THE EFFECTS OF AUGMENTATIVE AND ALTERNATIVE COMMUNICATION ON SPEECH-LANGUAGE OUTCOMES: A META-ANALYSIS

by

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The Effects of Augmentative and Alternative Communication on Speech-Language Outcomes: A Meta-Analysis

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ABSTRACT

Existing meta-analyses within speech-language pathology, augmentative and alternative communication (AAC), and early intervention have been either group designs or systematic reviews of single-subject experimental designs (SSED) that have employed non-parametric methods. The purpose of the study was to use meta-analytic procedures across both SSED and group designs to: examine the effectiveness of SSED of speech-language interventions with and without the use of AAC strategies and technology on speech-language outcomes of individuals ages birth to 6 with developmental disabilities; identify study characteristics that predict or correlate with language outcomes; identify study characteristics that moderate intervention effects; and evaluate the quality of speech-language intervention research for this population.

Univariate and multivariate meta-analyses were completed for 32 effect sizes from 16 studies. The dependent variable was expressive language outcomes from the studies. The focal independent variable was whether the intervention used AAC technology and strategies. The control variables included the age of the child participant, type of research design, treatment dose in hours, training dose for the primary communication partner in hours, and type of speech-language pathology intervention (i.e., naturalistic or responsive). The analysis provided insight into the impact that early intervention services, specifically speech-language pathology services, have on children.
with significant expressive language disabilities or delays. Although the results of the analysis were not statistically significant, the analysis provided an evidence base that using AAC with traditional speech-language pathology interventions produces a positive large effect on expressive outcomes for children with disabilities ages birth to 6. Additional implications for policy, research, and practice also were explored and discussed.
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# TABLE OF CONTENTS

## CHAPTER

### I. INTRODUCTION

- Problem Statement ........................................... 4
- Purpose of the Study ........................................... 5
- Research Questions ............................................ 6
- Significance of the Study ....................................... 7

### II. LITERATURE REVIEW

- Prevalence of Developmental Disability .......................... 8
- Early Intervention Policy ........................................ 10
- Early Intervention Research ....................................... 19

### III. METHODOLOGY

- Design ............................................................... 39
- Research Questions ............................................. 40
- Research Approach and Philosophy .............................. 41
- Systematic Review Process ....................................... 48
- Data Extraction .................................................. 53
- Variables .......................................................... 54
- Statistical Analysis .............................................. 57
- Meta-Analyses .................................................... 59
- Risk of Bias ....................................................... 62
LIST OF TABLES

TABLE

1. Summary of What Works Clearinghouse Criteria for Experimental Designs……51
2. Variables Used in Random-Effects and Robust Variance Estimation Model…..56
3. Participants, Setting, and AAC Variables………………………………………56
4. Reason Studies Were Excluded from the Meta-Analysis………………………68
5. SSED that Met WWC Design Standards with Reservations..........................69
6. Participants and Gender………………………………………………………70
7. Participants Ethnicity…………………………………………………………71
8. Associated Medical Factors…………………………………………………72
9. Interventionist, Setting, and Service Model Characteristics………………………73
10. AAC Technology………………………………………………………………74
11. AAC Interface and Encoding Characteristics…………………………………74
12. AAC Language Representation…………………………………………………..75
13. Expressive Language Outcomes for Each Study……………………………76
14. Studies that Used AAC…………………………………………………………76
15. Communication Partner Strategies……………………………………………..78
16. Communication Partner Strategies by Naturalistic or Responsive Intervention Category………………………………………………………………78
17. Instructional Techniques for Communication Partner Education……………..79
18. Instructional Techniques for Communication Partner Education by Citation……80
19. Descriptive Statistics .................................................................80
20. Study Design by Citation and Effect Size.............................81
21. Results of Random-Effects Meta-Regression Using 16 Studies with 32 Effect Sizes.................................................................84
22. Adjusted Averages for Variables..................................................86
23. Results of Meta-Regression with RVE Using 16 Studies with 32 Effect Sizes.................................................................88
LIST OF FIGURES

FIGURE

1. Records identified and retained at each stage of the selection process.............67
2. Funnel plot for effect sizes estimates from 16 studies with 32 effect sizes...........89
CHAPTER I

INTRODUCTION

The development of speech and language skills allows a child to engage in exchanges that lead to the acquisition of cultural and linguistic knowledge, the development of social interactions and relationships, and the stimulation of cognition including organizing and sharing of thoughts, as well as perceiving and communicating a sense of self and participation within society (Rosenbaum & Simon, 2016). The acquisition of speech and language starts at birth and continues through adolescence as a seemingly an automatic process, but a percentage of the child population within the United States (US) experiences disorders or delays in speech and language developmental milestones, potentially impairing overall function and disrupting the child’s ability to communicate (Rosenbaum & Simon, 2016). The combination of a severe speech and language delay or disorder with other risk factors, including poverty, has been reported to increase the likelihood of more adverse quality of life outcomes, including social isolation, mental health disorders, learning disabilities, behavioral disorders, poor academic achievement, and chronic underemployment (Rosenbaum & Simon, 2016).

Developmental disabilities are defined by the Centers for Disease Control and Prevention (CDC) as a diverse group of conditions due to impairment in learning, physical, language, or behavior areas (CDC, 2015). The American Speech-Language-Hearing Association (ASHA, n.d.b) reported a person can be characterized as having a developmental disability resulting in substantial limitations without a concomitant intellectual disability (i.e., autism spectrum disorder or cerebral palsy). Intellectual
disability is characterized as a subset of a developmental disability (ASHA, n.d.b). The CDC (2015) indicated developmental disabilities are common; specifically, about one in six children in the US had developmental disabilities in 2006-2008. According to Rosenbaum and Simon (2016), 3% to 16% of the general population of children within the US from birth through age 21 experience problems with speech or language. Given the prevalence of children with developmental disabilities and the projected ongoing educational, social, and healthcare supports needed by this high-risk population, early intervention policy was instituted within the US.

Federal and state policy has indicated a need for early intervention for students with greater accountability, improved educational outcomes, and increased standards for instructors of children within special education classes (University of Kansas [KU], 2018). Significant barriers remain for children with disabilities in accessing inclusive high-quality preschool and early intervention services despite provisions under early intervention policy entitling children with disabilities ages 3 to 5 to a free appropriate public education (US Department of Education, 2016). The specific barriers for children with disabilities ages 3 to 5 indicated in the literature review were limited options to be included with age appropriate peers without disabilities, limited opportunity to use or trial high technological AAC devices when appropriate, and lack of conclusive evidence to guide the most effective speech-language pathology treatments including AAC.

Children with disabilities frequently were offered only the option of receiving special education services in settings separate from peers without disabilities (HHS, 2015). Also, the provision of speech-language pathology services has typically been
provided within a 1:1 setting for early intervention services (Schooling, Venediktov, & Leech, 2010).

Children with disabilities typically have not been offered the opportunity of using AAC options or have been offered only limited types of devices and strategies (Campbell, Milbourne, Dugan, & Wilcox, 2006). The objective of AAC intervention is the long-term development of functional communication and language skills (Constantino & Bonati, 2014). Research and debate regarding the use of AAC are limited to a specific area of habilitation or rehabilitation (e.g., speech-language pathology and special education) and have rarely reached the broader medical community (Constantino & Bonati, 2014). A better knowledge of AAC and its possible impact on children and families is important for improving timely referral and potentially increasing the quality of life of children with disabilities and helping to prevent behavioral problems and cognitive deterioration (Constantino & Bonati, 2014).

Last, conclusive evidence is not available to guide selection of the most effective speech-language approach and/or strategy, including AAC for children birth to 6 with varying types of delays and disabilities (ASHA, 2008). The speech-language pathologist (SLP) has the responsibility of embedding the best assessment of evidence-based interventions within family-identified, preferred routines, or a comprehensive curriculum (for early care and education group settings) that target functional outcomes individualized for the child (ASHA, 2008).

The research base indicated a large variety of speech-language interventions and techniques classified within the transactional model of social communication development and further narrowed into categories along a continuum from directive to
responsive, with naturalistic or hybrid approaches falling in the middle of the continuum (ASHA, 2008). The research specific to speech-language interventions with early intervention populations with and without disabilities has suggested that naturalistic or responsive interventions have increased receptive and expressive language outcomes for this population (Roberts and Kaiser, 2011). Caregiver-implemented language interventions have been reported to produce a significant positive impact on receptive and expressive language skills of children with and without intellectual disabilities (Kaiser and Roberts, 2011). Also, the importance of caregiver responsiveness associated with the advances of a child’s cognition and language development has been well documented within speech and language research specific to early intervention populations (Tamis-LeMonda, Bornstein, & Baumwell, 2001).

Previous AAC research has indicated a predictor of successful implementation of AAC use was the amount of support provided at home by family members (Parette & Angelo, 1996). The research specific to AAC interventions have suggested that interventions focusing on family-centered AAC services that supported caregivers in implementing the communication goals with their children reported better outcomes for children who use AAC devices (Kaiser, Hester, & McDuffie, 2001; Ruble, McDuffie, King, & Lorenz, 2008).

**Problem Statement**

Most of the research to date has used data from children with mild to moderate disabilities and has not assessed the impact of early intervention services from birth to 6 related to speech-language intervention and the use of AAC for children with developmental delays and associated disabilities. At present, conclusive evidence is not
available to guide the selection of the most effective speech-language approach and/or
strategy, including AAC for infants and toddlers with varying types of delays and
disabilities (ASHA, 2008). No single speech-language approach or strategy is equally
effective for all children or families, and not all children in outcome studies have
benefited to the same degree (ASHA, 2008). The ASHA (2008) reported a need for
additional research that focuses on what works best for young children with varying types
of delays and disabilities. Romski, Sevcik, Barton-Hulsey, and Whitmore (2015) also
indicated the need to examine and compare the different treatment approaches to advance
the necessary prescriptive elements of speech-language pathology (i.e., type of
intervention and intensity) for children with delays and disabilities.

**Purpose of the Study**

The intent of this systematic review and meta-analysis is to estimate the size of
the effect of speech-language interventions, with and without AAC, of children birth to 6
with developmental disabilities at a particular point in time and to quantify how the effect
changed over time and across cases. The design of the study was formulated using the
Preferred Reporting Items of Systematic reviews and Meta-Analyses (PRISMA)
according to the CONSORT 2010 statement using updated guidelines for reporting
parallel group randomized trials (Schulz, Altman, & Moher, 2010). The primary purpose
of this review is to use meta-analytic procedures across both SSED and group designs to
(a) examine the effectiveness of speech-language interventions with and without the use
of AAC strategies and technology on speech-language outcomes of individuals ages birth
to 6 with developmental disabilities; (b) identify study characteristics that predict or
correlate with language outcomes; (c) identify study characteristics that moderate
intervention effects; and (d) evaluate the quality of speech-language intervention research for this population.

**Research Questions**

The study answers the following research questions:

1. What are the effect sizes of speech-language interventions, with and without AAC, for SSED and group designs for children ages birth to 6 with developmental disabilities?

2. To what extent do the effect sizes vary as a function of treatment approach (with or without AAC) when controlling for other covariates (i.e., age, length of intervention provided to child participant, length of training provided to adult interventionist or communication partner, type of language intervention, and study design)?

3. What study characteristics moderate the overall effect of early intervention outcomes associated with speech-language intervention targets and outcomes within children ages birth to 6 with developmental disabilities?

4. What is the quality of the speech-language intervention research studies that are included in the meta-analysis?

Therefore, statistical modeling and the use of parametric meta-analytic methods were considered. Two parametric meta-analysis techniques were utilized to answer Research Questions 1 through 3. A standard random-effects meta-regression was used, and a meta-regression with robust variance estimation was used as a sensitivity analysis to further assess the dependency between the effect sizes compared to the result of the standard random-effects meta-regression. A quality analysis was used to answer Research
Question 4. An analysis of the quality and rigor of the studies was conducted during study screening and data extraction to determine the inclusion of the studies within the meta-analysis, as defined by the What Works Clearinghouse (WWC) standards and guidelines for SSED (Kratochwill et al., 2010) and group designs (WWC, 2017).

Significance of the Study

Existing meta-analyses completed within speech-language pathology, AAC, and early intervention have been either group designs or systematic reviews of single-subject experimental designs (SSED) that have employed non-parametric methods. The increased accountability of early intervention policy and evidence-based practice movements with requirements for data-driven interventions and investigations has heightened the need for stakeholders to evaluate literature and conduct clinical research to determine the most effective speech-language interventions with and without the use of AAC in order to improve outcomes. As of today, no meta-analysis has been conducted of SSED and group designs investigating speech-language pathology interventions with or without the inclusion of AAC for children ages birth to 6 with developmental disabilities that compares effects of intervention using parametric statistical techniques. Effective AAC provisions for children and families will become extended to the larger medical, early intervention, and speech-language pathology community only with supporting knowledge, research, and clinical evidence. With access to appropriate assistive technology at the early stages of development, young children with complex communication needs may be able to maximize language and communication development and achieve their full potential (Constantino & Bonati, 2014).
CHAPTER II
LITERATURE REVIEW

The literature review provides an overview of the prevalence of developmental disabilities within the US and a brief summary of early intervention policies within the US. Next, a broad summary of early intervention research is highlighted, followed by a more specific discussion regarding speech-language early intervention techniques specific to children with developmental disabilities. Last, AAC intervention policy recommendations are outlined and an overview of AAC meta-analyses findings is summarized.

Prevalence of Developmental Disability

The CDC and Prevention (2015) indicated developmental disabilities are common; specifically about one in six children in the US had developmental disabilities in 2006-2008. According to Rosenbaum and Simon, (2016), 3% to 16% of the general population of children within the US from birth through age 21 experience problems with speech or language. According to data from the National Survey of Children’s Health (NS-CH) from 2011-2012 (Child and Adolescent Health Measurement Initiative [CAHMI], 2013) approximately 14.6 million children ages 0-17 in the US (19.8%) had special healthcare needs; the prevalence of children with special healthcare needs (CSHCN) ranged from 14.4% to 26.4% across the 50 states and the District of Columbia; and about 65% of CSHCN experienced more complex service needs beyond a primary need for prescription medications to manage associated health condition compared to children not meeting CSHCN criteria. In addition, CSHCN were more likely to be male and between the ages of 12-17 (CAHMI, 2013). All children within the CSHCN
experienced at least one of the following types of ongoing health conditions that resulted in a routine need for health and related services: learning disability (27%), attention deficit disorder or attention deficit hyperactivity disorder (32.3%), depression (8.5%), anxiety problems (13.4%), autism spectrum or Asperger syndrome (8.0%), behavioral problems (13.6%), developmental delay (14.7%), intellectual disability (4.8%), cerebral palsy (1.0%), speech problems (15.6%), Tourette’s syndrome (0.2%), asthma (30.2%), diabetes (1.4%), epilepsy (3.1%), hearing problems (4.2%), vision problems (3.2%), bone joint or muscle problems (7.7%), and brain injury (1.1%; CAHMI, 2013).

According to the Data Resource Center for Child and Adolescent Health (DRC), a project of the CAHMI, each state had a percentage of children (3 three to 17) who had unmet communication needs (NS-CH, 2010). Although aggregated data were used regarding the 14 different services or equipment surveyed, the necessity for speech-language therapy and communication aids or devices was factored into the questions that indicated a range of need (9.8% to 18.8% of families surveyed with one unmet need and 4.3% to 14.9% of families surveyed with two or more unmet needs) among children within the US to access communication devices and speech-language therapy (NS-CH, 2010). Two and a half percent (confidence interval 2.2 to 2.8) of the sample, a count of 989 with a population estimate of 258,531, needed a communication aid, and 2.2% of the sample still had unmet communication needs ranging from 1.0% to 5.5% within the US (NS-CH, 2010). The exact prevalence of individuals using AAC within the US could not be estimated due to the wide variability across disabilities, diagnosis, age, location, communication modality, and extent of AAC use (ASHA, n.d.a). The prevalence is growing due to increased access to technology and awareness of AAC and individuals
with complex communication needs (ASHA, n.d.a). Beukelman and Mirenda (2013) estimated 1.3% of the population (approximately four million people) in the US were unable to reliably communicate using natural speech.

At the most severe and profound level, developmental disorders have been reported to persist over a lifetime (Rosenbaum & Simon, 2016). Children with significant developmental delays at age 3 to 5 are at the highest risk for future functional speech, language, learning, and academic delays that persist to adulthood (Bashir & Scavuzzo, 1992; Catts, Fey, Tomblin, & Zhang, 2002; De Koning et al., 2004; Peterson, Pennington, Shriberg, & Boada, 2009; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004). According to Rosenbaum and Simon (2016), children with mild to moderate speech and language disorders benefit from a variety of treatments but, for children with severe speech and language disorders, treatment improves function; however substantial functional limitations will persist. A severe disorder persists over time necessitating ongoing educational, social, and health supports, especially children from low-income families needing continuing eligibility for financial assistance (Rosenbaum & Simon, 2016). Given the prevalence of children with developmental disabilities and the projected ongoing educational, social, and healthcare supports needed by this high-risk population, early intervention policy has been instituted within the US.

**Early Intervention Policy**

In 1975, the US Congress passed Public Law 94-142, the Education for All Handicapped Children Act (EHA), ensuring all school-aged children receive a free appropriate public education, due process protections for children with disabilities and their families, and improved specification on how children with disabilities are identified.
Early intervention services for infants and toddlers with disabilities were not part of Pub. L. 94-142 until reauthorization of the law in 1986. In 1986, the US Congress established the program of early intervention for infants and toddlers with disabilities to enhance the development of children with disabilities and to minimize potential for developmental delay, reduce the educational cost to society by minimizing the need for special education and related services, minimize the likelihood of institutionalization for people with disabilities and maximize potential for independent living; and enhance the capacity of families to meet the needs of infants and toddlers with disabilities (Education of the Handicapped Act Amendments of 1986, 1986). In 1997, The EHA became the Individuals with Disabilities Education Act (IDEA) with several key amendments that emphasized providing all students with access to the same curriculum and giving states the authority to define the inclusion criteria for a developmental delay (KU, 2018). In 2004, the US Congress amended IDEA, calling for early intervention services for students with greater accountability, improved educational outcomes, and increased standards for instructors of children within special education classes (KU, 2018).

