with varying levels of preintervention speech production. Flippin et al. (2010) also conducted a meta-analysis of PECS interventions for individuals with ASD (participants with other categorical disabilities or comorbid disorders were excluded). Results indicted PECS had minimal effect on speech outcomes based on the use of PND and Glass's delta effect sizes. The impact of other aided AAC interventions such as SGDs was not analyzed. Neither Millar et al. nor Flippin et al. provided information regarding differential effects on speech production outcomes that might have occur due to pre-intervention speech levels. While Hart and Banda found positive results related to speech outcomes, these results are limited by the use of PND.

Ganz, Earles-Vollrath, and colleagues (2012) meta-analytically reviewed 24 single-case studies published between 1980 and 2008 that implemented aided AAC interventions (i.e., PECS, SGDs, and other picture-based AAC) for participants with ASD to determine differential effects that occurred due to the type of AAC device utilized and effectiveness on categories of dependent variables (i.e., communication, social skills, challenging behaviors, and academic skills). Using improvement rate difference (IRD) effect sizes, results indicated moderate to large effect sizes across types of AAC, with PECS yielding a larger effect size ($p<.05$) than other systems. Although Ganz, Earles-Vollrath, et al. (2012) provided additional information regarding specific intervention effects, participant characteristics were not included as moderators in the meta-analysis.

Meta-analyses of AAC systems have previously documented differential effects that occur when the type of AAC device (Ganz, Earles-Vollrath, et al., 2012) and when participant characteristics, specifically age and disability, are considered (Ganz et al., 2011). Results indicated larger effect sizes ($p<.05$) for preschool age participants (5 and under) compared to older participants. Furthermore, results indicated AAC methods to be most effective for participants with a diagnosis of ASD and no other comorbid disorder. However, Ganz et al. (2011) aggregated all types of aided AAC systems and did not provide specificity regarding the type of AAC that might be more effective for each age and/or diagnostic category. For instance, Ganz et al. (2011) indicated AAC to be most effective for preschool-aged participants, yet this study did not indicate if differential effects were present when PECS was implemented as opposed to SGD devices for these participants. Additionally, Ganz et al. (2011) indicated that differential effects were present for included studies when diagnostic category was considered, noting that aided AAC in general was only moderately effective for participants with ASD and multiple disabilities. Development of specific guidelines for AAC decision-making would require further specificity than what was provided by these meta-analyses. Categorizing effects of particular types of aided AAC interventions by participant age and diagnostic categories would provide practitioners with information by which to make informed intervention decisions, allowing them to match interventions to their particular clients.

Purpose and Research Questions

One purpose of this meta-analysis was to provide a more up-to-date analysis on three types of aided AAC (i.e., PECS, SGDs, and other picture-based AAC) than previous meta-analyses. That is, although Ganz et al. (2011) and Ganz, Earles-Vollrath, et al. (2012) recently published meta-analyses on aided AAC use with individuals with ASD, the current meta-analysis includes an additional 11 articles that were published between 2009 and 2011. A second purpose of this meta-analysis is to provide a more fine-grained investigation of the differential impact of AAC systems with regard to participant characteristics, including the differential impact of AAC on speech production with regard to speech of the participants at study onset. This was possible due to the addition of the more recent articles, which allowed for a sufficient number of studies to be included in more refined subcategories than previously investigated via meta-analysis. Research questions investigated included: (a) does AAC implementation have differential impacts on speech outcomes related to participant speech abilities at onset of intervention; (b) are there differential effects for individual types of AAC interventions on overall AAC outcomes based on the participant's presence or absence of co-morbid disabilities; and (c) are there differential effects for individual types of AAC interventions on overall AAC outcomes based on the participant's age at time of implementation?

Method

Literature Search

Literature investigating the use of AAC with learners with ASD was reviewed for this meta-analysis. Online databases including *Social Sciences Full Text*, *Education Full Text*, *ERIC*, *PsychINFO*, and *Professional Development Collection* were used to search for documents published between 1980 and September 2011. Each of the following keywords were used in the search: *Asperger**, *Asperger syndrome*, *Asperger's syndrome*, *ASD*, *autis**, *autism spectrum disorder**, *PDD*, *PDD-NOS*, and *pervasive developmental disorder** combined with each of the following keywords: *augmentative communication*, *alternative communication*, *AAC*, *augmentative and alternative communication*, *Picture Exchange Communication System*, and *PECS*. In this search, 292 articles, books, book chapters, dissertations, and other literature were found.

Procedures

Each of the documents were evaluated to determine if they met the following criteria, based on the criteria used by Ganz, Earles-Vollrath, et al. (2012): (a) at least one participant had a diagnosis of a pervasive developmental disorder (i.e., autistic disorder, Asperger syndrome, or pervasive developmental disorder – not otherwise specified); (b) dependent variables included academic skills, challenging behavior, communication, and/or social skills; (c) independent variables were aided AAC system; (d) single-case research designs were implemented that could demonstrate experimental control (e.g., reversal/withdrawal, multiple-baseline); (e) line graphs of the data were included; (f) articles were peer-reviewed; and (g) articles were written in English. The works that did not meet all of the inclusion criteria were not included in the meta-analysis.