**IDEA**

IDEA is a law ensuring the provision of early intervention, special education, and related services to more than 6.5 million eligible infants, toddlers, children, and youth with disabilities (US Department of Education, n.d.). Infants and toddlers with disabilities (birth to 3) and families receive early intervention services under IDEA Part C, and children and youth (ages 3 to 21) receive special education and related services under IDEA Part B.
**IDEA Part B.** IDEA guarantees that eligible preschoolers, age 3 to 5, receive an Individualized Education Program (IEP) and special education services through the public school system. The IEP is a legally binding document that indicates services and accommodations the school district will provide to meet the child’s needs. Preschool special education is a federally-mandated program for three- and four-year-old children who meet state eligibility criteria for special education and are experiencing challenges in learning and development (Colorado Department of Education [CDE], 2015). Eligibility for special education preschool is indicated if the child has a significant delay in one or more areas of development, learning, speaking, or playing (CDE, 2015). If eligible, the children had the benefit of a free appropriate education in the least restrictive environment (inclusive setting) at no cost to the parent (Colorado Department of Education, 2015). The IEP team has traditionally determined and written within the IEP the provision of special education preschool services (i.e., special education, speech-language therapy, physical therapy, occupational therapy, counseling, nursing, and psychological services).

**IDEA Part C.** From birth to age 3, children can receive services through early intervention, as indicated by requiring that every state provide early intervention. If a child has been diagnosed with a disability or serious developmental delay, services such as speech-language therapy are provided within the home (IDEA, n.d.b). A comprehensive multidisciplinary evaluation of each child’s strengths and needs must identify appropriate resources (assistive technology, audiology, speech-language therapy, counseling and training for families, medical, nursing, nutrition, occupational therapy, physical therapy, and psychological therapy services) appropriate to meet the needs of the
child. Parental input is vital in the selection and implementation of services, especially assistive technology (IDEA, n.d.b).

**IDEA and assistive technology.** IDEA provisions indicate an assistive technology device is any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of children with disabilities, excluding a medical device that is surgically implanted or the replacement of such a device (IDEA, n.d.a). Assistive technology services are any service that directly assists a child with a disability in the selection, acquisition, or use of an assistive technology device (IDEA, n.d.a). Assistive technology is a broad term referring to assistive, adaptive, and rehabilitative products, equipment, and systems used to enhance learning, working, and daily living for persons with disabilities (Assistive Technology Industry Association [ATIA], 2017). Augmentative and Alternative Communication (AAC) is a subcategory of assistive technology (ATIA, 2017). According to ASHA (n.d.a), AAC is an area of clinical practice that addresses the needs of individuals with significant and complex communication disorders characterized by impairments in speech-language production and/or comprehension, which can include spoken and written modes of communication. AAC uses a variety of no, low, and high technological techniques and tools to help individuals express thoughts, wants and needs, feelings, and ideas (ASHA, n.d.a). AAC is augmentative when used to supplement existing speech and alternative when used in place of absent or not functional speech (ASHA, n.d.a). AAC also is characterized as being temporary (used postoperatively in intensive care) or permanent (used throughout the person’s lifetime; ASHA, n.d.a).
Section 504 of the Rehabilitation Act

Section 504 of the Rehabilitation Act of 1973 is a civil rights statute that prohibits agencies and programs that receive federal funds from discriminating against individuals with disabilities (US Department of Education, 2015). Under Section 504, an individual with a disability is defined as a person who has a physical or mental impairment which substantially limits one or more major life activities, a record of such impairment, or been regarded as having such impairment (The Early Childhood Technical Assistance Center [ECTA], 2017; US Department of Education, 2015). Some children who are not eligible for special education services may be able to receive services under the protection of Section 504. Public preschools, elementary schools, and secondary schools that have been and are federally funded must provide students with disabilities a free appropriate public education and ensure students are afforded an equal opportunity to participate in all academic and extracurricular school programs (US Department of Education, 2015). Schools may need to make special accommodations, including the provision of assistive technology devices and/or services, to allow students with disabilities access to the full range of programs and activities (US Department of Education, 2015).

The Americans with Disabilities Act

The Americans with Disability Act (ADA) was passed in 1990 to protect the rights of persons with disabilities in school, work, and recreation (US Department of Justice, Civil Rights Division, n.d.). Title II of ADA covers state and local government services. It prohibits discrimination against qualified individuals in the services, programs, or activities of the public entity, public school systems and publicly operated preschool programs (US Department of Justice, Civil Rights Division, n.d.). Regulations
of Title II of ADA state that no qualified individual with a disability shall, on the basis of disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of a public entity, or be subjected to discrimination by the public entity (US Department of Justice, Civil Rights Division, n.d.). Aids, benefits, and services provided to children with disabilities must be equal to those afforded to others and must be as effective in affording equal opportunity to obtain the same result, to gain the same benefit, or to reach the same level of achievement (US Department of Justice Civil Rights Division, n.d.). In order to comply with Title II, school systems (including private schools and daycare programs) are required to make reasonable modifications in policies, practices, and procedures or to provide auxiliary aids and services to the student with a disability, and to include assistive technology devices such as tape recorders, computers, and listening devices (US Department of Justice Civil Rights Division, n.d.).

**Every Student Succeeds Act**

The Every Student Succeeds Act (ESSA), Public Law 114-95, was signed into law December 2015 replacing the No Child Left Behind Act (US Department of Education, 2017) with greater flexibility for states to create accountability systems, academic goals, and reporting requirements (ASHA, 2016). ESSA was to be fully implemented during the 2017-2018 academic school year. The changes within ESSA impact professional learning, literacy, early intervention services, and assessment of children with disabilities (ASHA, 2016). With the shift in authority from the federal to the state level, each state education department plays a larger role in the plan for the provision of services (ASHA, 2016). The provisions for ESSA include guidelines in supporting schools and community-based organizations to support early learning in three
ways: expand access to high-quality early learning, encourage alignment and
collaboration with birth through third-grade education, and support educators (US
Department of Education, 2016). One area that was recommended by the US Department
of Education (2016) within the provisions of ESSA is to support children with
disabilities.

The US Department of Education and US Department of Health and Human
Services (HHS, 2015) state that all young children with disabilities should have access to
inclusive, high-quality early childhood programs where the children are provided with
individualized and appropriate support in meeting high expectations. States and local
educational agencies are encouraged to consider promoting greater coordination and
collaboration for children with disabilities receiving services under IDEA, as inclusion of
children with disabilities within high-quality preschool programs and early intervention
services has demonstrated improvement in development, learning, and social benefits for
children with and without disabilities (US Department of Education, 2016). The Head
Start Impact Study found children with special needs randomly assigned to Head Start at
age 3 made significant gains in math and social-emotional development at the end of
first-grade, compared with peers assigned to the control group (HHS, 2010). Research on
the Tulsa pre-kindergarten program found children with mild to moderate special needs
who participated in pre-kindergarten experienced significant improvements in reading
skills and writing skills (Phillips & Meloy, 2012). According to Yoshikawa et al. (2013),
findings of positive effects for children with special needs being included within high-
quality preschool programs have been documented but warrant more research to replicate
and extend the results.
As the local educational agencies continue to plan the availability of high-quality preschool programs, the US Department of Education (2016) has recommended special attention be paid to how children with disabilities are identified and meaningfully included. This recommendation has been supported by the claim that children with disabilities continue to encounter significant barriers to accessing inclusive, high-quality preschool and early intervention services despite provisions under IDEA that entitle children with disabilities age 3 to 5 to a free appropriate public education (US Department of Education, 2016). Children with disabilities frequently have been offered only the option of receiving special education services in settings separate from peers without disabilities (HHS, 2015). In addition, children with disabilities typically have not been offered the opportunity of using AAC options or have been offered only limited types of AAC devices and strategies. Campbell et al. (2006) conducted a survey study of the assistive technology practices of multidisciplinary early intervention providers across the US. The results of the survey indicated providers did not select AAC or other assistive technology options for children until a child was older than 24 months; and if AAC was provided, low-tech options were selected more frequently (55.2%) over high-tech communication devices (8.4%). Most preschoolers with complex communication needs use gestures, nonelectronic communication boards, or simple AAC technologies with digitized speech output, and very few children use AAC technologies that offer a greater breadth of communication options (Binger & Light, 2006).

The objective of AAC interventions is the long-term development of functional communication and language skills (Costantino & Bonati, 2014). Reducing the communicative gap is critical, as a toddler with a severe language and communication
delay may have difficulty interacting socially, gaining information, developing cognitive skills, and learning from the environment, which could have consequences on global development and increase the risk of behavior problems (Costantino & Bonati, 2014). Research and debate regarding the use of AAC are limited to a very specific area of habilitation or rehabilitation (e.g., speech-language pathology and special education) and rarely have reached the broader medical community (Costantino & Bonati, 2014). A better knowledge of AAC and its possible impact on children and families is important to guarantee timely referral of children and families and, therefore, improve their quality of life and help to prevent behavioral problems and cognitive deterioration (Costantino & Bonati, 2014). Most of the research to date has used data from children with mild to moderate disabilities and has not assessed the impact of early intervention services from birth to 5 related to speech-language intervention and the use of AAC for children with developmental delays and associated disabilities.

According to Diamond, Justice, Siegler, and Snyder (2013), more evidence is available, but a need still exists to understand aspects of effective instruction for young children with significant learning needs, including the most effective and efficient approaches for improving children’s attention, self-regulation, language, literacy, math, science, and adaptations to support effective instruction for every child. Rigorous research that has addressed important questions about approaches for improving children’s development and learning can provide educators and stakeholders with important guidance regarding scientifically-based practices and policy (Diamond et al., 2013). Exploratory research evaluating the impact of intervention on programs, practices, and policies on education outcomes has been encouraged to determine the relationship
between education outcomes and factors that can be changed (i.e., practices), as well as mediators and moderators of those relations (Diamond et al., 2013). Research has improved in providing educational leaders and practitioners with scientifically valid information on which intervention appears to be effective or ineffective in achieving intended goals, but additional research is warranted to further test interventions and programs that produce positive effects on educational outcomes for children with developmental disabilities (Diamond et al., 2013).

**Early Intervention Research**

Policy, research, and clinical evidence have pointed to the importance of early childhood education or early intervention (Duncan & Magnuson, 2013). Existing preschool programs include private, nonprofit, and for-profit options, with the average cost of full-time, center-based care for a four-year old ranging from $3,900 to $14,000 (Duncan & Magnuson, 2013). Given the high cost of center-based care, the federal government has sought to increase the participation of low-income children in early childhood education programs through Head Start, pre-kindergarten programs, and mean-tested childcare assistance programs. Duncan and Magnuson (2013) completed a meta-analysis on preschool programs that have quasi-experimental methods with impact estimates for cognitive and achievement outcomes. According to Duncan and Magnuson, programs beginning in 1980 produced significantly larger effect sizes than more recent programs. The decline in effect sizes over time was attributed to counterfactual conditions for children in the control conditions improving since 1980. The counterfactual conditions included an increase in the mother’s postsecondary education purported to be linked to improving the quality of home life, and early intervention policy
and practitioners targeting environmental enrichment, including responsive caregiving and language-rich interactions associated with better developmental outcomes and stronger early language development (Tamis-LeMonda, Borenstein & Baumwell, 2001). The research suggested models of early intervention or early childhood investment (home visitations for high-risk, first-time mothers; developmental screenings; and interventions) for children living within high-risk populations may be a more effective way of building a child’s capacity during early life (Duncan & Magnuson, 2013).

Neuroscience evidence also has highlighted the plasticity of cognitive and language abilities that are highly malleable to environmental enrichment during early childhood (Center on the Developing Child, 2017). The Center on the Developing Child (2017) highlighted three design principles for policymakers and practitioners that include supporting responsive relationships for children and adults, strengthening core life skills, and reducing sources of stress in the lives of children and families. The experiences of children early in life and the environments in which experiences are shaped impact a child’s brain architecture, affecting developmental instructions carried in genes (Center on the Developing Child, 2017). Stable and responsive relationships in the earliest years of a child’s life help to protect the child from harm caused by excessive stress and in adulthood by providing the protection necessary for resilience (Center on the Developing Child, 2017).

The importance of caregiver responsiveness associated with the advances of a child’s cognition and language development has been well documented within speech and language research specific to early intervention populations (Tamis-LeMonda et al., 2001). More recent evidence pointing to the importance of caregiver responsiveness has
been indicated in meta-analyses that have focused on the use of parent-implemented language interventions for children with developmental delays within the early intervention populations. Roberts and Kaiser (2011) completed a meta-analysis to systematically evaluate the effects of parent-implemented language intervention on language skills of children ages 18 to 60 months with primary and secondary language impairments. The results indicated parent-implemented language interventions have a significant positive impact on receptive and expressive language skills of children with and without intellectual disabilities. The critical features of parent-implemented language interventions include the following triadic interventions: parent training, parent implementation of intervention strategies, and child language outcomes. Roberts and Kaiser indicated several specific implications for clinical practice: interventions should focus on socially communicative interactions between parents and children, parents should be taught to increase the use of linguistic forms through models and expansions, parents should be trained at home and across daily routines, parent-implemented interventions may be effective across a range of intellectual and language skills, and training parents once per week may be sufficient to improve child language outcomes.

Gladfelter, Wendt, and Subramanian (2011) completed a systematic review of speech-language interventions or techniques that are effective in improving speech-language outcomes for children with speech-language delays in the birth-to-3 population. The results of the review indicated only the Hanen Parent Program showed conclusive evidence of improving speech-language outcomes. The Hanen Parent Program, combined with focused stimulation, had an effect on increasing vocabulary, phonetic inventories, and syllable structure repertoires. Preponderant outcomes were indicated for the use of
other strategies; expansion, recasting, parallel talk, child-directed speech, visual cues, feedback, and increasing interaction opportunities had an effect on increasing mean length of utterance (Gladfelter et al., 2011).

Kaat-van den Os, Danielle, Jongmans, Volman, and Lauteslager (2017) completed a systematic review to evaluate the effect of parent-implemented language interventions on parent-child interaction behavior and child communication and language outcomes in children with developmental disabilities ages 1 to 5. Five of the seven studies indicated a significant effect of intervention on parent responsiveness; child communication (i.e., intentional communication acts, verbal turns, and vocal turns); and aspects of language (i.e., vocabulary diversity, lexical diversity, and mean length of utterance). No studies have reported significant effects of intervention on expressive language vocabulary; Kaat-van den Os et al. (2017) purported this was linked to the populations within the study, specifically children with Down syndrome and intellectual delays. The authors stated that intellectual delays seemed to influence the effect of parent-implemented language interventions on expressive language. They further indicated effect sizes for expressive vocabulary (but not receptive vocabulary) were significantly smaller in children with an intellectual disability compared to those without (mean effect sizes 0.23 and 0.80, respectively), and expressive vocabulary was harder to influence in children with an intellectual disability than children without.

Kaat-van den Os et al. (2017) also indicated children with developmental delays require “consistent and high levels of language support strategies to stimulate expressive language development” (p. 136), and further research is indicated to identify the optimal intervention strategies for enhancing language development. The parent education
programs included within the review by Kaat-van den Os et al. (2017) reported the use of sign language (unaided AAC) but did not include the use of aided AAC strategies and technology. Kaat-van den Os et al. concluded the findings of the systematic review suggested there may be significant positive effects of parent-implemented early language intervention programs for children with developmental delays, including children with Down syndrome, on communicative behavior; but the effects of intervention on language were smaller.

The importance of caregiver responsiveness and its impact on cognition, language, and behavior also have been well documented regarding children with disabilities (Kaiser et al., 2001; Ruble et al., 2008). Family-centered AAC services have supported parents in implementing the communication goals with their children and report better outcomes for children who used AAC devices (Kaiser et al., 2001; Ruble et al., 2008). A predictor of successful implementation of AAC is the amount of support provided at home by family members (Parette & Angelo, 1996). Outcomes for families and children with complex communication needs who used an AAC device improved when the communication partner was provided specific instruction on adapting responses to the child, the environment, and specific communication opportunities (Beukelman & Mirenda, 2013; Cress & Marin, 2003). Communication partner instruction for caregivers, teachers, and siblings has been recognized as important to successful outcomes for individuals who use AAC (Kent-Walsh & Mcnaughton, 2005; Kent-Walsh, Murza, Malani, & Binger, 2015). The goals of family-centered services were reported to meet the communicative and social needs of children and families by addressing the interaction between child, communication partners, and the environment (Odom & Wolery, 2003).
The family plays a critical role in the development of language and communication skills for the young child, and research has supported this evidence, suggesting parents and other communicative partners can use AAC strategies with young children (Romski et al., 2015). In addition, family participation has been mandated in US early intervention programs, and defining that role for AAC early interventions is essential to the long-term success of AAC (Romski et al., 2015).

Although parent responsiveness and parent-implemented treatment strategies are indicated as an effective intervention, additional speech-language interventions have not been as widely researched. The following section outlines the current policy recommendations for speech-language intervention for early intervention populations, children with intellectual disabilities, and the provision of AAC.

**Speech-Language Interventions: Policy Recommendations**

**Early Intervention Techniques**

A large variety of speech-language interventions and techniques have been used to improve communication skills in the birth-to-3 population. Speech-language intervention strategies for supporting and enhancing early child communication are referred to as falling along a continuum from directive to responsive, with naturalistic or hybrid approaches falling in the middle of the continuum. The focus of all of the strategies is to increase the frequency and complexity of the child's communication and language (ASHA, 2008). Directive interaction strategies typically have encompassed the adult structuring the interaction by selecting ways to elicit a particular communicative act while supporting the child in the interaction to gain the desired response, which often requires the adult to provide a tangible reward for the correct performance (ASHA,
Responsive interaction strategies are designed to encourage the child's engagement and interaction, opportunities for child-initiated behavior and reciprocity, and balanced turn-taking with communication partners (ASHA, 2008). A combination of strategies have provided varying amounts of directive and responsive interaction to promote communication competence and have been described as more naturalistic (Hepting & Goldstein, 1996).