Two raters independently considered 72% of the documents to determine whether all of the inclusion criteria were met. If the two authors disagreed on the acceptance or rejection of a document, either a third rater considered the document further and the final decision was the one made by the majority of authors, or the two raters discussed the document to come to consensus. Dissertations and descriptive articles made up most of the rejected documents. Another common reason that articles were rejected was that the single-case designs used were not designed to demonstrate experimental control (e.g., A-B-A designs). After the articles were chosen, one rater did a hand-search of the reference sections of the accepted articles to find any additional articles that met the criteria. When data collection and analysis began, three of the originally included articles were later excluded because there were no baseline data to allow analysis that was comparable to the other articles (Beck, Stoner, Bock, & Parton, 2008), the investigators faded AAC use and began requiring verbalization so we were unable to distinguish data that applied only to AAC use (Ostryn & Wolfe, 2011), and the text of one article identified it as a multiple-baseline design while there was not evidence of this design in the article and graph (intervention did not appear to have been implemented in a stepwise fashion across behaviors; Travis &

Geiger, 2010). Following these procedures, a total of 35 articles were accepted for inclusion in the meta-analysis.

Data Extraction

All of the articles accepted for the meta-analysis were analyzed and summarized. The following elements were coded for each article: authors(s) and year, participant diagnoses, participant ages, number and sex of participants, type of aided AAC implemented (i.e., PECS, SGDs, and other picture-based AAC), target behaviors, summary of the results, overall quality of the research, speech at onset of the study, and setting. Table 1 summarizes the articles. The age, diagnosis, type of intervention, target behaviors, previous skills, and setting were recorded in the table. Further, key moderators were coded for use in IRD analyses, as described in the next section.

Measurement of Effect Sizes and Forest Plots

The Improvement Rate Difference (IRD), an effect size measure, was calculated, along with confidence intervals, by analyzing the data for magnitude of change between baseline and intervention phases (Parker et al., 2009). Generalization and maintenance data were not used for calculating IRD because studies did not consistently include generalization and maintenance data points. IRD is a comparison of high scores in baseline to those in intervention (Parker et al., 2009). That is, scores in both phases are compared and categorized as improved or not improved, related to the researcher's expectation. For example, one would expect challenging behaviors to decrease as a result of intervention; thus, high rates of behavior in baseline would be considered to be "not improved" while low rates of behavior in the intervention phase would be considered to be "improved." These scores are translated into ratios of improved over not improved+improved (total data points) and the "improvement rate" of the baseline phase is subtracted from the improvement rate of the intervention phase to come up with the difference, i.e., a score between 0 and 1, or the IRD. Parker et al. (2009) suggest the following interpretation: scores under .50 are small or chance effects, scores between.50 and .70 are moderate effects, and scores of .70 or better are large or very large effects. Further information regarding how IRD is calculated is provided in detail in Parker et al. (2009). IRD scores and their corresponding 83.4% confidence intervals for moderator categories were graphed in forest plots for ease of interpretation. The decision was made to use 83.4% CI because comparison of two 83.4% CIs corresponds with an inference test at p=.05 (Browne, 1979; Payton, Greenstone & Schenker, 2003; Payton, Miller & Raun, 2000; Schenker & Gentleman, 2001), with non-overlapping CIs indicating statistically significant ($p = .05$) differences. This allows the reader to visually determine statistical significance (p=.05) between IRD scores as illustrated on forest plots in figures 1-3. Additionally, 83.4% CIs are sufficient for decision-making regarding implementation of interventions in educational and therapeutic settings that are not high stakes (Parker, Vannest, Davis, & Clemmons, 2010).

The following aggregate IRD scores were calculated. First, omnibus effects were calculated by aggregating all of the IRD scores for all of the dependent variables measured in each study. This provided an overall effectiveness estimate for aided AAC in general across AAC outcomes. However, because this overall score provides little information without dividing the data into subcategories, IRD scores were combined by moderators.

Speech outcomes based on speech at outset of study. Studies measuring speech outcomes as a dependent variable were examined by the amount of speech exhibited by participants at the outset of the study. Level of speech was determined based on the narrative descriptions of the participants reported in each article. Standardized communication assessment scores were not provided for most of the included articles. Two initial speech categories, *some speech* and *non-speaking* at outset, were analyzed. Some speech was defined as minimal speech, which may have been spontaneous but was usually prompted and may have only occurred in imitation. Participants with no speech had no vocalizations or used 10 or fewer words spontaneously and functionally, as described before study commencement. Thus, to evaluate the impact of aided AAC on speech outcomes based on level of speech at the beginning of the studies, IRD scores were categorized and combined in the following ways. IRD scores for all speech dependent variables were isolated (i.e., IRD scores for all other variables, such as use of AAC system to communicate, were excluded) and separated into two groups of participants: those who initially had some speech and those who had none. Then, those moderator group IRD scores were analyzed to allow for the comparison of effects.

Disability category and type of AAC. Participant outcomes were evaluated by examining individual disability category and disaggregated by type of AAC. Unlike in previous meta-analyses (e.g., Ganz et al., 2011), in which diagnostic co-morbidity was determined based solely on articles' declaration of participants' diagnoses of ASD or ASD with an intellectual/developmental disability (IDD), the current study considered assessment data reported by study authors. That is, participants may have had IDD yet were referred to within the original article as individuals with an ASD, not specifically as also having IDD; thus, for the current meta-analysis, participants were considered to have *ASD and IDD* if the article indicated delays of more than 2 years below actual age via age equivalents on standardized adaptive behavior scales, or scores below 70 on standardized adaptive behavior scales, or IQs below 70.

The *type of AAC* moderator variable was divided into three levels. PECS included cases in which the article specified that PECS was implemented and the PECS procedures (Bondy &

Frost, 2011) were specified and reportedly followed. *SGD* included any studies that reported implementing AAC with speech-generating devices or voice-output communication aids. *Other picture-based AAC* included cases that reported using static pictures or photos as expressive AAC systems that did not follow the PECS protocol (Bondy & Frost, 2011).

To calculate aggregate IRD scores, scores were grouped by both type of aided AAC implemented in the study and the participant's diagnosis/diagnoses. That is, IRD scores for all dependent variables were aggregated, but subdivided by two moderators. That is, for example, those IRD scores for participants with ASD only who were taught to use PECS were combined, while scores for participants with ASD and IDD who were taught PECS were combined into another aggregate IRD score, and so forth for each comorbid diagnosis and type of aided AAC.

Age and type of AAC. Similarly to the techniques used to aggregate scores by comorbidity and aided AAC type, scores were also categorized by the moderators of age and type of aided AAC. Thus, for example, aggregate IRD scores for preschool participants using SGDs could be compared to aggregate IRD scores for preschool participants using PECS. Participant age ranges were specified as preschool (0 to 5 years), elementary (6 to 10 years), or secondary participants plus adults (11 years and above).

Inter-rater Agreement for Effect Size Calculations

Each of the 35 articles in the current meta-analysis had more than one IRD score, due to the inclusion of multiple participants and dependent variables. As a result, there were 274 total IRD calculations. The improvement rate cells (number of improved and unimproved data points for both baseline and intervention phases) for one hundred forty-five (53%) were independently calculated by two raters. Inter-rater agreement was determined by dividing agreements (111) by the total IRD calculations (122), resulting in an inter-rater agreement of 88%. All disagreements were then discussed by both raters and recalculated as necessary until agreement was reached. The few disagreements that existed were due to difficult-to-view crowded graphs and counting errors.

Results

Descriptive Analysis

The 35 studies that were included in the analyses are summarized in Table 1. Some moderator categories have sums that exceed the total number of participants or studies because they fit within multiple categories, for example, some studies included participants with both ASD and with ASD and IDD. Also of note, some studies were not specific in providing thorough participant information (e.g., study stated age range of participants spanned both preschool and elementary ages but did not specifically note age of each participant); thus, those participants were excluded from the categorical moderator analyses. Nine studies included measures of speech as a dependent variable and were included in the analysis of the impact on speech outcomes based on speech at study onset. Within those 9 studies, 6 participants started the study with no speech and 9 participants with some speech. The remaining analyses included all dependent variables measured in the studies. Overall, 16 of the included studies involved implementation of PECS, 10 implemented SGDs, and 10 implemented other picture-based AAC. Of the participants included in this meta-analysis, 43 had ASD only and 38 participants had ASD and IDD. Three participants had ASD, IDD and sensory disabilities. Considering ages of participants, 40 were preschool-aged, 25 were elementary-aged, 13 were secondary-school-aged or older, and the remainder were unspecified and unable to be included in the age-related analysis.

Omnibus Effects

Data from this meta-analytic review yielded 274 separate effect sizes from 35 studies on 81 participants. The mean IRD for the 35 studies was .71 [.69, .72] with a range of .00 to .95. Given the variability of effectiveness of AAC for participants with an ASD, we examined the interaction between participant characteristics and types of AAC to determine if these interactions could explain the variability of effect size scores.

Speech Outcomes Based on Speech at Outset of Study

Within the speech dependent variable, some speech at outset had 14 separate effect sizes from 6 studies with (IRD = .55, range = .00 to .92). The non-speaking at outset variable had 23 separate effect sizes from 4 studies (IRD = .43, range .00 to .85). As demonstrated in Figure 1 by the lack of overlap between the CIs, the difference between the two mean IRD effect sizes was statistically significant (p<.05). Participants with some speech had significantly better effects on speech than children with no speech at study outset.

Disability Category and Type of AAC

The first disability category analyzed was the sole diagnosis of an *ASD* (see Figure 2). Within this disability category, PECS had 90 separate effect sizes from 11 studies (IRD = .68, range = .00 to .94). Studies utilizing SGDs had 38 effect sizes from 5 studies (IRD = .74, range .00 to .94). Finally, studies utilizing other picture-based AAC had 15 separate effect sizes from 3 studies (IRD = .74, range = .36 to .83). The lack of overlap of confidence intervals in the forest plot (Figure 2) indicates that there were no statistically significant differences between types of SGDs and other picture-based AAC for participants with a sole diagnosis of an ASD; however, a statistically significant (p = .05) larger effect size was obtained for SGDs than the IRD obtained for PECS for this population. IRD scores for all types of AAC demonstrated at least moderate effects.