According to ASHA (2008), a number of intervention strategies have empirical support within the literature, which include environmental arrangement (which may include assistive technology adaptations; Kaiser, Yoder, & Keetz, 1992); milieu approach (Kaiser & Hancock, 2003); and responsive adult interaction patterns (Mahoney, Powell, & Finger, 1986). Appendix A contains a description of interventions. The provision of early intervention services within natural context also has been supported in the literature (Hepting & Goldstein, 1996), including basic techniques as following the child's lead, providing natural consequences, embedding techniques throughout the child's daily routines and activities, and providing caregiver support and training in multiple settings and contexts (Grisham-Brown, Perti-Frontczak, Hemmeter, & Ridgley, 2002).

Law, Garrett, and Nye (2004) completed a meta-analysis of intervention for children and adolescents with primary developmental speech and language delays or disorders. Only group designs with experimental and control groups were included within the analysis. The data were categorized depending upon the control group (no treatment, general stimulation, or routine speech and language therapy) and the effects of intervention on expressive or receptive speech and language (phonology, syntax, and vocabulary) outcomes. Thirteen studies were used within the meta-analysis, with results
indicating speech-language therapy may be effective for children with phonological and expressive vocabulary difficulties. Mixed evidence was indicated for interventions for expressive syntax difficulties and no evidence for receptive language delays. No difference was noted between interventions provided by trained parents compared to clinicians. The review indicated duration of treatment longer than eight weeks is potentially a factor in better clinical outcomes. Law et al. reported the lack of quality (i.e., blinding, attrition, and randomization) limited the inclusion of studies within the analysis. In addition, the description of participants and interventions was not sufficiently described to allow for clear interpretation and replication.

**Intervention for Children with Intellectual Disabilities**

Research has supported the provision of communication intervention for children with intellectual disabilities (Brady et al., 2016). The American Association on Intellectual and Developmental Disabilities (AAIDD, 2013) indicated the level of life functioning improves for a person with an intellectual disability if appropriate personalized supports are provided over a sustained period, and if the goal of treatment is to minimize the potential debilitating effects of disabilities on clients to maximize the likelihood of desirable outcomes.

According to ASHA (n.d.b), the following treatment strategies are recommended for individuals with intellectual disability: family-centered, culturally-appropriate practices, collaborative teams, strength-based perspective, maximize self-sufficiency, recognize individual variability, foster community environment of respect and inclusion, use natural environments for intervention settings, and involve peers as communication partners. A strength-based perspective is described as practitioners considering the
potential and individual wishes of a person and his or her family and building trusting relationships with families in the natural environment with natural supports (ASHA, n.d.b; AAIDD, 2013). A community of respect and inclusion is defined as a community that provides the opportunity to a person with an intellectual disability to communicate effectively with a variety of individuals, improve the quality of his or her life, have new learning opportunities, and include family participation within treatment and assessment (ASHA, n.d.b).

Additionally, ASHA (n.d.b) states treatment targets for a child with an intellectual disability may include early communication skills (i.e., turn-taking, joint attention, pointing); social interaction; play; pragmatic conventions (verbal and non-verbal); speech production; written language; literacy; compensatory communication strategies and techniques including AAC or other assistive technology; feeding; and swallowing. The SLP is charged with prioritizing the treatment targets on an individual basis that have the greatest potential for improving communication (ASHA, n.d.b). Treatment modalities include AAC (Beukelman & Mirenda, 2013); activity schedules and supports (Hart & Whalon, 2011); computer-based instruction (Neely, Rispoli, Camargo, Davis, & Boles, 2013); and video-based instruction (video modeling; Shukla-Mehta, Miller, & Callahan, 2010). Behavioral treatment options include Applied Behavioral Analysis, environmental arrangement, Functional Communication Training, incidental teaching, milieu therapy, and time delay (ASHA, n.d.b). Peer-mediated treatment options include Learning Experiences and Alternative program, circle of friends, and integrated playgroups (ASHA, n.d.b).
AAC Intervention

According to ASHA (n.d.a), the goal of AAC intervention is defined as maximizing the efficiency and effectiveness of communication for individuals who are unable to communicate using traditional means. Intervention is recommended to take place in the natural environment to promote generalization and the development of adequate functional communication, language, literacy, speech production, social skills, and use of multiple modalities of communication (i.e., gestures, speech, unaided, and aided AAC systems; ASHA, n.d.a). After the acquisition of an AAC or speech-generative device, the treatment initially focuses on the individual and caregivers in providing instruction and support in using the device followed by incorporating the device within the natural environment to achieve communication, language, literacy, and social communication goals (ASHA, n.d.a). The following treatment approaches and instructional strategies are indicated: augmented input, Discrete Trial Training, milieu therapy, incidental teaching, time delay, core vocabulary approach, Functional Communication Training, Language Acquisition through Motor Planning, mentoring programs, Picture Exchange Communication System, Pragmatic Organization Dynamic Display, Total Communication, video-based instruction, visual prompting strategies, visual schedules, language acquisition through AAC, and literacy development.

At present, conclusive evidence is not available to guide selection of the most effective speech-language approach and/or strategy, including AAC for children birth to 6 with varying types of delays and disabilities (ASHA, 2008). No single speech-language approach or strategy is equally effective for all children or families, and not all children in outcome studies have benefited to the same degree (ASHA, 2008). ASHA (2008)
reported a need for additional research that focuses on what works best for young children with varying types of delays and disabilities. SLPs have the responsibility of embedding the best assessment of evidence-based interventions within family-identified, preferred routines, or a comprehensive curriculum (for early care and education group settings) that target functional outcomes individualized for the child (ASHA, 2008). The following paragraphs provide an overview of meta-analyses completed regarding the use of AAC technology and strategies separately or combined with speech-language intervention techniques broadly within the field of AAC and the early intervention population.

**Meta-analyses of AAC interventions.** Constantino and Bonati (2014) completed a systematic review to evaluate the outcomes of AAC interventions in children with limited speech-language skills and the rigor of evidence of included studies. The inclusion criteria for studies within the meta-analysis were randomized control trials which totaled 14 studies (two group designs and 12 SSED). No attempt was made to aggregate outcomes across studies due to each having different outcomes. Also, an effect size estimation was not used, as studies differed substantially in design features and quality. Constantino and Bonati indicated clinical and expert evidence of the positive effects of AAC interventions in children with severe communication disorders has been reported, but conclusive evidence still needs to be generated. There was no evidence of any harmful effects of AAC in children with speech-language difficulties, and positive treatment trends in communication were shown in the systematic review (Constantino & Bonati, 2014).
Romski et al. (2015) completed a narrative review and synthesis of early intervention and AAC research studies and articles over the last 30 years published within the *Augmentative and Alternative Communication Journal*. Romski et al. (2015) highlighted the changes in the service delivery of AAC starting from 1985 with AAC first being considered within the research literature as a viable intervention strategy during the preschool years, especially for children with motor disorders (Light, Collier, & Parnes, 1985). A systematic review of the literature was conducted, and 143 articles were identified and reduced to 70 that included systematic methods, with the number of participants ranging from 1 to 144. Romski et al. highlighted findings across all 70 articles according to the following themes: enhancing child communication and language development; increasing child speech development; evaluating assessment approaches; using typical child development models; exploring literacy development; and examining early AAC service delivery models. The majority of the articles in the review were in the category of enhancing child communication and language development and employed SSED or quasi-experimental designs (Romski et al., 2015). The SSED included multiple probes across participants or outcomes and investigated the effects of intervention strategies ranging from naturalistic teaching on speech-generating device use (Schepis, Reid, Behrmann, & Sutton, 1998) to more directive approaches (i.e., aided language stimulation on vocabulary development; Drager et al., 2004). The majority of studies measured expressive language skills, and a few focused on receptive language skills (Romski et al., 2015). Few studies compared outcomes across different AAC interventions. According to Romski et al., additional research has examined the different approaches compared to each other to start the process of refining intervention and
providing more definitive information about the utility of different interventions for children with specific communication profiles.

Previous meta-analyses have been conducted over the last 17 years consisting of narrative reviews to analyses utilizing a variety of non-parametric statistical techniques. Each review moved the literature base forward but also documented significant limitations due to the quality of the available studies and the availability of statistical techniques.

Schlosser and Lee (2000) conducted a meta-analysis of 20 years of AAC research to identify strategies that are effective at promoting initial, generalization, and maintenance of treatment effects. The independent variables included location of intervention, instructional methods employed (i.e., individual or group), and the person who delivered the intervention. The types of intervention were not coded or categorized due to the wide range of interventions: Picture Exchange Communication System, Functional Communication Training, systematic social interactive training, teaching conversational exchanges with peer partners and communication books, Enhanced Milieu Teaching, using visual supports to teach initiations, application of object and movement cues to teach receptive language, and time delay to promote speech. The analysis was completed using the Percentage of Non-Overlapping data technique to compare 50 studies across intervention, generalization, and maintenance effects. Most of the studies (95.7%) reported the intervention was followed by positive and immediate results for most or all participants (Schlosser & Lee, 2000). Three of the four group designs indicated moderate to strong effect sizes in application of communication intervention for individuals with severe disabilities (Schlosser & Lee, 2000). Across all age groups and
participants, unaided AAC approaches were significantly more effective than aided approaches in regard to acquisition or intervention, but no difference was found in regard to generalization and maintenance (Schlosser & Lee, 2000). Limitations to the analysis included minimal reporting of treatment fidelity, generalization and maintenance not consistently assessed across studies, inadequate descriptions of intervention for replication impacting the ability to compare treatment interventions, inconsistent reporting of treatment intensity and duration, and lack of complete and comparable participant descriptions ranging from narrative description to standardized assessments.

Mirenda (2003) conducted a narrative review of the research to determine the comparative effectiveness of unaided and aided AAC systems with children with autism spectrum disorders and concluded that manual signs, graphic symbols, and AAC technologies have potential as communication aids for individuals with autism. The limited number of research studies and methodological flaws limited the conclusive evidence of the review (Mirenda, 2003).

Schlosser and Sigafoos (2006) completed a narrative synthesis comparing AAC interventions using SSED involving participants of any age with developmental disabilities. The independent variable was a comparison of at least two treatments or conditions in terms of effectiveness or efficacy of an AAC intervention. Three categories of interventions included aided, unaided, or a combination. The studies were only included based upon a priori appraisal evidence, as outlined by Schlosser and Sigafoos. The majority of the studies were categorized as suggestive or preponderant level of evidence, with only nine rated as conclusive (Schlosser & Sigafoos, 2006). The studies that were conclusive included six that supported the use of aided communication, one that
supported the use of unaided communication, and one study supporting the use of either unaided or aided communication. Each study that was conclusive had a different instructional goal and outcome that limited the generalizability of the review (Schlosser & Sigafoos, 2006). The aided AAC approaches provided the largest number of SSED with conclusive evidence, according to the narrative review completed by Schlosser and Sigafoos (2006).

Snell, Chen, and Hoover (2006) completed descriptive meta-analyses of SSED that utilized AAC interventions. The purpose was to identify evidenced-based interventions that enabled individuals with severe disabilities from birth to 21 to communicate with others using AAC alone or with spoken words. The studies included participants with severe disabilities (i.e., moderate to profound mental retardation, cerebral palsy, hearing loss, vision limitations, autism, and young children with extensive developmental delays). Additional selection criteria included targeted communication forms (i.e., prelinguistic or symbolic AAC expressive responses); SSED; the independent variable of teaching intervention; and the dependent variables including interactive communication responses that were nonverbal or others that related to communication (e.g., eye contact, receptive language skills, reduction of problem behavior, and speaking; Snell et al., 2006). Results were reported as percentage calculated on the total data set of 40 studies and additional descriptive analyses. Twenty of the 40 studies addressed communication intervention as a means of reducing problem behavior (Snell et al., 2006). Results were categorized according to the type of teaching intervention of either antecedent, consequence, problem behavior, or multiple intervention strategies (Snell et al., 2006). The most effective interventions were naturalistic language interventions used
during routine interactions and contexts that were more child-directed that utilized antecedent (following the child’s lead, partner proximity, expectant look from partner, embedding instruction within the activity, engineering the environment, waiting for a response, and temptation) and consequence interventions (praise, play contingently with object chosen by the child, delivering desired consequence; Snell et al., 2006). Functional Communication Training was the method of choice indicated when communication and problem behavior were targeted (Snell et al., 2006). Limitations of the review included the types of communication partners interacting with children who used AAC, as the majority of studies looked at interaction with an adult partner instead of an age-appropriate peer or sibling; variability of experimental rigor across studies; utility of multiple treatment techniques or strategies that limited the ability to separate components contributing to the measured effect; limited treatment fidelity reported; inconsistent reporting of treatment intensity (i.e., number of trials or amount of training in days); and variability of description about participants’ baseline skills (Snell et al., 2006).

Light and Drager (2007) provided a narrative review of AAC systems for young children and highlighted future research needs related to AAC technologies to enhance outcomes for children with complex communication needs. Research studies have indicated the youngest children (age 2.5 years) were most accurate in locating vocabulary using the visual scene displays compared to the grid layouts. Light et al. also found that, by age 4 and 5, the children were able to locate vocabulary with the visual scene displays and the grid layouts with similar levels of accuracy, but they had significant difficulty learning to use iconic encoding. In addition, the use of visual scene displays and visual scene cues resulted in significant improvements in performance compared to spoken
input alone (Shane, 2006). Drager et al. (2004) indicated the children were more accurate in locating vocabulary using the visual scene displays, with screenshots of the scenes on the menu page for navigation, and were less accurate using the traditional grid display with the traditional menu design. Light and Drager indicated future research should investigate preferences and priorities of young children with complex communication needs and their families, improved designs of AAC technologies to better meet the needs of young children and older beginning communicators, improved designs of AAC technologies to better support parents and professionals in implementing AAC effectively with young children and other beginning communicators, effective interventions to support beginning communicators in learning the skills to become competent communicators, advocacy and public policy to ensure early identification of and early intervention for young children with complex communication needs, and preservice and in-service training to close the gap between research and practice to improve services and results for beginning communicators who require AAC.

Branson and Demchak (2009) conducted a systematic review of the literature about AAC use with infants and toddlers (birth to 3 years of age) across a 25-year time period. The study included 12 (seven SSED studies involving a total of 32 participants and five group design studies involving a total of 158 participants), with seven of the 12 (58%) providing conclusive evidence. Six addressed only unaided strategies (i.e., signs, eye contact, and gestures); two focused on comparing an aided AAC method to an unaided method; and five focused on aided AAC (Branson & Demchak, 2009). Most of the participants had unspecified developmental delays (i.e., cerebral palsy, autism, Down syndrome, and unspecified developmental delays). Intervention procedures targeted a
child’s behavior, training caregivers to encourage more intentional communicative acts, and evaluation of an inclusive preschool program (Branson & Demchak, 2009). Targeted skills included increasing intentional communication acts: prelinguistic unaided AAC (i.e., vocalizations, body movement, gestures); participants’ use of symbolic communication through Picture Exchange Communication System or signs; spontaneous and responsive communicative acts in interactive and conversational manner; use of symbolic AAC (i.e., conventional gestures, signs, various line drawing symbols, and Voice Output Communication Aids); requesting the use of Picture Exchange Communication System compared to using signs; and communication functions (i.e., requesting, choice making, protesting, and commenting). Percentage of Non-Overlapping data was used to calculate the effect size for single-subject and group designs (Branson & Demchak, 2009). The reviewed studies reported the following outcomes of AAC use with infants and toddlers: improved communication, communication partners were successfully taught to create more communicative opportunities for the child and to increase the child’s use of intentional communication acts by responding contingently, a variety of AAC systems used successfully with children 36 months of age and younger, and children with various disabilities taught to use AAC methods to improve communication. Studies that included children under the age of 2 tended to use unaided (e.g., gestures, eye gaze, and sign language) rather than aided methods. All 135 participants with higher quality of evidence demonstrated an improvement in communication skills following the AAC intervention. Improvements in a variety of communication acts occurred across all disabilities represented within the studies and across ages of children beginning at 16 months of age. Improvements also were noted
across a wide range of intervention intensity and frequencies (three sessions a week for 10 weeks and two sessions a week for 8 months).

Based upon the information from the synthesis, the recommendation was for clinicians to try a variety of AAC methods, including multi-modal AAC with young children, before concluding a particular child was not ready for AAC (Beukelman & Mirenda, 2013; Branson & Demchak, 2009). In addition, most of the studies were conducted within university early intervention clinics, and the recommendation was for future research to be conducted within homes and childcare centers where functional use of AAC methods during daily routines could be further investigated to help bridge the gap between research and practice in early intervention (Branson & Demchak, 2009).

Branson and Demchack encouraged both providers and parents of infants with disabilities to explore the use of AAC methods as early as possible, as the review indicated children as young as 15 months old were taught to use sign language and pictures (DiCarlo, Stricklin, Banajee, & Reid, 2001) and children as young as 30 months old were taught to use a Voice Output Communication Aid (Iacono & Duncum, 1995).

Ganz, Rispoli, Mason, and Hong (2014) completed a meta-analysis to evaluate the moderating effects of intervention setting and type of aided AAC on outcome variables for students with autism spectrum disorder. Improvement rate difference was used to calculate the effect size for the SSED (Parker, Vannest, & Brown, 2009). The results indicated the largest effect for aided AAC was in the general education classroom setting (Ganz et al., 2012). In addition, results from speech-generating devices and Picture Exchange Communication Systems were associated with larger effects than other picture-based systems. Last, speech-generating devices produced larger effects than the Picture
Exchange Communication Systems in reducing challenging behavior. Results indicated speech-generating devices are effective for improving outcomes in behavior, communication, and academic outcomes. The Picture Exchange Communication System was effective in improving outcomes in communication and social skills (Ganz et al., 2012). Ganz et al. (2012) highlighted the importance of practitioners choosing the most appropriate aided AAC for the skill being addressed.

The meta-analyses completed within speech-language pathology, AAC, and early intervention have been either group design or systematic reviews of SSED that have employed non-parametric methods. The increased accountability of early intervention policy and evidence-based practice movement with requirements for data-driven interventions and investigations have increased the need for stakeholders to evaluate literature and conduct clinical research to determine the most effective speech-language interventions with and without the use of AAC devices and strategies to improve outcomes. Currently, a meta-analysis has not been conducted of SSED and group designs to investigate speech-language pathology interventions for children ages birth to 6 with developmental disabilities to compare effects of intervention with or without the use of AAC using parametric statistical techniques. Effective AAC provision for children and families will become extended to the larger medical, early intervention, and speech-language community only with supporting knowledge, research, and clinical evidence. With access to appropriate assistive technology at the early stages of development, young children with complex communication needs may be able to maximize language and communication development and achieve their full potential (Constantino & Bonati, 2014).
CHAPTER III

METHODOLOGY

Design

The design of the study was formulated using the Preferred Reporting Items of Systematic reviews and Meta-Analyses (PRISMA) according to the CONSORT 2010 statement using updated guidelines for reporting parallel group randomized trials (Schulz, Altman, & Moher, 2010). Methods were adopted from the PRISMA statement and checklist including problem formulation, search literature, evaluating certainty of evidence, extracting relevant data, and performing qualitative analysis of best evidence (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009; Schulz et al., 2010).

Problem Formulation

Systematic review and meta-analysis has not occurred in the current research relative to speech-language interventions for early intervention populations between the ages of birth to 6 with developmental disabilities using AAC compared to similar interventions that did not use AAC. Systematic reviews have been completed using group comparison of speech-language intervention for early intervention populations (Gladfelter et al., 2011). The exclusion of SSED from these reviews has been a matter of concern because information about the variation between subjects and the magnitude of treatment effects tends to be lost in group comparison designs that provide averages and effect sizes for the entire group (Van den Noortgate & Onhenga, 2003a, 2003b, 2008). The primary purpose of the this study was to use meta-analytic procedures across both SSED and group designs to examine the effectiveness of SSED of speech-language interventions with and without the use of AAC strategies and technology on speech-
language outcomes of individuals ages birth to 6 with developmental disabilities, identify study characteristics that predict or correlate with language outcomes, identify study characteristics that moderate intervention effects, and evaluate the quality of speech-language intervention research for this population.

**Research Questions**

This study answered the following research questions:

1. What are the effect sizes of speech-language interventions, with and without AAC, for SSED and group designs for children ages birth to 6 with developmental disabilities?
2. To what extent do the effect sizes vary as a function of treatment approach (with or without AAC) when controlling for other covariates (i.e., age, length intervention provided to child participant, length of intervention provided to adult interventionist or communication partner, type of language intervention, and study design)?
3. What study characteristics moderate the overall effect of early intervention outcomes associated with speech-language intervention targets and outcomes within children ages birth to 6 with developmental disabilities?
4. What is the quality of the speech-language intervention research studies that are included in the meta-analysis?

Two parametric meta-analysis techniques were utilized to answer Research Questions 1 through 3. A standard random-effects meta-regression was used to answer the questions, and meta-regression with robust variance estimation was used as a sensitivity analysis to further assess the dependency between the effect sizes compared to
the result of the standard random-effects meta-regression. A quality analysis was used to answer Research Question 4. An analysis of the quality and rigor of the studies was conducted during study screening and data extraction to determine the inclusion of the studies within the meta-analysis as defined by the WWC standards and guidelines for SSEd (Kratochwill et al., 2010) and group designs (WWC, 2017).

Research Approach and Philosophy

Evidenced-Based Practice

The emphasis of evidence-based practice has encouraged the use of adequate empirical support or research to validate interventions and practices (Shernoff, Kratochwill, & Stoiber, 2002). A practice could include a precise intervention, procedure for documenting a controlling mechanism, or larger program with multiple components (Horner et al., 2005). In order for legislative and policy initiatives to support the use of evidenced-based practices, the research method should define objective criteria that stakeholders may use to determine whether the practice or intervention is evidence-based (Shernoff et al., 2002). Meta-analysis is a statistical procedure that integrates the results of several independent studies and has played a central role in evidence-based practice. It has been widely used as a research method defining objective criteria stakeholders can utilize to determine the efficacy of a practice (Haidich, 2010; Lipsey & Wilson, 2001).

Within the hierarchy of evidence proposed by Straus, Richardson, Glasziou, and Haynes (2005), the highest level of evidence was systematic reviews and meta-analysis of randomized controlled trials and single-case studies. Hierarchies of levels of evidence have also been proposed within the field of AAC and special education, providing
support that meta-analysis of SSED ranks equally as high as meta-analysis of quasiexperimental group designs (Schlosser, Wendt, & Sigafoos, 2007).

**Meta-Analysis**

Meta-analysis has been used within the field of special education (Wang, Parrilla, & Cui, 2013); speech-language pathology (Gladfelter et al., 2011; Kaat-van den Os et al., 2017; Law et al., 2004; Roberts & Kaiser, 2011); and AAC (Branson & Demchak, 2009; Ganz et al., 2014; Romski et al., 2015; Schlosser & Lee, 2000; Schlosser & Sigafoos, 2006; Snell et al., 2006; Walker & Snell, 2013) to synthesize research findings and evaluate the effectiveness of treatments within group studies. Most of the literature on meta-analysis has focused on group studies and has not included SSED (Van den Noortgate & Onghena, 2008). The valuable information specific to SSED has not always been included within meta-analyses, and the majority of research studies available in SSED have not been properly utilized within the evidence-based movement due to limited use within meta-analysis. Although SSED has not been widely included within meta-analyses; the broader field of social sciences has accepted SSED as a viable source of evidence (Howard, Best, & Nickels, 2015).

**Single-Subject Experimental Designs**

Research has been cited as the foundation for determining evidence-based practice in special education (Tankersley, Harjusola-Webb, & Landrum, 2008). The low incidence of some disabilities has required researchers to use single-case designs rather than more conventional group designs (Ganz et al., 2012). As a result, the field of AAC, early intervention, speech-language pathology, and special education includes large numbers of SSED that vary by type of design (e.g., AB, reversal, multiple baseline
design); outcome measures; and participants, which has been difficult to evaluate and synthesize without aggregating and transforming the data into a useable format that is analyzed with a common statistical metric or meta-analysis (Ganz et al., 2012). SSED have been supported in the literature (Horner et al., 2005; Vance & Clegg, 2012) to provide evidence-based practice by (a) documentation that an experimental effect can be obtained under typical conditions (i.e., school or home) with individuals with low-incidence or heterogeneous populations (i.e., special education and children with disabilities); (b) allowing analysis of participants who do not respond to the intervention in the study in comparison to group designs which often report aggregated mean outcomes of the group but do not provide insight into participants who did not respond to the intervention; (c) analyzing the relationship between the individualized interventions employed and the socially valued outcomes; (d) testing the validity of theoretical constructs and theory; and (e) being cost effective (Horner et al., 2005). Given the increased recognition and acceptance of SSED as evidence-based research, SSED have only recently been used in meta-analysis (Wang et al., 2011) involving individuals with disabilities as statistical modeling and applications have improved.

Meta-Analysis of Single-Subject Experimental Designs

Given the vast heterogeneity within low-incidence populations typically studied within SSED, a growing need has emerged among stakeholders to synthesize SSED (Schlosser & Lee, 2000; Schlosser et al., 2007; Van den Noortgate & Onghena, 2003a, 2003b). The synthesis of SSED using meta-analytic techniques has been determined as a valid and appropriate analysis (Baek et al., 2014; Hedges, Pustejovsky, & Shadish, 2012, 2013; Schlosser et al., 2007; Van den Noortgate & Onghena, 2003a, 2003b) and has been
used in research involving individuals with disabilities (Ganz et al., 2014; Schlosser & Lee, 2000; Snell et al., 2006; Walker & Snell, 2013; Wang et al., 2013); however it has seldom capitalized on the utility of regression-based techniques. The typical method of analysis for SSED has utilized visual analysis, which has been strongly criticized as producing either a Type I error or Type II error (Howard et al., 2015). Consensus on the use of the best meta-analytic method to use with SSED without large sample sizes has not been established (Kratchowill et al., 2010). The primary debate has centered on the most appropriate effect size metrics and statistical approaches (regression- or non-regression-based approaches) to measure the effect while taking into consideration the characteristics of SSED (Schlosser et al., 2007). Parameters of the SSED also have been discussed, which include the minimum number of data points (Howard et al., 2015; Kratchowill et al., 2010); type of SSED (i.e., multiple-baseline); assumptions of data distributions; and nature of the data (i.e., autocorrelation; Beretvas & Chung, 2008). Limitations have been reported, which have included bias of interpreting graphed data specifically in the ability to detect changes in the level and trend of graphed data, changes in the slope, and direction of the change (Center, Skiba, & Casey, 1985; Kratchowill et al., 2010).

The intent of this systematic review and meta-analysis was to estimate the size of the effect at a particular point in time and to quantify how the effect changed over time and across cases. Therefore, statistical modeling and the use of parametric meta-analytic methods were considered. Two parametric meta-analysis techniques were utilized, which included a standard random-effects meta-regression and meta-regression with robust variance estimation. The between-case parametric measure was utilized with standard
random-effects meta-regression. The meta-regression with robust variance estimation was used as a sensitivity analysis to compare within study dependence. The following sections discuss each method and reason for consideration related to this synthesis.

**Multilevel Modeling**

Multilevel modeling has been used as a meta-analysis method for SSED within the social sciences field (Center et al., 1985; Van den Noortgate, & Onghena, 2008). Multilevel modeling has been reported to correct autocorrelation or the violation of the independence of data measurements of parametrical inferential statistical techniques (Byiers, Reichle, & Symons, 2012; Kratochwill et al., 2010). As a result, $p$ values have been reported to be artificially inflated, which affects Type I error rates (Byiers et al., 2012; Kratochwill et al., 2010). Baek et al. (2014) indicated multilevel modeling could handle dependency in errors due to autocorrelation, heterogeneous variances, linear and nonlinear trends, and count outcomes. In addition, multilevel modeling addresses research questions specific to the individual effects, average intervention effect, how the average intervention effect changes over time, how much the intervention effect varies across cases, and whether case or study characteristics moderate the size of the intervention effect (Baek et al., 2014). Also, previous studies have indicated multilevel modeling is a valid statistical method to combine data from SSED, with the advantage of the ability to estimate within-subject, between-subject, and between-study variance (Moeyaert, Ugille, Ferron, Beretvas, & Van den Noortgate, 2013; Shadish & Rindskopf, 2007; Van den Noortgate & Onghena, 2003a, 2003b, 2008).

**Between-case parametric measures.** Hedges et al. (2012, 2013) proposed a novel approach to defining and estimating an effect size for SSED that was directly
comparable to standardized mean difference for between-group designs. The effect size involved modeling and summarizing the data across multiple participants simultaneously instead of estimating a separate effect size for each case (Pustejovsky & Ferron, 2017). The approach was based upon a hierarchical model that described the functional relationship for each case and how the pattern of results varied across individual subjects in the study (Pustejovsky & Ferron, 2017). The methods proposed for multiple baseline designs involved the following assumptions: stable baseline data, intervention had immediate change in level, the intervention effect was constant across cases, the outcome was normally distributed across case and phase specific mean levels, and the errors followed a first-order auto-regressive process (Hedges et al., 2013). The between-case standardized mean difference effect size estimate allowed for a certain type of serial dependence rather than assuming independence of the outcome measurements (Pustejovsky & Ferron, 2017). Certain advantages were noted specific to using the between-case standardized mean difference effect sizes; the effect size described the results in a metric familiar to researchers working with between-group designs and allowed comparison of results from SSED to results of between-group designs (Shadish, Hedges, Horner, & Odom, 2015). After an effect size was extracted according to the procedures of Hedges et al. (2012, 2013), the effect size for each study was used as the dependent variable within a standard random-effects meta-regression (Losinski, Cuenca-Carlino, Zablocki, & Teagarden, 2014).

**Meta-Regression with Robust Variance Estimation**

Complex data structures are common within meta-analysis of intervention effectiveness research (Tanner-Smith, Tipton, & Polanin, 2016). Complex data
structures in meta-analysis are a concern statistically due to correlated and hierarchical effects (Hedges, Tipton, & Johnson, 2010). Correlated effects occur when primary studies provide multiple effect size estimates measured on the same unit of analysis measured multiple times or on multiple tests (Hedges et al., 2010). Hierarchical effects occur when effect sizes are estimated on the same units (Hedges et al., 2010). The dependency is a result of research organizations (labs or groups) publishing the results of multiple independent experiments in the same or different studies producing dependency within the results due to similar study characteristics (i.e., subject pool, protocols, and analysis methods; Hedges et al., 2010). Statistically dependent effect sizes typically have been synthesized using multivariate meta-analysis methods by modeling the dependencies using multilevel models or meta-analysts and have used data processing and selection techniques for dependent effect sizes. Data processing and selection techniques have included selecting one effect size per study or creating a single synthetic effect size per study by averaging all the effect sizes within a given study (Tanner-Smith et al., 2016). These data processing and selection techniques leave out potentially valuable information. An alternative for handling statistically dependent effect sizes is to use a meta-regression with robust variance estimation. This method permits the inclusion of statistically dependent effect sizes within a meta-analysis, allowing the meta-analysts to use all available information reported in the primary study (Tanner-Smith et al., 2016).

A benefit of a meta-regression with robust variance estimation instead of a multilevel model is the requirement of fewer distributional assumptions and less computational power (Hedges et al., 2010). In addition, standard multivariate meta-
analysis requires complex models that are computationally difficult to estimate; and the robust variance estimate does not require such complex models, making it intuitive and simple to implement (Hedges et al., 2010). Authors have suggested this method does not require knowledge of the underlying covariance structure and is practical for use in many scenarios (Hedges et al., 2010). Recent advances in meta-analytic software also have made robust variance estimates easier to implement (Tanner-Smith et al., 2016).

**Systematic Review Process**

**Data Sources/Search Strategy**

The search strategy consisted of the following techniques: computerized keyword searches in reference databases, examining the references of previous reviews, manually examining the table of contents of subject area journals, and examining references of studies already identified as meeting inclusion criteria (Schlosser & Lee, 2000; White, 1987). Databases were searched for the period 2008 to October 2018 with the following (combination of) keywords: augmentative and alternative communication; speech and language intervention; early intervention; developmental delay; language intervention; speech and language therapy; SSED; developmental disability; expressive language outcomes; multiple baseline designs, ages birth to 6; and genetic and congenital disorders. The initial date of 2008 was chosen to select only the last 10 years of research, as a significant shift has occurred in theory, practice, and policy specific to the use of AAC within early intervention populations (Romski et al., 2015; Schlosser & Lee, 2000). Databases that were searched include APA PsycNet, BMC Medical Education, BMC Developmental Biology, Catalog of US Government Publications, CINAHL Plus with Full Text, ERIC, American Association for the Education of the Severely/Profoundly
Handicapped, PubMed, Web of Science, Sage Journals, Google Scholar, Taylor & Francis Online, PubMed Central, and Kramer Library One Search. Manual searches were conducted in relevant professional journals, which included *American Journal of Speech-Language Pathology; Journal of Speech, Language, and Hearing Research; Language, Speech, and Hearing Services in Schools;* and *Augmentative and Alternative Communication Journal.* Reference lists of empirical studies or systematic reviews completed in early intervention, speech-language intervention, and AAC were crosschecked for current articles and additional references (Kaat-van den Os et al., 2017; Schlosser & Lee, 2000). During the first selection phase, the abstracts and articles were screened according to the inclusion criteria. During the second phase, abstracts and articles were screened according to certainty of evidence analysis (i.e., quality coding criteria). During the third phase, the entire article was reviewed and screened for inclusion criteria.

**Inclusion and Exclusion Criteria**

Studies included in the systematic review met predetermined inclusion criteria. Participants in the study were early intervention ages, specifically birth to 6 with developmental disabilities; speech-language interventions targeting improvement in expressive speech-language outcome with or without the use of AAC strategies or technology; speech-language interventions that were naturalistic or responsive; speech-language interventions that were triadic or included caregiver training, caregiver implementation with or without mentoring from an SLP, and child participant language outcomes (Roberts & Kaiser, 2011); met or met with reservations the standards of the
quality appraisal tool; and the study was SSED that included multiple baseline designs or 
group design specifically with a randomized control trial or quasi-experimental design. 
Articles were excluded if the participants had a primary hearing loss (conductive or 
sensorineural). Articles were excluded that did not use a naturalistic speech language 
intervention or a transactional model of social communication development (McLean & 
Synder-McLean, 1987) and included a communication partner as the primary 
terventionist.

Multiple baseline designs were only included, as the internal validity of multiple 
baseline designs was ensured by multiple replication of intervention delivered across 
behaviors, subjects, or settings (Morgan & Morgan, 2009). In addition, only multiple 
baseline designs that had three data points per phase were included to allow for the 
calculation of the between-case standardized mean difference (Valentine, Tanner-Smith, 
Pustejovsky, & Lau, 2016).

In addition, a certainty of evidence analysis or quality appraisal tool was used to 
assess the methodological rigor of all studies using the WWC study design standards. The 
group design standards from the WWC have been well established and accepted within 
the field of education and research and were used to rate the quality of the group designs 
according to the *WWC Standards Handbook* Version 4.0 (WWC, 2017). The WWC Pilot 
Standards (Kratochwill et al., 2010) were used to rate the quality of the SSED. The SSED 
standards were not as well known and were applied in specific steps. The WWC Pilot 
Standards for SSED were based upon the conceptualization of evidence quality by 
Horner et al. (2005) and developed as inclusion criteria for meta-analyses (Kratochwill et 
al., 2010). Studies were included that either met the standard or met the standard with
reservations. To satisfy the design standards, a study had to meet the criteria as indicated in Table 1. Studies that did not meet the design standards were excluded from the study.

Table 1 provides a narrative description of the WWC three-step sequence to complete quality appraisal of the SSED included within the study.