The second disability category analyzed was an ASD with IDD. Within this disability category, PECS had 20 separate effect sizes from 6 studies (IRD = .84, range = .34 to .95). Studies utilizing SGDs had 73 separate effect sizes from 7 studies (IRD = .70, range = .00 to .93). Other picture-based AAC had 35 separate effect sizes from 9 studies (IRD = .63, range = .00 to .89). As illustrated by the lack of overlap between confidence intervals on Figure 2, for individuals with ASD and IDD, PECS demonstrated statistically significant larger effects than both of the other types of aided AAC and SGDs were more effective, at a statistically significant ($p = .05$) level, than other picture-based AAC.

Further, PECS was more effective, for individuals with ASD and IDD than individuals with ASD only. In fact, mean IRD for ASD with IDD disaggregated by PECS produced a statistically significant difference compared to all other mean IRDs calculated. No statistically significant difference was found between the effectiveness of SGDs with participants with an ASD and participants with an ASD and IDD. As seen in Figure 2, the lack of overlap between the obtained CIs for participants with an ASD and participants with ASD and IDD, indicates a statistically significant difference exists when other picture-based AAC is implemented, with participants with an ASD yielding a greater magnitude of change. There were not enough IRD calculations for participants with ASD, IDD, and sensory impairments to allow for comparisons across types of AAC.

Age and Type of AAC

Participant outcomes were analyzed by participant age by type of AAC utilized (see Figure 3). The first age group examined was preschool participants (0 to 5 years). Within this age group, PECS had 60 separate effect sizes from 11 studies (IRD = .75, range = .05 to .95). SGDs had 24 separate effect sizes from 3 studies (IRD = .80, range = .19 to .91). Finally, other picture-based AAC had 37 separate effect sizes from 5 studies (IRD = .61, range = .00 to .87). For preschoolers, no statistically significant difference was found between the effectiveness of PECS and SGDs, but both yielded statistically significant differences when compared to other picture-based AAC which yielded the smallest effect size. The second age group analyzed was elementary participants (6 to 10 years). Within the elementary age group, PECS had 38 separate effect sizes from 7 studies (IRD = .67, range = .00 to .92). SGDs had 44 separate effect sizes from 5 studies (IRD = .69, range = .00 to .94), and other picture-based AAC had 9 separate effect sizes from 4 studies (IRD = .75, range = .00 to .89). For elementary participants, statistically significant differences between effects across type of AAC were not found.

The final age group analyzed was secondary participants plus adults (11 years and above). PECS, when utilized with this age group, had 15 effect sizes from 4 studies (IRD = .65, range = .00 to .87), and SGDs had 19 effect sizes from 1 study (IRD = .63, range = .21 to .86). Other picture-based AAC disaggregated by the secondary plus adult age group only yielded four IRD calculations and therefore was not included in the analysis. No statistically significant differences were found for the secondary plus adult age group by type of AAC.

Further, when examining confidence intervals by type of AAC, PECS was found to have a statistically significant larger effect for preschoolers than any other age group. Like PECS, SGDs were also more effective at a statistically significant level for preschoolers than other age groups. Finally, other picture-based AAC with preschool participants yielded statistically significant smaller effect size than other picture-based AAC with elementary participants.

Discussion

Overall, this meta-analysis investigated the impacts of three types of AAC on participant outcomes by examining differential effects based on the characteristics of the participants.

Specifically, impacts related to participant speech levels prior to implementation of AAC, comorbid diagnoses, and ages of the participants were examined. These investigations were further parsed according to the three types of aided AAC included in the analyses. Therefore, this work provides more fine-grained analyses than provided by previous literature reviews and meta-analyses (Flippin et al., 2010; Ganz et al., 2011; Ganz, Davis, et al., 2012; Ganz, Earles-Vollrath, et al., 2012; Millar et al., 2006).

The first question investigated in this study considered whether there were differential effects of AAC on speech outcomes depending on the initial level of speech displayed by the participant. No previous meta-analyses have investigated the impact of aided AAC on speech outcomes with consideration for differential impacts based on initial speech functioning. Not surprisingly, participants who began with more speech had better collateral speech outcomes than participants who did not speak or who used little spontaneous, functional speech at the outset of the study. However, the results are encouraging, particularly considering PECS, which was the AAC type for which speech outcomes were most often measured (6 of the 9 studies investigating speech outcomes implemented PECS). Caregivers often comment that their children will use AAC as a “crutch” instead of speaking (Flippin et al., 2010; Millar et al., 2006). However, this meta-analysis supports Romski and Sevcik’s (2005) contention that for children who can talk, particularly those who had at least some functional speech, aided AAC will likely have at least small effects on speech outcomes. Further, although there were lower effects for children who began the studies with little to no functional speech, there were at least small to moderate improvements in speech for many of these children. This is important information because it indicates that, rather than impeding speech developoment, in some children, implementation of aided AAC, particularly PECS, may enhance, or at least is unlikely to inhibit, speech. Although promising, it should be noted that only a total of 9 studies were included in this analysis, due to the limited number of studies that measured speech as a collateral outcome. Thus, results should be viewed with some caution. Further research that included measures of speech outcomes would strengthen the validity of these results.