Table 1

Summary of What Works Clearinghouse Criteria for Experimental Designs

<table>
<thead>
<tr>
<th>Design element</th>
<th>Meets standard</th>
<th>Reservation</th>
<th>Does not meet standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent variable(s)</td>
<td>Actively manipulated by researcher</td>
<td>___</td>
<td>Researcher does not control changes to conditions</td>
</tr>
<tr>
<td>Dependent variables(s)</td>
<td>Measured systematically over time</td>
<td>___</td>
<td>No systematic measurement (i.e.,)</td>
</tr>
<tr>
<td></td>
<td>Measured by more than one assessor</td>
<td>___</td>
<td>Only one assessor</td>
</tr>
<tr>
<td></td>
<td>Includes assessor agreement on at least 20% of data points in each phase</td>
<td>___</td>
<td>No interassessor agreement only in some phases, or in less than 20% of data points</td>
</tr>
<tr>
<td>Assessor agreement meets minimal thresholds</td>
<td>___</td>
<td>Poor assessor agreement</td>
<td></td>
</tr>
<tr>
<td>Length of phases</td>
<td>At least 5 points per phase</td>
<td>3-4 points per phase</td>
<td>&lt; 3 points per phase</td>
</tr>
<tr>
<td>Replication of effect</td>
<td>Multiple-baseline/multiple-probe: 6 phases across at least three cases</td>
<td>___</td>
<td>&lt; 3 cases: &lt; 6 phases</td>
</tr>
</tbody>
</table>

The first step was to conduct a visual analysis of the results to determine whether the data parameters (i.e., baseline, level, slope, and variability) suggested an experimental effect (Byiers et al., 2012). Each parameter had a definition and specific steps to complete the analysis. The analysis of experimental control in SSED is based upon visual comparisons between two or more conditions that typically include the baseline condition during a time prior to intervention, as well as one or more intervention conditions (Byiers et al., 2012). The data within the baseline phase must have certain qualities to be utilized in evidence-based practice, which included stability (data points display limited variability, the range within which future data points will fall is predictable) and the lack
of a clear trend of improvement within a minimum of three baseline data points (Byiers et al., 2012). All three of the following parameters were used as evidence of effects of the independent variable in SSED (Byiers et al., 2012). Level was the average rate of performance during a phase. Trend was the direction of change in data or the slope (positive or negative). Variability was the performance or data points recorded in the dependent measure having wide range of variability (0 to 100) as compared to being stable (range of 6) in the baseline or intervention phases (Byiers et al., 2012).

The third step to assess the overall state of the evidence in favor of an intervention by examining the number of times effectiveness was demonstrated within and across participants (Byiers et al., 2012). The replication of internal and external validity was necessary in determining the overall level of evidence of the treatment (Byiers et al., 2012). Experimental control is demonstrated when the effects of intervention are repeated or replicated reliably within single participants or across participants within a study (Byiers et al., 2012). The replication across participants or different types of participants increases the external validity of the treatment (Byiers et al., 2012). Direct replication is the application of intervention to new participants under the exact same conditions. Systematic replication is the reproduction of the original study while systematically varying one or more components of the intervention (Byiers et al., 2012; Kratochwill et al., 2010). The WWC panel indicates an intervention should have a minimum of five supporting SSED meeting the evidence standards to be combined into a single summary rating of the intervention’s effectiveness with studies conducted by at least three different research teams at different geographical locations with a combined number of a minimum of 20 participants or cases (Byiers et al., 2012; Kratochwill et al., 2010).
Data Extraction

Data were extracted from published group designs and SSED peer-reviewed articles. Data extracted from group designs included the mean and standard deviations of pretest and posttest expressive outcome measures, which was used to calculate the dependent variable or the standardized mean difference according to Hedges et al. (2012, 2013). Additionally, data were extracted by using summary statistics available within the publication per standardized reporting standards.

The data extracted from SSED consisted of only multiple baseline designs with graphs of raw data or summary statistics available within the publication per standardized reporting standards. The data were extracted using a similar procedure as cited by Nagler, Rindskopf, and Shadish (2008) scanning the graph from the original article into an electronic format using the PrintKey 2000 version 5.10 (Bolliger, 1999). The electronic graphs were then scanned into Ungraph (Biosoft, 2018). The graph space was defined and data read using Ungraph and procedures as indicated by Nagler et al. (2008). The data was then exported into Microsoft Excel and organized according to procedures established to convert the raw data into a between-case standardized mean difference for single-case designs (Valentine et al., 2016). Once the data file was set up, the scdhlm package (Hedges et al., 2012, 2013; Shadish, Hedges, & Pustejovsky, 2014; Pustejovsky, 2016) for R Statistical environment (R Core Team, 2013) was used to calculate the between-case standardized mean difference for single-case designs. A limitation of the between-case standardized mean difference was that it can be calculated only for studies that include at least three participants and use an across participant multiple baseline, across participant multiple probe, or withdrawal design. Also, the requirement to
calculate the between-case standardized mean difference included three data points per phase.

**Variables**

The variables selected for this research study were consistent with the specific variables selected in previous meta-analyses and research on AAC, early intervention, and speech-language pathology with children ages birth to 6 with developmental delays (Branson & Demchak, 2009; Ganz et al., 2012; Law et al., 2004; Romski et al., 2015; Schlosser & Lee, 2000; Schlosser & Sigafos, 2006; Snell et al., 2006; Walker & Snell, 2013).

**Dependent Variable**

The dependent variable was a standardized mean difference calculated according to Hedges et al. (2013). The dependent variable measured the expressive communication outcomes reported within each SSED and group design. Expressive communication outcomes were used as the majority of SSED and group designs within the analyses targeted the use of AAC to accommodate the speech and language delays of the sample. An expressive language outcome was defined as a direct observation or a standardized measure.

**Independent Variables**

The focal independent variable was whether the intervention used AAC technology and strategies. This intervention variable was chosen as the primary focus of the meta-analyses because prior meta-analyses and research within early intervention have indicated effect sizes for expressive outcomes (i.e., vocabulary) are smaller in children with developmental delays (Kaat-van den Os et al., 2017). Kaat-van den Os et al.
(2017) indicated children with developmental delays require consistent and high levels of language support strategies to stimulate expressive language development, with additional research needed to identify the optimal intervention strategies to enhance language development. Kaat-van den Os et al. did not consider the impact on expressive communication outcomes if the children were provided the opportunity to use AAC strategies and technology. Also, the intervention type variable was chosen as a primary focus because federal policy supports the provision of AAC within early intervention populations, especially for children with speech-language delays due to developmental and intellectual delays (ASHA, n.d.a). The analysis of expressive outcomes for children who received AAC intervention and technology, compared to similar children who did not receive AAC intervention and technology, provide insight into the effect of AAC on expressive language outcomes for children with developmental delays.

**Control Variables**

The control variables included age of child participant; training dose that was the total amount of treatment time in hours provided to the communication partner or interventionist (i.e., caregiver, teacher, or paraprofessional) by the SLP; treatment dose defined as the total amount of treatment time in hours a child participant received in intervention from SLP and interventionist; and type of study design. Table 2 summarizes the control variables and the coding that was used for each variable. Each control variable was included to determine whether the variable was correlated with the dependent variable and whether there was an interaction. The control variables that were included were related to policy initiatives in determining the most appropriate treatment or
combination of treatment related variables on outcomes (Schooling, Venediktov, & Leech, 2010).

Table 2

*Variables Used in Random-Effects and Robust Variance Estimate Model*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of intervention</td>
<td>Dichotomous (without AAC = 0, with AAC = 1)</td>
</tr>
<tr>
<td>Type of design</td>
<td>Dichotomous (SSED = 0, group design = 1)</td>
</tr>
<tr>
<td>Age in months</td>
<td>Continuous</td>
</tr>
<tr>
<td>Total amount of time in treatment for child participant in hours</td>
<td>Continuous</td>
</tr>
<tr>
<td>Total amount of training time for primary interventionist in hours</td>
<td>Continuous</td>
</tr>
<tr>
<td>Type of speech-language intervention</td>
<td>Dichotomous (responsive = 0, naturalistic = 1)</td>
</tr>
</tbody>
</table>

*Note: AAC = Augmentative and Alternative Communication, SSED = single-subject experimental design*

**Participant, Setting, and AAC Variables**

Participant, setting, and AAC related variables were coded to calculate descriptive statistics but were not included within the meta-regression models. The variables and coding are listed in Table 3.

Table 3

*Participant, Setting, and AAC Variables*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Dichotomous (male = 0, female = 1)</td>
</tr>
<tr>
<td>Race / Ethnicity</td>
<td>Nominal (American Indian or Alaska native, Asian, Black or African American, Hispanic or Latino, Native Hawaiian or other Pacific Islander, White, unknown)</td>
</tr>
<tr>
<td>Associated medical factor</td>
<td>Nominal (Anoxic Brain Damage, Attention Deficit Disorder, Autism &amp; Related Disorder, Brain Tumor, Cerebrovascular issue, Craniofacial Factors, Developmental Delay, Head Injury, Hearing Loss - Conductive, Hearing Loss- Sensorineural, Mental Retardation, Neuromotor Disorders, Seizure Disorder, Syndrome, Other, None)</td>
</tr>
<tr>
<td>Interventionist</td>
<td>Nominal (caregiver, teacher, or paraprofessional)</td>
</tr>
<tr>
<td>Setting</td>
<td>Nominal (school, clinic, home, or early childhood center)</td>
</tr>
<tr>
<td>Service delivery model</td>
<td>Nominal (collaborative consult, individual treatment, group treatment, training only, self-combined</td>
</tr>
<tr>
<td>AAC interface</td>
<td>Continuous calculated as a percentage (grid display, visual scene, or hybrid)</td>
</tr>
<tr>
<td>Type of AAC technology</td>
<td>Nominal (unaided, aided without speech output, aided with speech output, or multimodal)</td>
</tr>
<tr>
<td>Level of technology</td>
<td>Nominal (no, low, or high technology)</td>
</tr>
<tr>
<td>Language representation</td>
<td>Nominal (single meaning pictures, semantic compaction, or alphabet-based)</td>
</tr>
</tbody>
</table>

*Note: AAC = Augmentative and Alternative Communication*
Statistical Analysis

Univariate Analysis

Study results were converted to a common metric to express the size of association between the dependent variable and the independent variable or an effect size (Ugille, Moeyaert, Beretvas, Ferron, & Van den Noortgate, 2014). Standardized effect sizes were used to compare dependent variables measured on different scales across studies (Van den Noortgate & Onghena, 2003a, 2003b). The univariate analysis is displayed using a forest plot, the typical presentation of univariate analysis, using the effect size and confidence intervals (Borman & Grigg, 2009). The standardized effect sizes for group designs were extracted and calculated according to procedures indicated by Hedges and Olkin (1981). The calculations were completed using Microsoft Excel. The study used the formula devised by Hedges and Olkin (1981) to obtain the Hedges’g-value (the difference in averages divided by pooled SD) as the effect size. The calculation of the standardized measure of effect size was completed by using summary statistics (\(M\) and \(SD\)) from research articles of group designs (Lipsey & Wilson, 2001).

The following procedures calculated the standardized effect sizes of the SSED for data without trends in phases (baseline or treatment). The calculation of the standardized measure of effect size was completed by using raw data or summary statistics (test statistics, \(p\) values, or measures of effect) from research articles of SSED (Hedges et al., 2013; Van den Noortgate & Onghena, 2003a, 2003b). A standardized mean difference or single-case equivalent of standardized mean difference was calculated as indicated by Hedges et al. (2013) using the scdhlm package (Pustejovsky, 2016) within the R statistical environment (R Core Team, 2013). The effect size parameter corresponded to
the standardized mean difference between groups at post-test (Cohen’s $d$), a widely used effect size parameter in between-subject designs (Hedges et al., 2013). The effect size placed treatment effect from single-case designs on the same metric used in between-subject designs (Hedges et al., 2013). The effect size parameter ($\delta$), or standardized mean difference, was defined as $\delta = \frac{D}{S}$ or $\delta = \frac{\mu^T - \mu^C}{\sqrt{\sigma^2 + \tau^2}}$ where $\mu^T - \mu^C$ represents the treatment effect in the form of a level shift between baseline and treatment periods; $\sigma^2$ is the within-case variance of an observation; $\tau^2$ is the between-case variance of observations in the same treatment groups; and $\sigma^2 + \tau^2$ is the total variance (Hedges et al., 2013). The effect size was estimated by constructing unbiased estimates of the numerator $\mu^T - \mu^C$ and the square of the denominator $\sigma^2 + \tau^2$ and then combining these estimates and making a small sample size correction (Hedges et al., 2013). The numerator of the effect size estimate was the unweighted mean difference between treatment and baseline conditions:

$$\bar{D} = \frac{1}{m} \sum_{i=1}^{m} (\bar{Y}^T_i - \bar{Y}^B_i)$$

where $\bar{Y}^B_i$ and $\bar{Y}^T_i$ are the average outcomes for individual $i$ within the baseline and treatment conditions (Hedges et al., 2013). The computation of the numerator took into account that some individuals move from baseline to treatment at different times than others. This is also referred to as a staggering of treatment data points. The denominator of the effect size was defined as $S^2$ across individuals within the same treatment phase at each given time point, pooled over time points, and across treatments. The denominator or variance took into account the staggering of treatment data points. The sample variance, pooled across time points and treatment groups, was as follows:
\[
S^2 = \frac{1}{g - K} \sum_{j=1}^{N} \sum_{p \in G_j} \sum_{i \in G_j} \left( Y_{ij} - \mu_{ij} \right)^2
\]

where \( g \): is the total number of observations; \( K \) is a degrees-of-freedom correction; and \( G_j^p \) indicated which cases are in condition \( p \) at time point \( j \) for \( j = 1, \ldots, N \); \( p = B \) for baseline; and \( T \) for treatment (Hedges et al., 2013). The effect size was then corrected for small sample size bias following Hedges et al. (2013) by applying a multiplicative factor:

\[
J(\nu) = 1 - \frac{3}{4^\nu - 1}
\]

where \( \nu \) is an estimated degree of freedom between the number of cases and the total number of time points depending on the autocorrelation and the intraclass correlation.

Computational formulas for \( \nu \) were determined on whether the data were from an AB design or from a multiple baseline design. The bias-corrected effect size, Hedges' \( g \), was then given by \( g = J(\nu) \times \text{ES} \). Given the degrees of freedom \( \nu \) and the effect size estimator \( g \), an approximate variance estimator of \( g \) was given by:

\[
V(g) = J(\nu)^2 \left[ \frac{\nu^2}{\nu - 2} + g^2 \left( \frac{\nu}{\nu - 2} - \frac{1}{J(\nu)^2} \right) \right]
\]

where \( \theta \) is defined as \( \theta = \frac{\sqrt{V(\text{d})}}{\sqrt{\nu^2 + \sigma^2}} \) in order to reflect the variance of the numerator of \( d \), although it was computed in such a way to take into account the autocorrelation, intraclass correlation, number of time points, and number of cases (Hedges et al., 2012, 2013).

**Meta-Analyses**

Two approaches were used to examine the effect sizes, to include a standard random-effect meta-regression and a meta-regression with robust variance estimation (Pustejovsky & Ferron, 2017; Tanner-Smith et al., 2016).
Standard Random-Effect Meta-Regression

After calculation of standardized mean difference effect size estimates and variance using procedures as indicated by Hedges et al. (2013) for group designs and procedures indicated by Hedges et al. (2012) for SED for each study, these parameters were used within a multivariate random-effect meta-regression (Borenstein, Hedges, Higgins, & Rothstein, 2009) using metafor (Viechtbauer, 2010) within the R statistical environment (R Core Team, 2013). According to Borenstein et al. (2010), a standard random-effect meta-analysis with independent effect sizes is specified as:

\[ y_j = \beta_0 + u_j + e_j \]

where \( y_j \) is an effect size in the \( j \)th study \((j = 1\ldots m)\) and \( \beta_0 \) is the average population effect; \( u_j \) is the study level random effect \( \sim N(0, \tau^2) \); and \( e_j \) is the study level residual \( \sim N(0, \nu_j) \). In addition, the effect of moderator variables was of interest to account for some of the observed variability in effect sizes, and the simple random effect meta-analytic model was extended to include covariates or effect size moderators:

\[ x_1 \ldots x_p: y_j = \beta_0 + \beta_1 x_1 + \ldots + \beta_p x_p + u_j + e_j \]

where \( \beta_0 \) is the intercept, \( \beta_1 \ldots \beta_p \) are the regression coefficients for the covariates, and variance \( u_j = \tau_{res}^2 \) is the heterogeneity after adjusting for the covariates (Tanner-Smith et al., 2016). The random-effect model was used to allow the true effect to vary from one study to the next and distribution of effects for all studies within a subgroup (Borenstein et al., 2009). Under the random-effect model, the effect size was interpreted as the mean of the true effect sizes for all studies with a given value of the covariates. The variance within the random-effect models measured the variance within studies plus the variance between studies \( (\tau^2) \). \( \tau^2 \) reflected the dispersion of true effects for studies with the same
predicted value (the same value on the covariates) and was computed for each point on
the prediction slope (Borenstein et al., 2009). The observed effect \( Y_i \) for any study is
given by the grand mean, the deviation of the study’s true effect from the grand mean,
and the deviation of the study’s observed effect from the study’s true effect (Borenstein et
al., 2009) as follows: \( Y_i = \mu + \zeta_i + \epsilon_i \). Therefore, to predict how far the observed effect \( Y_i \)
was likely to fall from \( \mu \) in any given study, both the variance of \( \zeta_i \) and the variance of \( \epsilon_i \)
were considered (Borenstein et al., 2009). The distance from \( \mu \) to each \( \theta_i \) was dependent
on the standard deviation of the distribution of the true effects across studies, or \( \tau^2 \) for its
variance (Borenstein et al., 2009). The same value of \( \tau^2 \) applied to all studies in the meta-
analysis (Borenstein et al., 2009). The study \( i \) of a total of \( n \) studies provided an estimate,
\( Y_i \), of the effect of interest (Hedges’ \( g \), standardized mean difference). Each study
provided a standard error for this population estimate, \( \sigma_i \), which was assumed to be
unknown.