Results of this meta-analysis provide an update to the previous meta-analyses of aided AAC (Ganz, Earles-Vollrath, et al., 2012; Ganz et. al, 2011), adding approximately two additional years of single-case studies, and allowing for more in depth analyses of participant characteristics. This study extended the previous meta-analyses regarding disability category (Ganz, Earles-Vollrath, et al, 2012). Participants were recategorized to include a broader definition of developmental disabilities. That is, although participants in many studies were only identified as having an ASD, their standardized assessments indicated that they had additional delays; thus, this study categorized such individuals as having both ASD and IDD. This likely provides a more accurate description of the participants and this modification plus the addition of more studies allowed for a finer grained analysis of what type of AAC is most effective with individuals with and without comorbid intellectual/developmental.

This meta-analysis resulted in evidence that, for participants with ASD without additional comorbid disabilities, SGDs were significantly more effective on various dependent variables than PECS, though no other differences were detected among types of AAC for individuals with ASD only. However, caution in interpreting these results is warranted; the SGD data were gleaned from only 5 studies. It is possible that, given significantly more research on the use of SGDs with individuals with ASD only would have weaker results. The results of this meta-analysis indicate that PECS is more effective than SGDs and other picture-based systems on dependent variables in general when implemented with individuals with both ASD and IDD.

Further, SGDs were found to be significantly more effective with this population than other picture-based systems. It may be that the act of physically exchanging pictures to receive preferred items provides a concrete understanding of asking for and receiving items. A reliance on concrete (e.g., visual, gross motor) versus abstract communication may be particularly useful when working with individuals with IDD. Again, some caution is warranted given the limited number of studies for PECS (6 studies) and SGDs (7 studies); however the difference between PECS and SGDs is notable.

The current meta-analysis also extended the previous meta-analyses by investigating the interaction between participant age and type of AAC. According to the findings, for preschoolers, both PECS and SGDs were significantly more effective on dependent variables in general than other picture-based AAC. Results regarding the moderate to large effects of PECS on preschoolers is relatively strong, given that they were gleaned from 11 studies, thus, this effect size has a narrow confidence interval; however, results for the use of SGDs and other picture-based AAC must be interpreted with more caution. The comparison with PECS must be interpreted with some caution, given the low number of studies that investigated the use of these types of AAC with very young participants.

Differences in effectiveness on dependent variables in general between the types of AAC did not hold up for older individuals. That is, there was no significant difference found between PECS, SGDs, or other picture-based AAC for elementary participants, nor between PECS and SGDs for adults. It may be that the older individuals had more experience in general with picture-based communication and symbols through the use of picture schedules, aided AAC, and visual supports, possibly explaining the lack of a significant difference in effectiveness between the systems for participants older than preschool-aged. It is possible that, given the small number of adult participants, differences in effectiveness may become more apparent given additional studies. Also of interest, implementation of PECS and SGDs for preschool participants were significantly more effective than they were for older participants, albeit these types of AAC were still found to be at least moderately effective for all age groups.

There are some limitations to this study. First, several moderators, when combined, included few studies in each level. For example, we were unable to evaluate the impact on individuals with ASD and sensory impairments across types of aided AAC due to the small numbers of studies with individuals with sensory impairments. Second, this meta-analysis is limited to single-case research studies. Thus, larger group studies were excluded, though they may provide valuable information regarding the efficacy of AAC for use with individuals with ASD. Third, although some conclusions can be drawn from this work, in some cases, results within combined moderator levels were drawn from a small number of studies, thus limiting the ability to draw firm conclusions. Fourth, the types of AAC identified were grouped by the particular communication mode for two categories (SGDs and Other Picture-Based AAC), while one referred to both a mode and a specific teaching protocol. Thus, the categories selected were dissimilar and a meta-analysis investigating specific intervention procedures may be warranted.

This meta-analysis provides justification for several future avenues for investigation. The majority of the studies investigating speech outcomes involved implementation of PECS; thus, while results relating to speech outcomes were low to moderate, these results can only be applied to PECS with any confidence. Further single-case or large group studies investigating the collateral impacts of SGDs and other picture-based AAC, particularly on speech outcomes, would be useful. Further investigations are warranted to determine if other types of aided AAC, particularly handheld computer-based SGDs, would also have collateral effects on speech, perhaps accelerating speech in children who begin with some echolalia or a few spontaneous and functional phrases or words. Most of the included studies had only narrative descriptions of the participants' language skills. The field would benefit from more concise definitions of language levels, such as those suggested by Tager-Flusberg et al. (2009) and by providing standardized or criterion-referenced assessment results so that participant language levels could be more precisely categorized. This would allow meta-analyses to more reliably evaluate the impact of interventions on participants based on their characteristics. Similarly, studies provided only limited assessment information regarding intellectual and functional abilities, limiting the ability to evaluate whether or not participants had comorbid IDD. Although an attempt was made to categorize the participants based on the information provided, it is likely that some participants had IDD in addition to ASD, but were not identified as such by the authors of those studies. It would be helpful if the field and future researchers reported participants' standardized and diagnostic measures.