**Meta-Regression with Robust Variance Estimation**

After calculation of the standardized mean difference effect size estimates (or
effect sizes) and variance according to procedures indicated by Hedges et al. (2013) for
group designs and procedures indicated by Hedges et al. (2012) for SSED, the parameters
were used within a meta-regression with robust variance estimation to account for the
dependency in the effect sizes from the same study. Robumeta (Fisher, Tipton, &
Zhipeng, 2017) within the R statistical environment (R Core Team, 2013) was used to run
the meta-regression with robust variance estimation. Hedges et al. (2010) outlined the
following approach:

\[
ES_{ij} = B_0 + \beta_1 X_{ij} + \ldots + \epsilon_{ij}
\]

61
where $ES_{ij}$ is the effect size $i$ study $j$ parameter extracted from SSED and group designs, $X_{ij}$ is a moderator variable of interest to account for some of the observed variability in effect size, and $\varepsilon_{ij}$ is random error variance for effect size $i$ study $j$. The robust variance estimate addressed statistical dependency of data (correlated and hierarchical effects) with the following model, assuming correlated effects with multiple effect size estimates nested within studies:

$$y_j = \beta_0 + u_j + e_j$$

where for $i \ldots k_j$, $j = 1 \ldots m$, $y_{ij}$ is the $i$th effect size in the $j$th study, $\beta_0$ is the average population effect, $u_j$ is the study level random effect, such that $\text{Var}(u_j) = \tau^2$ is the between-study variance component and $e_j$ is the residual for the $i$th effect size in the $j$th study. To examine effect sizes with moderators, the robust variance estimation model was extended to include $p$ control variables $x_1 \ldots x_p$ where:

$$y_{ij} = \beta_0 + \beta_1 x_{1ij} + \ldots + \beta_p x_{p|ij} + u_j + e_{ij}.$$  

The robust variance estimation approach differed from the standardized meta-analysis approach in the estimation of the variance $b$ (Tanner-Smith et al., 2016).

**Risk of Bias**

Publication bias occurs when studies with positive findings are more likely to be published than those with negative findings (Sutton, 2009). Published scientific literature documents only a proportion of the results of all research completed, and published work is systematically different from unpublished work (Sutton, 2009). Publication bias is a major threat to the validity of meta-analysis. The methods used for identifying publication bias were the funnel plot and linear regression tests (Sutton, 2009).
The funnel plot was constructed using a scatter plot of a measure of study size against a measure of effect sizes. The data for the funnel plot, specifically the standardized effect sizes and SE, were extracted and calculated according to procedures as indicated by Hedges et al. (2013). The calculations were completed using Microsoft Excel. The data were then imported into R statistical environment (R Core Team, 2013), and a funnel plot was created using metafor (Viechtbauer, 2010). The funnel plot was created with the SE on y-axis versus the residual value on the x-axis for the 32 effect sizes. The residual value was the observed fitted value which was calculated as the raw effect size minus the mean effect size from the univariate analysis (RDocumentation, n.d.). The interpretation of the funnel plot was completed by visual inspection of the symmetrical distribution of the effect sizes and funnel shape (Sutton, 2009). If publication bias were present, a gap demonstrated within the funnel plot would indicate a suppression of studies within the literature base (Sutton, 2009).

The linear regression test recommended to detect asymmetry of a funnel plot was an alternative parametric test based on linear regression by Egger, Smith, Schneider, and Minder (1997). The regressed standard normal deviate, \( z_i \) (i.e., \( z_i = T_i / \sqrt{v_i} \)), against \( 1 / \sqrt{v_i} : z_i = \beta_0 + \beta_1 (1 / \sqrt{v_i}) + \epsilon_1 \), where \( \epsilon_1 \sim N(0, \sigma^2) \). The regression was referenced to fit a line to Galbraith’s radial plot, in which the fitted line is not constrained to go through the origin (Sutton, 2009). The intercept provided a measure of asymmetry and the standard two-sided test of whether \( \beta_0 = 0 \) (that is \( \beta_0 / se(\beta_0) \)) compared to a \( t \)-distribution with \( n - 2 \) degrees of freedom. If the Egger’s regression test was statistically significant, this would have indicated the intercept of the Egger’s regression line was further from 0 than was expected by chance. A negative intercept would have indicated smaller studies...
were associated with bigger effects. The detection of funnel asymmetry has been suggested to imply publication bias.

**Reliability, Validity, and Generalizability**

A sensitivity analysis was conducted to compare parametric estimates of the standard random-effect meta-regression to the results of the meta-regression with robust variance estimation. The results of both types of analyses were compared over estimators to determine whether results were consistent regarding the interventions that were more or less effective (Kratochwill et al., 2010). Additionally, WWC provided the framework for the reliability, validity, and generalizability of the results. The reliability and validity of the results was dependent upon the level of evidence available for review within the SSED and group studies. The results were generalizable to a similar population as the research sample within the meta-analysis. In addition, the generalizability was dependent on the number of SSED and the total number of subjects within each study. The larger the number of studies and subjects, the larger the power of the statistical analysis, lending to greater generalizability.

**Ethical Issues**

No ethical issues occurred. All data were published and de-identified, which minimized ethical issues (e.g., identification).

**Limitations**

**Small Sample Size**

The meta-analysis included only 32 effect sizes from 16 studies and, as a result, the models for the meta-regression analysis were not powered to detect small moderator effects. The effect size sample was limited for a number of reasons: the quality of studies
was limited to WWC criteria, and search results likely did not find all of the articles in the universe that relate to this analysis; and a smaller research base existed for this population, given the level of heterogeneity between the participants. In addition, all the variables extracted from the data sources were not able to be used within the meta-regression models limiting the ability to account for each variable’s contribution to the efficacy of the intervention on the outcomes. In addition, some of the moderator variables were not assessed at a fine-grain analysis but were aggregated into larger variable categories.

As a result of the small effect size sample, the use of AAC and the specific speech-language interventions included within the analysis are not generalizable to the overall early intervention population. The information from the study is generalizable to participants with disabilities and significant expressive language impairment benefitting from the use of AAC between the ages of birth to 6.

**Scope of the Intervention for Child Participants**

This analysis included only a specific type of speech-language intervention, naturalistic and responsive intervention, with a communication partner education component. The fidelity of the application of the communication partner strategies that were included had some variation across research studies and participants. An attempt was made to model this variation within the meta-analysis; however, given the small sample size, the individual types of communication partner strategies were collapsed into larger categories.
Scope of Intervention for Communication Partner Participants

This analysis broadly defined intervention for communication partners as time invested by the SLP with the primary communication partner. The specific type of intervention or communication partner training was coded, but the small sample size did not permit each type of training technique implemented by the SLP to be used within the meta-analysis as moderators. This limited the analysis of a more fine-grained set of categories and comparisons.

Expressive Language Outcome Domain

This analysis used a broad definition of expressive language outcomes that were collapsed within one larger domain. The limitation of collapsing specific expressive outcomes into a larger domain inhibits the meta-analysis from pinpointing the specific expressive outcome that was impacted by the intervention.
CHAPTER IV

RESULTS

Study Selection

A search for research that tested the effects of early intervention, speech-language intervention, and AAC for children birth to 6 with disabilities resulted in the identification of 384 eligible studies based upon title and abstract reviews. Multiple databases were searched and, initially, 294 were identified and 19 duplicate records were excluded. Furthermore, an ancestral search and appraisal of other literature reviews resulted in the identification of an additional 130 studies. Ultimately, full-text evaluation of the 384 identified studies reduced the number of eligible studies to 16. Six studies were identified through ancestral search, and 10 studies identified through database search. All of the studies included were published in the US with the exception of one from the Netherlands (Duifhuis et al., 2017). Figure 1 identifies the number of studies at each stage of the process. In this figure, a “record” refers to a single citation from one database.

Figure 1. Records identified and retained at each stage of the selection process.
Exclusion of articles during the full-text screen occurred for various reasons, which are listed in Table 4. The majority of articles did not meet inclusion criteria or were duplicate articles. The third most frequent reason for exclusion was type of intervention. The different types of intervention that were excluded were as follows: peer-to-peer intervention, intervention to increase multi-symbol use on a speech generative device by SLP only, intervention to increase expressive communication with a speech-generative device without a caregiver or primary communication partner as the interventionist, video modeling, mentoring from older AAC users, or AAC to support behavioral interventions.

Table 4

<table>
<thead>
<tr>
<th>Reason for Exclusion</th>
<th>Number Excluded</th>
<th>Percentage Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 participant in the study</td>
<td>12</td>
<td>3.13</td>
</tr>
<tr>
<td>2 participants in the study</td>
<td>9</td>
<td>2.34</td>
</tr>
<tr>
<td>Age of participants older than inclusion criteria and type of treatment different from inclusion criteria</td>
<td>22</td>
<td>5.73</td>
</tr>
<tr>
<td>Age of participants older than inclusion criteria</td>
<td>2</td>
<td>0.52</td>
</tr>
<tr>
<td>Age of participants older than inclusion criteria and design that did not meet inclusion criteria</td>
<td>1</td>
<td>0.26</td>
</tr>
<tr>
<td>Study not complete</td>
<td>3</td>
<td>0.78</td>
</tr>
<tr>
<td>Dependent variable did not meet inclusion criteria</td>
<td>33</td>
<td>8.59</td>
</tr>
<tr>
<td>Design did not meet inclusion criteria (i.e., RCT, quasi-experimental group design, or multiple baseline design)</td>
<td>55</td>
<td>14.32</td>
</tr>
<tr>
<td>Group design did not meet WWC standards</td>
<td>6</td>
<td>1.56</td>
</tr>
<tr>
<td>SSED did not meet WWC standards</td>
<td>5</td>
<td>1.30</td>
</tr>
<tr>
<td>Duplicate</td>
<td>64</td>
<td>16.67</td>
</tr>
<tr>
<td>Insufficient data or statistical reporting for effect size extraction</td>
<td>2</td>
<td>0.52</td>
</tr>
<tr>
<td>Population diagnosis did not meet inclusion criteria</td>
<td>24</td>
<td>6.25</td>
</tr>
<tr>
<td>Publication date did not meet inclusion criteria</td>
<td>4</td>
<td>1.04</td>
</tr>
<tr>
<td>Synthesis or review article</td>
<td>73</td>
<td>19.01</td>
</tr>
<tr>
<td>Type of treatment was different from inclusion criteria</td>
<td>69</td>
<td>17.97</td>
</tr>
</tbody>
</table>

*Note.* WWC = What Works Clearinghouse, SSED = single-subject experimental design, RCT = randomized control trial.
The quality of the articles or study rating also contributed to the exclusion of articles. The quality of the study for group designs was defined by The WWC Group Design Standards 4.0 (WWC, 2017). All group designs included in the meta-analysis met standards, with the exception of the one quasi-experimental design (Duifhuis et al., 2017), which met standards with reservations. Quasi-experimental designs were reported to meet WWC standards with reservations according to the WWC (2017). The WWC Supplemental Training on Single-Case Design Studies (Bleeker, Furgeson, Monahan, & Schulte, 2016) and The WWC Systematic Review Process for Single-Case Designs (Bleeker & Hitchcock, 2014) were used to code and rate the quality of the SSED. A total of eight SSED with 13 effect sizes met the WWC standards, and five studies (six effect sizes) met with reservations. The studies that met with reservations are listed in Table 5. Finally, effect sizes were not able to be extracted from two articles due to insufficient data (i.e., $M$, $SD$ or similar statistic) for a group design and insufficient data points to calculate an effect size for a SSED (i.e., 3 data points per phase).

Table 5

<table>
<thead>
<tr>
<th>Citation</th>
<th>Reason for Meeting with Reservations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binger, Kent-Walsh, Berens, Del Campo, &amp; Rivera (2008)</td>
<td>Study did not demonstrate an effect at three different points in time</td>
</tr>
<tr>
<td>Binger, Kent-Walsh, Ewing, &amp; Taylor (2010)</td>
<td>Study did not demonstrate an effect at three different points in time</td>
</tr>
<tr>
<td>Kent-Walsh, Binger, Hasham (2010)</td>
<td>Study did not demonstrate an effect at three different points in time</td>
</tr>
<tr>
<td>Olive et al. (2007)</td>
<td>Study did not demonstrate inter-assessor agreement and an effect at three different points in time</td>
</tr>
<tr>
<td>Randolph, Stichter, Schmidt, &amp; O’Connor (2011)</td>
<td>Study did not demonstrate an effect at three different points in time</td>
</tr>
</tbody>
</table>

**Descriptive Information**

**Participants and Setting Characteristics**

Data were extracted related to age, ethnicity, disability type, inclusion criteria, setting characteristics, and AAC technology to provide understanding of the populations
within the study and are summarized in Tables 6-12. The study involved 626 participants, with 598 from group designs and 28 from SSED. A total of 331 participants were in the treatment group, 303 were group designs, and 28 from SSED. The control group consisted of 141 participants from group designs only. The mean chronological age was 22.62 (SD 19.36) months. The gender indicated in Table 6 included 404 males and 233 females. One group study did not report gender (Casenhisier et al., 2013), and one did not report gender in an interpretable statistic (Fey et al., 2013).

Table 6

Participants and Gender

<table>
<thead>
<tr>
<th>Citation</th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Binger et al. (2008)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Binger et al. (2010)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>McDuffie et al. (2016)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Kent-Walsh et al. (2010)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Harjusola-Webb &amp; Robbins (2012)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Douglas, Light, &amp; McNaughton (2013)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Olive et al. (2007)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Randolph et al. (2011)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cabell et al. (2011)</td>
<td>237</td>
<td>116</td>
</tr>
<tr>
<td>Kaiser &amp; Roberts (2013)</td>
<td>77</td>
<td>38</td>
</tr>
<tr>
<td>Fey, Yoder, Warren, &amp; Bredin-Oja (2013)</td>
<td>64</td>
<td>31</td>
</tr>
<tr>
<td>Duinhuis et al. (2017)</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Casenhisier, Shanker, &amp; Stieben (2013)</td>
<td>49</td>
<td>25</td>
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<tr>
<td>Fey et al. (2006)</td>
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<td>Hardan et al. (2015)</td>
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<td>22</td>
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<tr>
<td>Kasari et al. (2014)</td>
<td>55</td>
<td>27</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>626</td>
<td>141</td>
</tr>
<tr>
<td><strong>Group Design</strong></td>
<td>598</td>
<td>303</td>
</tr>
<tr>
<td><strong>SSED</strong></td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

*Note. SSED = single-subject experimental design, NA = no data available.*
The ethnicity indicated in Table 7 included the following: 15 Asian participants, 152 African American participants, 29 Hispanic or Latino participants, 270 White participants, and no ethnicity was listed for 148 participants.

Table 7

Participant Ethnicity

<table>
<thead>
<tr>
<th>Citation</th>
<th>African American</th>
<th>Hispanic or Latino</th>
<th>White</th>
<th>Other</th>
<th>None</th>
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</thead>
<tbody>
<tr>
<td>Binger et al. (2008)</td>
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<td>Binger et al. (2010)</td>
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<td>McDuffie et al. (2016)</td>
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<td>2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Harjusola-Webb &amp; Robbins (2012)</td>
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<td></td>
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<tr>
<td>Douglas et al. (2013)</td>
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<tr>
<td>Olive et al. (2007)</td>
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<td>Randolph et al. (2011)</td>
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</tr>
<tr>
<td>Cabell et al. (2011)</td>
<td>110</td>
<td>17</td>
<td>147</td>
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<td>30</td>
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<td>Kaiser &amp; Roberts (2013)</td>
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<td>Fey et al. (2013)</td>
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<td>Duinhuis et al. (2017)</td>
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<tr>
<td>Casenbiser et al. (2013)</td>
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<td>5</td>
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<tr>
<td>Hardan et al. (2015)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Kasari et al. (2014)</td>
<td>12</td>
<td>14</td>
<td>3</td>
<td>29</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15</strong></td>
<td><strong>152</strong></td>
<td><strong>29</strong></td>
<td><strong>270</strong></td>
<td><strong>60</strong></td>
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<tr>
<td><strong>Group design</strong></td>
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<td><strong>150</strong></td>
<td><strong>24</strong></td>
<td><strong>266</strong></td>
<td><strong>58</strong></td>
</tr>
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<td><strong>SSED</strong></td>
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<td><strong>4</strong></td>
<td><strong>2</strong></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>

*Note. SSED = single-subject experimental design.*

The type of associated medical factors indicated in Table 8 included 210 participants with Autism, one participant with a craniofacial factor, 105 participants with a developmental delay, 99 participants with a neuromotor disorder, 99 participants with a syndrome, and 237 participants had no indicated disability all from group designs.
Table 8

Associated Medical Factors

<table>
<thead>
<tr>
<th>Citation</th>
<th>Autism</th>
<th>Craniofacial Factors</th>
<th>Developmental Delay</th>
<th>Neuromotor Disorders</th>
<th>Syndrome</th>
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<tr>
<td>McDuffie et al. (2016).</td>
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<tr>
<td>Kent-Walsh et al. (2010).</td>
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<tr>
<td>Harjusola-Webb &amp; Robbins (2012).</td>
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<td>Douglas et al. (2013).</td>
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<td>1</td>
</tr>
<tr>
<td>Olive et al. (2007).</td>
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<tr>
<td>Randolph et al. (2011).</td>
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<td></td>
<td></td>
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<tr>
<td>Cabell et al. (2011).</td>
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<td>NA</td>
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<tr>
<td>Kaiser &amp; Roberts (2013).</td>
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</tr>
<tr>
<td>Casenhiser et al. (2013).</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fey et al. (2006).</td>
<td></td>
<td>17</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardan et al. (2015).</td>
<td>49</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Kasari et al. (2014).</td>
<td>61</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td>210</td>
<td>1</td>
<td>105</td>
<td>5</td>
<td>99</td>
</tr>
<tr>
<td>Group design</td>
<td>201</td>
<td>101</td>
<td>2</td>
<td>88</td>
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</tr>
<tr>
<td>SSED</td>
<td>9</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>11</td>
</tr>
</tbody>
</table>

Note. SSED = single-subject experimental designs, NA = no data available.

The interventionist, setting characteristics, and service model are listed in Table 9.

The interventionist was coded as caregiver, teacher, or paraprofessional. The frequency count for interventionist was at the study level. There are 11 caregivers, three teachers, and two para-professionals. The setting characteristics were as follows: four schools, five clinics, four homes, two early childhood centers, two clinics and homes, and two homes and early childhood centers. The service model at the settings included two collaborative consultations all from group designs; 13 studies used individual treatment for caregiver and child; and one SSED used a group treatment.
Information about AAC was summarized, if provided, and is referenced in Tables 10-12. The total number of effect sizes that used AAC was nine from six studies. The total number of studies that used aided AAC without speech output is four. The number of studies that used aided AAC with speech output is five. The type of technology used included 12 studies with no technology, three with low technology, and four with high technology. Three studies used graphic symbols with text labels; one used a combination of graphic symbols and photographs; and one used graphic symbols only. Graphic symbols listed included Picture Communication Symbols, Unity Icons, and Dynasymns. Language representation methods included single meaning pictures and one semantic compaction or multiple meaning icons. A Fitzgerald Key was noted in three studies.
### Table 10

**AAC Technology**

<table>
<thead>
<tr>
<th>Citation</th>
<th>Type of Technology</th>
<th>Level of Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UniAided</td>
<td>Speech Output</td>
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<tr>
<td>Binger et al. (2008)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Binger et al. (2010)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>McDuffie et al. (2016)</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Kent-Walsh et al. (2010)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Harjusola-Webb &amp; Robbins (2012)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Douglas et al. (2013)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Olive et al. (2007)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Randolph et al. (2011)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Caball et al. (2011)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kaiser &amp; Roberts (2013)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fey et al. (2013)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Duffus et al. (2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Casenbriar et al. (2013)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fey et al. (2006)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hardan et al. (2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kasari et al. (2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td><strong>Group</strong></td>
<td>6</td>
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<tr>
<td><strong>Single-Subject Experimental Design</strong></td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 11

**AAC Interface and Encoding Characteristics**

<table>
<thead>
<tr>
<th>Citation</th>
<th>Interface</th>
<th>Encoding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grid Display</td>
<td>Graphic Symbol</td>
</tr>
<tr>
<td>Binger et al. (2008)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Binger et al. (2010)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>McDuffie et al. (2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Kent-Walsh et al. (2010)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Harjusola-Webb &amp; Robbins (2012)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Douglas et al. (2013)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Olive et al. (2007)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5</td>
<td>3</td>
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<tr>
<td><strong>Single-Subject Experimental Design</strong></td>
<td>5</td>
<td>3</td>
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</tbody>
</table>

74
Table 12

**AAC Language Representation**

<table>
<thead>
<tr>
<th>Citation</th>
<th>PCS</th>
<th>Unity</th>
<th>Icons</th>
<th>Dynasys</th>
<th>Unknown</th>
<th>Single Meaning</th>
<th>Semantic Picture</th>
<th>Semantic Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binger et al. (2008)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binger et al. (2010)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>McDuffie et al. (2016)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kent-Walsh et al. (2010)</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harjusola-Webb &amp; Robbins (2012)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Douglas et al. (2013)</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olive et al. (2007)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Single-Subject Experimental Design</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*Note: PCS = Picture Communication Symbols.*

**Dependent Variable**

The dependent variable analyzed in each study was expressive communication outcome(s). Table 13 provides an overview of each expressive language outcome used within the study. Effect size estimates were projected from the expressive language outcomes measured within the studies. Dependent variables were coded as direct observation or standardized assessment for expressive language. Direct observation was used for 20 outcomes and standardized measures for 12 outcomes. A total of 16 studies resulted in 32 effect sizes.
Independent Variables

The primary independent variable was the use or non-use of AAC in the intervention and is listed by study in Table 14. Six studies (five SSED, one group) and nine effect sizes (six SSED, three group) within the meta-analysis used AAC in the intervention.

Table 14

Studies that Used AAC

<table>
<thead>
<tr>
<th>Citation</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binger et al. (2008)</td>
<td>Single-Subject experimental design</td>
</tr>
<tr>
<td>Binger et al. (2010)</td>
<td>Single-Subject experimental design</td>
</tr>
<tr>
<td>Kent-Walsh et al. (2010)</td>
<td>Single-Subject experimental design</td>
</tr>
<tr>
<td>Douglas, et al. (2013)</td>
<td>Single-Subject experimental design</td>
</tr>
<tr>
<td>Olive et al. (2007)</td>
<td>Single-Subject experimental design</td>
</tr>
<tr>
<td>Kasari et al. (2014)</td>
<td>Group</td>
</tr>
</tbody>
</table>
A secondary independent variable was type of intervention. Only articles were included that used speech-language interventions that were classified within a transactional model of social communication development (McLean & Synder-McLean, 1987). A large variety of speech-language interventions and techniques have been classified within the transactional model of social communication development and have been further narrowed into categories along a continuum from directive to responsive, with naturalistic or hybrid approaches falling in the middle of the continuum (ASHA, 2008). This meta-analysis included only studies that were responsive or naturalistic. Responsive interaction strategies are designed to encourage the child’s engagement and interaction, opportunities for child-initiated behavior and reciprocity, and balanced turn taking with communication partners (ASHA, 2008). Naturalistic interaction strategies are strategies with varying amounts of directive and responsive interactions to promote communication competence (Hepting & Goldstein, 1996). The naturalistic interventions used a multicomponent intervention (directive and responsive) compared to the responsive intervention. The specific communication partner strategies are described and coded in Table 15. The coding of the communication partner strategies was then aggregated according to the type of intervention, specifically naturalistic or responsive, in Table 16. Intervention fidelity is reported for all 32 effect sizes and averaged at least 80% in all studies, with the exception of one study (Kasari et al., 2014) where the communication partner fidelity of intervention was lower.
All interventions included within the meta-analysis were triadic speech-language interventions. The critical features of caregiver-implemented triadic interventions were: caregiver training, caregiver implementation of intervention strategies, and child language outcomes (Roberts & Kaiser, 2011). Table 17 displays the instructional
techniques or the types of caregiver training used within all studies by the clinician to teach the primary caregiver the specific communication partner strategies. The types of techniques each study employed were different for each. The specific technique listed in Table 17 was then coded by study in Table 18.

Table 17

*Instructional Techniques for Communication Partner Education*

<table>
<thead>
<tr>
<th>Instructional Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pretest to solicit parent commitment to learning strategy</td>
</tr>
<tr>
<td>2. Direct instruction or specifically describing the strategy using PowerPoint, handouts, verbally, and/or with a video</td>
</tr>
<tr>
<td>3. Caregiver provide verbal practice of the strategy steps (i.e., using mnemonic) or recasting back strategy to clinician</td>
</tr>
<tr>
<td>4. Caregiver practiced or implemented the strategy in a controlled context (i.e., role play) with mentoring from clinician</td>
</tr>
<tr>
<td>5. Caregiver practiced or implemented the strategy in natural context (i.e., book reading) with mentoring from clinician</td>
</tr>
<tr>
<td>6. Caregiver completed post-test and clinician solicited parents' commitment to long-term implementation of strategy</td>
</tr>
<tr>
<td>7. Caregiver demonstrated generalized use of the strategy</td>
</tr>
<tr>
<td>8. Clinician demonstrated strategy to caregiver or used a video of strategy</td>
</tr>
<tr>
<td>9. Conversation and information sharing between clinician and caregiver</td>
</tr>
<tr>
<td>10. Active listening used by clinician</td>
</tr>
<tr>
<td>11. Joint problem solving and reflection between caregiver and clinician</td>
</tr>
</tbody>
</table>

**Control Variables**

The control variables were the age of child participant; treatment dose defined as the total amount of treatment time in hours a child participant received intervention from an SLP and interventionist; training dose that was the total amount of treatment time in hours provided to the communication partner or interventionist (i.e., caregiver, teacher, or paraprofessional) by and SLP; and study design. Table 19 provides the descriptive statistics for these variables.
Table 18

Instructional Techniques for Communication Partner Education by Citation

<table>
<thead>
<tr>
<th>Citation</th>
<th>Instructional Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binger et al. (2008)</td>
<td>1, 2, 3, 4, 5, 6, 7</td>
</tr>
<tr>
<td>Binger et al. (2010)</td>
<td>1, 2, 3, 4, 5, 6, 7,</td>
</tr>
<tr>
<td>McDuffie et al. (2016)</td>
<td>2, 4, 5, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Kent-Walsh et al. (2010)</td>
<td>1, 2, 3, 4, 5, 6, 7</td>
</tr>
<tr>
<td>Harjusola-Webb &amp; Robbins (2012)</td>
<td>2, 3, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Douglas et al. (2013)</td>
<td>1, 2, 3, 4, 5, 6, 7, 10, 11, 12</td>
</tr>
<tr>
<td>Olive et al. (2007)</td>
<td>2, 7, 9</td>
</tr>
<tr>
<td>Randolph et al. (2011)</td>
<td>2, 3, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Cabell et al. (2011)</td>
<td>2, 3, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Kaiser &amp; Roberts (2013)</td>
<td>1, 2, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Fey et al. (2013)</td>
<td>2, 3, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Duifhuis et al. (2017)</td>
<td>2, 3, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Casenhiser et al. (2013)</td>
<td>2, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Fey et al. (2006)</td>
<td>2, 3, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Hardan et al. (2015)</td>
<td>2, 3, 4, 5, 7, 9, 10, 11, 12</td>
</tr>
<tr>
<td>Kasari et al. (2014)</td>
<td>2, 3, 4, 5, 7, 9, 10, 12</td>
</tr>
</tbody>
</table>

Table 19

Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean or Proportion</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Hedges $g$</td>
<td>.778</td>
<td>1.063</td>
</tr>
<tr>
<td>Variance of $g$</td>
<td>.147</td>
<td>.173</td>
</tr>
<tr>
<td>Group design</td>
<td>.688</td>
<td>.471</td>
</tr>
<tr>
<td>Intervention with AAC</td>
<td>.281</td>
<td>.457</td>
</tr>
<tr>
<td>Age in months</td>
<td>22.617</td>
<td>19.367</td>
</tr>
<tr>
<td>Treatment dose in hours</td>
<td>20.410</td>
<td>17.609</td>
</tr>
<tr>
<td>Training dose in hours</td>
<td>12.285</td>
<td>18.139</td>
</tr>
<tr>
<td>Multicomponent treatment</td>
<td>.844</td>
<td>.369</td>
</tr>
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</table>

Note. AAC = Augmentative and Alternative Communication.

Data screening led to the transformation of four data points for the intervention dose variable specifically for effect sizes 11-13 and 24. The data points were transformed by Winsorization for only the corresponding intervention dose. The data points
corresponding to the effect sizes 11-13 were extracted from the study by Cabell et al. (2011), the data point corresponding to the effect size 24 was extracted from the study by Casenhiser et al. (2013). The process as indicated by Keselmen, Algina, Lix, Wilcox, and Deering (2008) was followed to transform the four data points, setting them at two standard deviations above the mean.

The last control variable was study design. The designs used across each study are listed in Table 20.

Table 20

*Study Design by Citation and Effect Size*

<table>
<thead>
<tr>
<th>ES</th>
<th>Citation</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Binger et al. (2008)</td>
<td>SSED</td>
</tr>
<tr>
<td>2</td>
<td>Binger et al. (2010)</td>
<td>SSED</td>
</tr>
<tr>
<td>3</td>
<td>McDuffie et al. (2016)</td>
<td>SSED</td>
</tr>
<tr>
<td>4</td>
<td>McDuffie et al. (2016)</td>
<td>SSED</td>
</tr>
<tr>
<td>5</td>
<td>Kent-Walsh et al. (2010)</td>
<td>SSED</td>
</tr>
<tr>
<td>6</td>
<td>Kent-Walsh et al. (2010)</td>
<td>SSED</td>
</tr>
<tr>
<td>7</td>
<td>Harjuola-Webb &amp; Robbins (2012)</td>
<td>SSED</td>
</tr>
<tr>
<td>8</td>
<td>Douglas et al. (2013)</td>
<td>SSED</td>
</tr>
<tr>
<td>9</td>
<td>Olive et al. (2007)</td>
<td>SSED</td>
</tr>
<tr>
<td>10</td>
<td>Randolph et al. (2011)</td>
<td>SSED</td>
</tr>
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<td>11</td>
<td>Cabell et al. (2011)</td>
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<td>Cabell et al. (2011)</td>
<td>Group</td>
</tr>
<tr>
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<td>Cabell et al. (2011)</td>
<td>Group</td>
</tr>
<tr>
<td>14</td>
<td>Kaiser &amp; Roberts (2013)</td>
<td>Group</td>
</tr>
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<td>15</td>
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<td>18</td>
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<td>Group</td>
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<td>19</td>
<td>Kaiser &amp; Roberts (2013)</td>
<td>Group</td>
</tr>
<tr>
<td>20</td>
<td>Fey et al. (2013)</td>
<td>Group</td>
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<td>21</td>
<td>Fey et al. (2013)</td>
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<td>22</td>
<td>Duifhuis et al. (2017)</td>
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<td>Duifhuis et al. (2017)</td>
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<td>24</td>
<td>Casenhiser et al. (2013)</td>
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<tr>
<td>25</td>
<td>Fey et al. (2006)</td>
<td>Group</td>
</tr>
<tr>
<td>26</td>
<td>Hardan et al. (2015)</td>
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<td>27</td>
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<td>28</td>
<td>Hardan et al. (2015)</td>
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<td>Hardan et al. (2015)</td>
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<td>30</td>
<td>Kasari et al. (2014)</td>
<td>Group</td>
</tr>
<tr>
<td>31</td>
<td>Kasari et al. (2014)</td>
<td>Group</td>
</tr>
<tr>
<td>32</td>
<td>Kasari et al. (2014)</td>
<td>Group</td>
</tr>
</tbody>
</table>

*Note.* SSED = single-subject experimental design
Only SSED that included multiple baselines across participants were included and coded. Group designs included randomized control trials and one quasi-experimental design (i.e., Duifhuis et al., 2017). Eight SSED with 10 effect sizes used multiple baseline designs, and eight studies with 22 effect sizes used group designs which included one quasi-experimental design with two effect sizes.

**Univariate Analyses**

The results of the univariate analyses are listed in Appendix B. The forest plot in Appendix B illustrates the individual effect size estimates and confidence intervals, along with the summary effect (weighted mean effect size) with corresponding confidence intervals.

The mean effect size for all studies was .36 standard deviation units (95% CI = [.28, .44], \(p = < .0001\)). The \(I^2\) statistic was 76.33%. The fifth effect size was the largest (4.62) and the sixth effect size was 3.60. Both of these effect sizes were from Kent-Walsh et al. (2010). The next largest effect size (2.29) was from Harjusola-Webb and Robbins (2012). The fourth largest effect size (2.31) was from Binger et al. (2010); and the largest effect sizes were observed within the SSED, which were effect sizes one through 10. The group design effect sizes 12 through 32.

**Meta-Regression**

In meta-regression, the outcome variable is the effect estimate (i.e., mean difference). The independent and control variables are characteristics of the study that may have influence on the size of the intervention effect. The regression coefficient obtained from the meta-regression analysis was a model-based estimate of how much the outcome variable (the intervention effect) changed with a one-unit change or increase in
the study characteristics (moderator variable). Each coefficient was a covariate-adjusted
difference in mean effect size between groups of effect sizes that differed by one level of
the moderator variable. The results of the random-effects meta-regression are reported in
Table 21.

One control variable had a statistically significant relationship with expressive
language outcomes, which was the specific type of study design. The study design
coefficient was -1.086 with a \( p \) value of \(< 0.0001\). The regression coefficient for the study
design represented the model-based estimate of the difference in average effects size for
group studies compared to SSED. Controlling for covariates, the model predicted that
group studies, on average, observe treatment effects 1.086 standard deviations smaller
than SSED on expressive language outcomes.

The intercept 0.701 provided an estimate of the overall mean effect size for the
study, and the 95% confidence interval around the intercept [0.558, 0.843] provided a
sense of the precision of the estimate. The heterogeneity in the effect sizes across studies
was measured by the \( I^2 \) and the \( \tau^2 \). The \( \tau^2 \) was 0.027 with a standard error of 0.023, and
the \( T \) was 0.155. The \( I^2 \) statistic estimated (in percent) the amount of the total variability
in the effect size estimate (which is composed of heterogeneity and sampling variability)
that can be attributed to heterogeneity among the true effects (\( \tau^2 = 0 \) therefore implies \( I^2
= 0\%\)). The \( I^2 \) statistic estimated 32.34% of the total variability in the effect size was
attributed to heterogeneity among the true effects (Viechtbauer, 2010). The unconditional
random-effects meta-regression reported the \( I^2 \) statistic at 83.94% which was a 52%
reduction in between-study variance with the addition of the moderators. Higgins,
Thompson, Deeks, and Altman (2003) provided guidelines for interpretation of \( I^2 \) as low
(<.25), moderate (.50), or high (.75). According to guidelines by Higgins et al. (2003), the heterogeneity was low to moderate.

Table 21

*Results of Random-Effects Meta-Regression Using 16 Studies with 32 Effect Sizes*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
<th>z value</th>
<th>p</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.701</td>
<td>0.078</td>
<td>9.984</td>
<td>&lt;.0001</td>
<td>0.559</td>
<td>0.843</td>
</tr>
<tr>
<td>Intervention with AAC</td>
<td>0.209</td>
<td>0.226</td>
<td>0.925</td>
<td>0.355</td>
<td>-0.234</td>
<td>0.651</td>
</tr>
<tr>
<td>Group design</td>
<td>-1.086</td>
<td>0.264</td>
<td>-4.114</td>
<td>&lt;.0001</td>
<td>-1.604</td>
<td>10.569</td>
</tr>
<tr>
<td>Age in months</td>
<td>-0.001</td>
<td>0.004</td>
<td>-0.254</td>
<td>0.800</td>
<td>-0.008</td>
<td>0.007</td>
</tr>
<tr>
<td>Treatment dose in hours</td>
<td>-0.002</td>
<td>0.006</td>
<td>-0.345</td>
<td>0.730</td>
<td>-0.014</td>
<td>0.010</td>
</tr>
<tr>
<td>Training dose in hours</td>
<td>0.010</td>
<td>0.014</td>
<td>0.727</td>
<td>0.467</td>
<td>-0.018</td>
<td>0.039</td>
</tr>
<tr>
<td>Multicomponent treatment</td>
<td>0.154</td>
<td>0.220</td>
<td>0.697</td>
<td>0.486</td>
<td>-0.278</td>
<td>0.585</td>
</tr>
<tr>
<td>$I^2$</td>
<td>32.340</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau^2$</td>
<td>0.027</td>
<td>0.024</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. AAC = Augmentative and Alternative Communication.*

The random-effects meta-regression was completed to test the potential relationship between study moderators and treatment effects. The primary research question was to determine whether the main effect differed among studies with participants who received AAC with the speech-language treatment, compared to studies with participants who received only speech-language treatment. The results of the random-effects meta-regression indicated the mean effect did not differ significantly between studies where participants were provided the opportunity to use AAC with the speech-language intervention, compared to those where the participants received a speech-language intervention alone. Studies testing AAC with speech-language intervention observed a higher mean effect size by 0.2087 standard deviations, on average.
The secondary research question was to determine the main effect of studies that employed multicomponent or naturalistic intervention compared to only a responsive intervention. The results of the random effects meta-regression indicated the mean effect did not differ significantly between studies. Studies with participants who received a multicomponent intervention observed larger mean effect sizes by 0.1536 standard deviations, on average, compared to those studies where participants received only a responsive intervention.