This meta-analysis is the first to investigate the correlation between speech at study onset and impact of aided AAC on speech outcomes. Further, no other meta-analysis has previously parsed impacts of different types of aided AAC on individuals with ASD, differentiating by age and by comorbid diagnoses. This meta-analysis encourages researchers to investigate several topics for future study, such as the impact of SGDs on speech and the impact of cutting-edge technologies via which to implement AAC, and to enhance single-case studies by providing more useful information on participant characteristics, including results of standardized and diagnostic testing. Further, additional single-case research and meta-analysis of specific intervention procedures and strategies related to the use of AAC with individuals with ASD is warranted. Overall, more single-case research is needed, which must then be synthesized, before practitioner and caregiver recommendations related to clinical decision-making are possible.

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Table 1

Summaries of Studies included in the Meta-analysis

Authors	Diag.	Age	Participants	Speech skills	Type of AAC	Target Behavior & Results
Angermeier et al. (2008)	ASD	Elem.	4 boys	No speech	PECS	All participants mastered Phase I and II with pictures that resembled the objects and those that resembled it less
Ben Chaabane et al. (2009)	ASD	Elem.	2 boys	Not Specified	PECS	Increased independent requests with novel stimuli
Buckley & Newchok (2005)	ASD	Elem.	1 boy	No Speech	PIC	Aggression decreased during FCT + extinction and picture exchanges were greatest during low effort condition
Cannella-Malone et al. (2010)	ASD	Elem., Secondary	2 girls	Speech	PECS	Increase in social interactions using PECS
Carré et al. (2009)	ASD	Preschool	2 boys, 1 girl	No Speech	PECS	Acquired spontaneous use of PECS skills rapidly

Charlop-Christy et al. (2002)	ASD	Secondary (12yrs.), Preschool (3-5yrs.)	3 boys	No speech	PECS	Met criteria for PECS quickly, speech and social communicative behavior increased, and challenging behavior decreased
Choi et al. (2010)	ASD & IDD	Elem.	2 boys	Not Specified	SGD, PIC	Increase in correct rejecting responses using AAC
Drager et al. (2006)	ASD, ASD & IDD	Preschool (3-5yrs)	1 boy, 1 girl	Speech	PIC	Increase symbol production (correct identification of target items) and comprehension and communication skills were maintained
Franco et al. (2009)	ASD & IDD	Elem.	1 boy	No Speech	SGD	Decrease in occurrence in challenging behavior
Frea et al. (2001)	ASD & IDD	Preschool (4yrs.)	1 boy	No Speech	PECS	Decrease in challenging behavior and increase in use of picture responses
Ganz & Simpson (2004)	ASD, ASD &	Preschool, Elem.	2 boys, 1 girl	Speech	PECS	Increase in words spoken and mastered PECS quickly

	IDD					
Ganz & Simpson (2008)	ASD, ASD & IDD	Preschool	2 boys, 1 girl	Speech, No speech	PECS	Two participants mastered the PECS phases, but one participant did not
Johnston et al. (2003)	ASD & IDD	Preschool	3 boys	Speech, No speech	PIC	Participants learned to request entrance into play groups using AAC
Johnston et al. (2009)	ASD & IDD	Preschool	2 boys	No speech	PIC	All participants met criterion for identification of letter sounds using fixed and gradual arrays; fixed array condition was more efficient
Jurgens et al. (2009)	ASD	Preschool	1 boy	Speech	PECS	Increase in PECS requests and quick acquisition; spontaneous request were low throughout
Keen et al. (2001)	ASD	Preschool, Elem.	3 boys, 1 girl	No Speech	PIC	Prelinguistic behaviors decreased and replacement communication via AAC increased

Kravits et al. (2002)	ASD & IDD	Preschool	1 girl	Speech	PECS	Frequency of spontaneous communication and social interaction with peer increased
Lund & Troha (2008)	ASD, IDD, & sensory impair.	Secondary	2 boys, 1 girl	Speech	PECS	Mastered use of independent picture exchanges rapidly
Marckel et al. (2006)	ASD	Preschool	2 boys	Not Specified	PECS	Amount of independent requests via PECS increased
McMillan (2008)	ASD & IDD	Elem., secondary	4 boys	No Speech	SGD	Increase in initiations starting in Phase 1 and 2 and continuing through phase 3
Nunes & Hanline (2007)	ASD & IDD	Preschool	1 boy	No Speech	PIC	Increase in responses verbally and with pictures
Ohtake et al. (2010)	ASD & IDD	Secondary	1 boy	No Speech	PIC	Increased repair requests only when a constant-time delay was introduced into instruction
Olive et al. (2007)	ASD,	Preschool	3 boys	No Speech	SGD	Increase in requests and using the SGD

	ASD & IDD					
Olive et al. (2008)	ASD	Preschool	1 girl	Speech	SGD	Increase requesting and correct pronoun use via the SGD
Park et al. (2011)	ASD	Preschool	3 boys	No Speech	PECS	All participants mastered PECS and two of the three had an increase in vocalizations
Reichle et al. (2005)	ASD & IDD	Secondary	1 man	No Speech	PIC	Increase in requests
Schepis et al. (1998)	ASD, ASD & IDD	Preschool	3 boys, 1 girl	Speech, No speech	SGD	Increase in social interactions
Schlosser et al. (1998)	ASD	Elem.	1 boy	Speech	SGD	Increase in words spelled correctly and letter sequence with SGD and the SGD combined with feedback
Schlosser et al. (2004)	ASD & IDD	Elem., secondary	4 boys	Speech, No Speech	SGD	All participants met criterion in one of the intervention phases for spelling

Schlosser et al. (2007)	ASD, ASD & IDD	Elem.	5 boys	Speech, No Speech	SGD	All participants had an increase in requests; only one participant improved request vocalizations
Thompson et al. (1998)	ASD & IDD	Elem.	1 boy	No Speech	PIC	Decrease in challenging behavior and increase in communication
Tincani (2004)	ASD & IDD	Preschool, Elem.	1 boy, 1 girl	Speech	PECS	Vocalizations increased and one participant requested more with PECS; the other requested more with sign language
Tincani et al. (2006)	ASD	Elem.	3 boys	Speech, No speech	PECS	Mastered PECS phase and one participant had an increase in vocalizations mostly in the reinforcement phase
Trembath et al. (2009)	ASD	Preschool	3 boys	Speech, No speech	SGD	Increase in communicative behaviors quickly after intervention started
Yokoyama et al. (2006)	ASD & IDD	Elem.	1 boy	No Speech	PECS	Increase in independent use of PECS

Notes: ASD = autism spectrum disorder; IDD = intellectual/developmental disability; PECS = Picture Exchange Communication System; PIC = other picture-based AAC; SGD = speech-generating device.

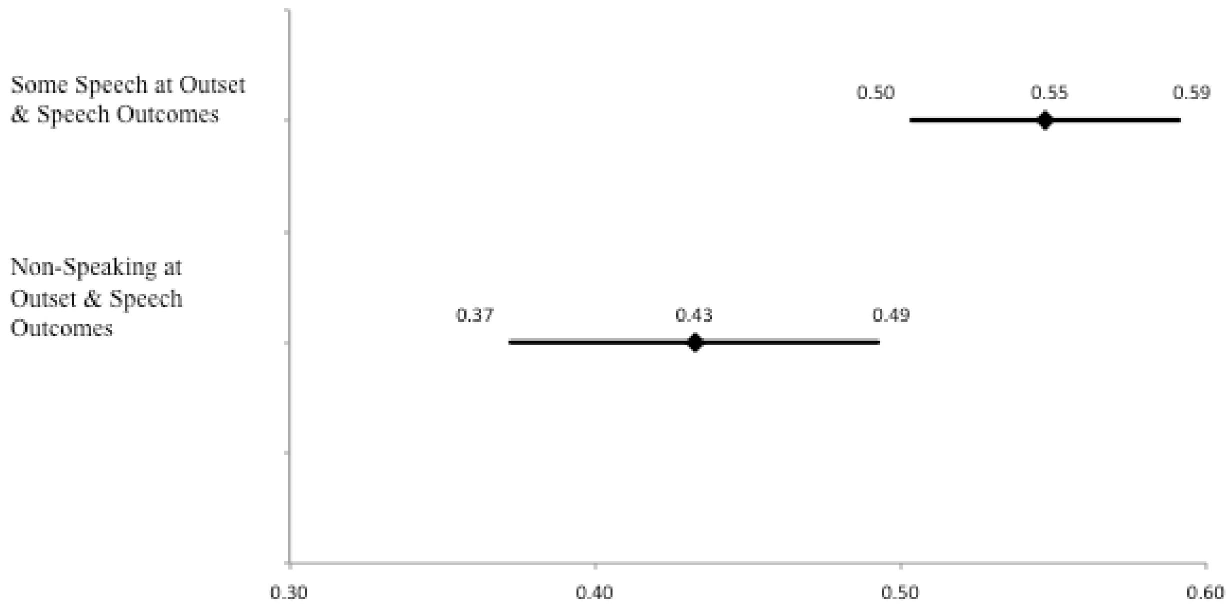

Figure 1. Forest plot of effect sizes by speech at outset of study.

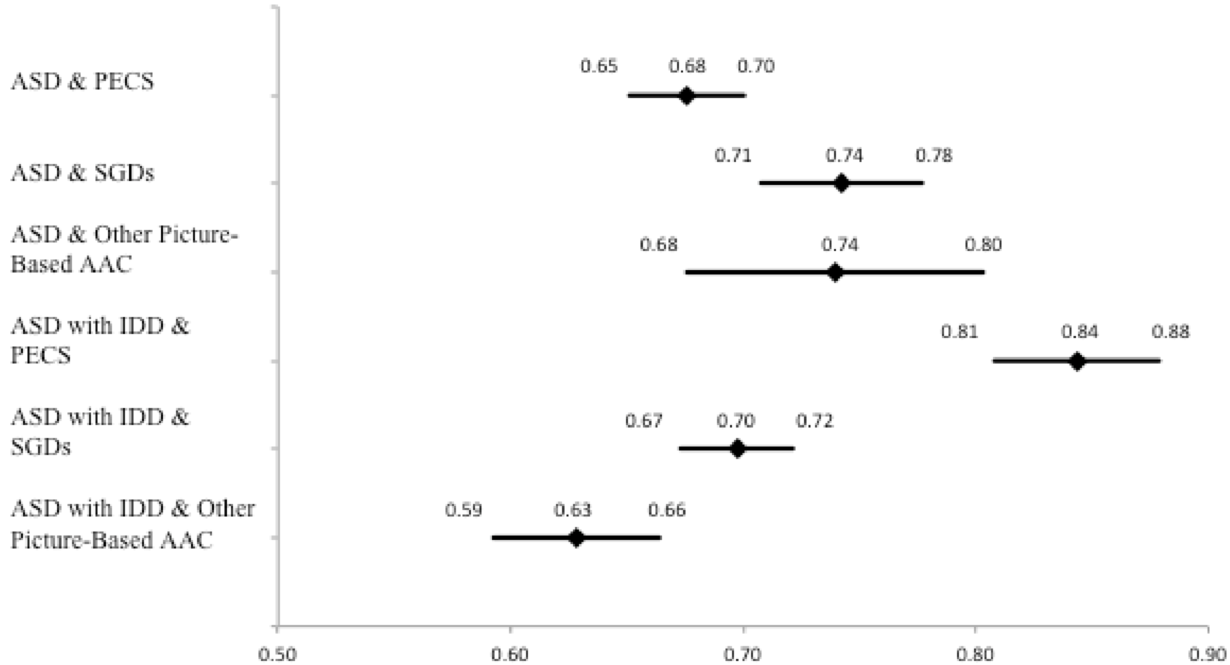

Figure 2. Forest plot of effect sizes disaggregated by disability category and type of AAC.

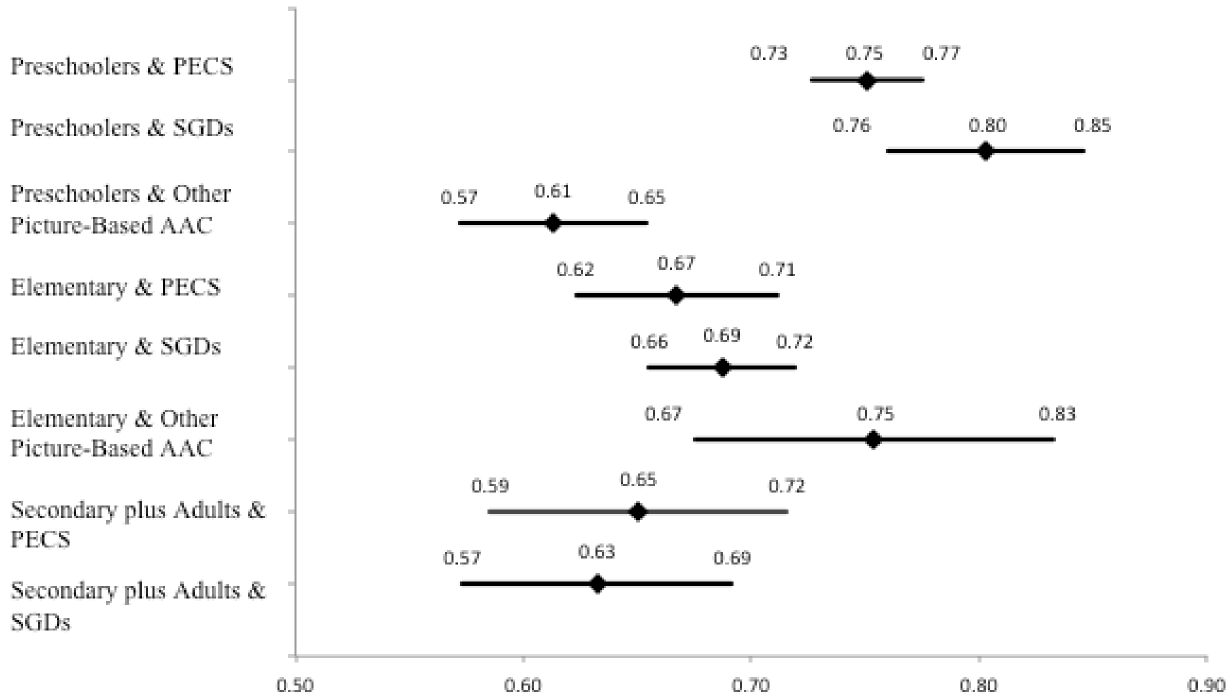

Figure 3. Forest plot of effect sizes disaggregated by age and type of AAC.