Three control variables did not have statistically significant results: the age of the participant, the amount of treatment time provided to the child participant, and the amount of training time provided to the interventionist. The results of the random-effects meta-regression indicated the mean effect sizes did not differ significantly for studies with participants who increased in age by one month. Studies involving participants who increased in age by one month were predicted to produce on average lower mean effect sizes on expressive outcomes by -0.0001 standard deviations.

The amount of treatment time (treatment dose) was measured in hours. The results of the random-effects meta-regression indicated the mean effect sizes did not differ significantly for one-unit increases in the average age of the study participants. Studies with participants, whose treatment time was one hour longer, on average, were predicted to experience lower mean effects sizes on expressive outcomes by 0.002 standard deviations.

The amount of training time (training dose) was measured in hours. The results of the random-effects meta-regression indicated the mean effect sizes did not differ significantly for studies with communication partners with different training. Although
the random-effects meta-regression did not indicate statistically significant results for this variable, studies with communication partners whose training was one hour longer, on average, were predicted to produce higher average effect sizes for expressive language outcomes by 0.010.

The random-effects meta-regression provided insight into the average study effect size for each variable. The intercept and estimates from the random-effects meta-regression for each dichotomous variable were then used to calculate the adjusted average effect size for each study variable category. The adjusted average effect size for each variable category is listed in Table 22. The intercept (0.701) was an estimate of the average effect size at the grand mean of all predictors, or the overall mean effect size for the studies within the meta-analysis sample. The overall mean effect size indicates only the average effect, not the specific effect or model-based averages for each variable. The model-based average for each variable, or the adjusted average effect, was calculated for each dichotomous independent variable using the model estimates (intercept and coefficients). For example, clients who used AAC had an adjusted average effect of 0.551, compared to 0.760 for clients who did not use AAC. The adjusted average for SSED was 1.040, compared to -0.046 for group designs. The adjusted average for clients who had responsive interventions was 0.676, compared to 0.831 compared to clients who received naturalistic interventions.

Table 22

**Adjusted Averages for Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Without AAC</th>
<th>With AAC</th>
<th>SSED Group</th>
<th>Responsive Intervention</th>
<th>Naturalistic Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAC</td>
<td>0.551</td>
<td>0.760</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of design</td>
<td></td>
<td></td>
<td>1.040</td>
<td>-0.046</td>
<td></td>
</tr>
<tr>
<td>Type of treatment</td>
<td></td>
<td></td>
<td></td>
<td>0.676</td>
<td>0.831</td>
</tr>
</tbody>
</table>

*Note. AAC = Augmentative and Alternative Communication.*
Sensitivity Analysis

The random-effects meta-analysis had multiple effects per study, increasing the likelihood of dependency between effect sizes. As a result, the meta-regression was repeated using robust variance estimate (RVE), and the results were compared to that of the meta-regression that assumed all effects were independent. Table 23 reports the results of the meta-regression with RVE. The meta-regression with RVE had similar results as the random-effects meta-regression, specifically the intercept and model estimates. The meta-regression with RVE model did not indicate any statistically significant results compared to the meta-regression that indicated the study design was statistically significant. However, the size and direction of the moderator effect for study design was consistent with the meta-regression without RVE and the difference in statistical conclusion is most likely due to the reduced power of the RVE approach. The intercept of 0.774 provided an estimate of the overall mean effect size for the study, and the 95% confidence interval around the intercept [0.425, 1.123] provided a sense of the precision of the estimate. The $\tau^2$ statistic was the same for both the meta-regression with RVE and the random-effects meta-regression. The notable difference between the random-effects meta-regression and the meta-regression with RVE was the heterogeneity results as indicated in the $I^2$ statistic. Higgins et al. (2003) provided guidelines for interpretation of $I^2$ as low (< .25), moderate (.50), or high (.75). The $I^2$ statistic estimated that 68.3% of the total variability in the effect size estimate was attributed to heterogeneity among the true effects (Viechtbauer, 2010). The unconditional meta-regression with RVE reported the $I^2$ statistic at 79% which was an 11% reduction in between-study and within-study variance with the addition of the moderators. The $I^2$
statistic was reported as an indicator of the type of model to use in the analysis (Higgins et al., 2003), and a high proportion of the $I^2$ statistic suggested the use of a random-effect meta-regression model.

Table 23

*Results of Meta-Regression with RVE Using 16 Studies with 32 Effect Sizes*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
<th>t value</th>
<th>df</th>
<th>p</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.774</td>
<td>0.154</td>
<td>5.019</td>
<td>9.000</td>
<td>0.001</td>
<td>0.425</td>
<td>1.123</td>
</tr>
<tr>
<td>Intervention with AAC</td>
<td>0.231</td>
<td>0.537</td>
<td>0.431</td>
<td>9.000</td>
<td>0.677</td>
<td>-0.983</td>
<td>1.446</td>
</tr>
<tr>
<td>Group design</td>
<td>-0.991</td>
<td>0.593</td>
<td>-1.671</td>
<td>9.000</td>
<td>0.129</td>
<td>-2.335</td>
<td>0.351</td>
</tr>
<tr>
<td>Age in months</td>
<td>-0.004</td>
<td>0.008</td>
<td>-0.543</td>
<td>9.000</td>
<td>0.600</td>
<td>-0.023</td>
<td>0.014</td>
</tr>
<tr>
<td>Treatment dose in hours</td>
<td>-0.005</td>
<td>0.010</td>
<td>-0.513</td>
<td>9.000</td>
<td>0.620</td>
<td>-0.028</td>
<td>0.018</td>
</tr>
<tr>
<td>Training dose in hours</td>
<td>0.008</td>
<td>0.028</td>
<td>0.289</td>
<td>9.000</td>
<td>0.779</td>
<td>-0.056</td>
<td>0.072</td>
</tr>
<tr>
<td>Multicomponent treatment</td>
<td>0.163</td>
<td>0.400</td>
<td>0.407</td>
<td>9.000</td>
<td>0.693</td>
<td>-0.742</td>
<td>1.068</td>
</tr>
<tr>
<td>$r^2$</td>
<td>0.68304</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau^2$</td>
<td>0.277</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* AAC = Augmentative and Alternative Communication

**Assessment of Bias**

Results of the risk of bias evaluation summaries are provided in Figure 2. The funnel plot of the effect size estimates specifically the $SE$ on y-axis versus the residual value on the x-axis for the 32 effect sizes is displayed in Figure 2. The residual value was the observed fitted value, which was calculated as the raw effect size minus the mean effect size from the univariate analysis (RDocumentation, n.d.). The distribution of the effect size estimates appears to be asymmetrical. The effect sizes missing from the funnel plot were from studies with small effects, small sample sizes, and presumably non-significant results. This visual assessment of asymmetry is consistent with robust Egger’s regression tests, $z = 3.73$, $p < .01$. The Egger’s regression test was statistically significant, indicating that intercept of the Egger’s regression line was farther from 0 than was expected by chance. The null hypothesis is that the intercept is equal to 0 in the
population, which was rejected. This asymmetry, both from the funnel plot and Egger’s regression test, suggests publication bias against studies with small samples and small effects.

*Figure 2.* Funnel plot for effect sizes estimates from 16 studies with 32 effect sizes.
CHAPTER V

DISCUSSION

Existing meta-analyses completed within speech-language pathology, AAC, and early intervention have been either group designs or systematic reviews of SSED that have employed non-parametric methods. The increased accountability of early intervention policy and evidence-based practice movements with requirements for data-driven interventions and investigations has increased the need for stakeholders to evaluate literature and conduct clinical research to determine the most effective speech-language interventions with and without the use of AAC to improve outcomes. Currently, no meta-analyses of SSED and group designs have investigated speech-language pathology interventions with or without the inclusion of AAC for children ages birth to 6 with developmental disabilities to compare effects of intervention using parametric statistical techniques. Effective AAC provisions for children and families will become extended to the larger medical, early intervention, and speech-language community only with supporting knowledge, research, and clinical evidence. With access to appropriate assistive technology at the early stages of development, young children with complex communication needs may be able to maximize language and communication development to achieve full potential (Constantino & Bonati, 2014).

In addition, most of the research to date has used data from children with mild to moderate disabilities and has not assessed the impact of early intervention services from birth to 6 related to speech-language intervention and the use of AAC for children with developmental delays and associated disabilities. At present, conclusive evidence is not available to guide the selection of the most effective speech-language approach and/or
strategy including AAC for infants and toddlers with varying types of delays and disabilities (ASHA, 2008). No single speech-language approach or strategy was equally effective for all children or families, and not all children in outcome studies have benefited to the same degree (ASHA, 2008). The ASHA (2008) reported a need for additional research that focuses on what works best for young children with varying types of delays and disabilities. Romski et al. (2015) also indicated the need to examine and compare the different treatment approaches to start the process of refining interventions and providing more definitive information about the utility of treatment techniques for children with specific communication profiles.

The primary purpose of this study was to use meta-analytic procedures to (1) examine the effectiveness of SSED of speech-language interventions with and without the use of AAC strategies and technology on speech-language outcomes of individuals ages birth to 6 with developmental disabilities; (2) identify study characteristics that were associated with the magnitude of treatment effects; and (3) evaluate the quality of speech-language intervention research for this population.

Research Question 1

What are the effect sizes of speech-language interventions, with and without AAC, for SSED and group designs for children ages birth to 6 with developmental disabilities?

The results of the univariate analyses indicate the mean effect size for all the studies was .36. Univariate analyses completed within previous systematic reviews of similar speech-language interventions with early intervention populations without disabilities also indicate a positive effect on expressive language outcomes. Gladfelter et
al. (2011) indicated an increase of vocabulary size ($d = .76$). Robertson and Weismer (1999) indicated an increase of the mean length of utterances ($d = 0.90$), the total number of words ($d = 1.08$), the number of different words ($d = 1.21$), and the percentage of intelligible utterances ($d = 1.62$). The primary difference between the extant literature (Kaat-van den Os et al., 2019) and the results of this meta-analysis is that similar types of interventions typically used with children without disabilities produced similar results in expressive outcomes for children with disabilities. Kaat-van den Os et al. (2017) did not report significant effects of intervention on expressive outcomes for children with disabilities with parent-implemented language interventions. A notable difference between the interventions within this meta-analysis and interventions included by Kaat-van den Os et al. (2017) is the multicomponent nature of the intervention.

The results of the multivariate analysis indicate the mean effect did not differ significantly between studies that tested speech-language interventions with AAC compared to studies with speech-language interventions alone. The overall effect size for studies that used speech-language interventions, with and without AAC, for SSED and group designs for children ages birth to 6 with developmental disabilities was not statistically significant. Although not statistically significant, a larger positive relationship was found between studies that used speech-language interventions with AAC and expressive language outcome measures. The sensitivity analysis using the meta-regression with RVE was used to compare results to that of the random-effects meta-regression that assumed all effects were independent. The meta-regression with RVE produced a similar model estimate for this variable, with a larger standard error and confidence interval. Although the results of the random-effects meta-regressions and
meta-regression with RVE were not statistically significant, it is notable that speech-language interventions with AAC were predicted to produce higher mean effect sizes by 0.208 standard deviations using the independent effects meta-regression or 0.231 standard deviations using the meta-regression with RVE. In addition, the adjusted average effect for speech-language interventions with AAC was 0.760 standard deviations, compared to 0.551 for speech-language interventions without AAC.

**Research Question 2**

To what extent do the effect sizes vary as a function of treatment approach (with or without AAC) when controlling for other covariates (i.e., age, length of intervention provided to child participant, length of training provided to adult interventionist or communication partner, type of language intervention, and study design)?

The effect sizes did not vary significantly as a function of treatment approach (with or without AAC) when controlling for other covariates (i.e., age, length intervention provided to child participant, length of intervention provided to adult interventionist or communication partner, type of language intervention, and study design). The univariate analysis produced an average effect size of .36 compared to a .701 coefficient for the random-effects meta-regression and a .774 coefficient for the meta-regression with RVE. The random-effects meta-regression afforded the opportunity to determine the effect of moderators on expressive language effect size measures while controlling for other covariates.

Previous early intervention research of preschool programs using quasi-experimental methods produced significantly larger effect sizes than more recent programs (Duncan & Magnuson, 2013). The decline in the effect sizes over time was
attributed to counterfactual conditions which included early intervention policy and practitioners targeting environmental enrichment, including responsive caregiving and language-rich interactions (Tamis-LeMonda et al., 2001). The speech-language interventions included within this study use similar methods (or responsivity education training) targeting environmental enrichment, responsive caregiving, and language-rich environments. The effect sizes across studies did not decline or produce a negative effect but rather a positive large effect. The importance of caregiver responsiveness or responsive speech-language interventions has been associated and well documented with advances of a child’s cognitive and linguistic development within speech and language research specific to early intervention populations (Tamis-LeMonda et al., 2001). In addition, Gladfelter et al., (2011) indicated responsive speech-language interventions (i.e., Hanen Parent Program), combined with focused stimulation (i.e., naturalistic intervention strategies), had an effect on increasing expressive language outcomes for early intervention populations.

**Research Question 3**

What study characteristics moderate the overall effect of early intervention outcomes associated with speech-language intervention targets and outcomes within children ages birth to 6 with developmental disabilities?

The study characteristics included within the analysis were type of treatment (i.e., naturalistic or responsive), age of child participants, the amount of treatment time provided to the child participants within the study, and the amount of training time provided to the interventionists within the study. The results of these characteristics are discussed in the following section.
Naturalistic Intervention

Naturalistic interventions were defined as multicomponent interventions using a combination of responsive and directive intervention strategies. The random-effects meta-regression was used to determine whether the effect sizes differed across studies with multicomponent interventions (naturalistic interventions) versus responsive interventions. The results of the random-effects meta-regression indicate the mean effect sizes did not differ significantly between studies with these types of interventions.

Studies with naturalistic interventions, compared to studies with responsive interventions, had a higher mean effect of 0.153. Sensitivity analysis using meta-regression with RVE indicated similar results, with a coefficient of 0.163 standard deviations, on average, and a slightly larger SE of 0.400. The adjusted average for studies with responsive interventions was 0.676 standard deviations, compared to 0.831 standard deviations for studies with naturalistic interventions. Studies with naturalistic interventions observed larger positive effects, compared to studies of responsive speech-language interventions. Interventions that had specific directive expressive language targets in conjunction with naturalistic speech-language interventions (multicomponent interventions), using AAC or without AAC, were more effective than general responsive speech-language interventions.

Early intervention research has revealed positive effects of naturalistic interventions on developmental outcomes, including expressive language outcomes for children with disabilities ages birth to 6 (Center on the Developing Child, 2017). In addition, early intervention stakeholders have been urged by policymakers to determine the evidence base to support trends toward naturalistic interventions, as compared to
structured direct intervention approaches (i.e., Applied Behavior Analysis; Gladfelter et al., 2011; Kaat-van den Os et al., 2017; Kaiser et al., 2001; Roberts & Kaiser, 2011; Tamis-LeMonda et al., 2001). The small positive differences of this analysis support a multicomponent intervention that uses primarily naturalistic interventions that occur within typical contexts of a child and caregiver, intervention targets that are specific to the child (directive intervention approach), and instructional strategies that are supportive to the communication partner and the child (directive and responsive).

**Age in Months**

The results of the meta-regressions indicate the effect sizes did not vary significantly with the age of the students. The results of the random-effects meta-regression indicate the effect sizes did not differ significantly with the age of the child participants. For every one-month increase in average participant age, the model predicted a -0.0001 standard decrease in mean effect sizes on expressive outcomes. The average age for participants in the studies was 22.62 (SD 19.36) months. This supports the use of early intervention services to address expressive language delays for children ages birth to 6 with disabilities. The random-effects meta-regression model predicted that the older the average age of the children, even with interventions, the smaller the intervention effects.

The importance of starting early to teach communication partners responsive speech-language interventions and specific targets (naturalistic interventions) for each child was highlighted within this study for children with disabilities. Neuroscience evidence has highlighted the plasticity of cognitive and language abilities that are highly malleable to environmental enrichment during early childhood (Center on the Developing
SLPs have an important role to play in providing the necessary education to communication partners for early intervention populations and helping to support specific expressive language targets and goals to improve overall expressive language outcomes. The importance of caregiver responsiveness associated with the advances of a child’s cognitive and language development has been well documented within speech and language research specific to early intervention populations (Tamis-LeMonda et al., 2001).

**Treatment Dose in Hours for Child Participants**

The amount of treatment time (treatment dose) was measured in hours. The total average treatment time for a child participant within the studies included within this meta-analysis was 20 hours ($SD$ 19.36). The results of the random-effects meta-regression indicate the mean effect sizes did not differ significantly for studies with participants that had an increase in treatment time by one hour, on average. Studies with participants who had an increase in treatment time by one hour, on average, were predicted to produce lower mean effect sizes on expressive outcomes by 0.002 standard deviations (-0.005 standard deviations for the meta-regression with RVE). This information contributes to the overall debate about the amount of treatment necessary to make positive changes in expressive language outcomes for children birth to 6 with disabilities. Most private insurance companies allocate 16 to 20 visits per calendar year. It is not coincidental that the average treatment time was 20 hours, as this is consistent with standard practice of care. This does not indicate additional speech-language intervention is not warranted; however, for the specific intervention analyzed in this study, specifically implementing naturalistic or responsive language intervention, the
average dose of 20 hours for child participant with direct intervention with the SLP and the caregiver indicated positive gains.

**Training Dose in Hours for Primary Caregiver**

The amount of training time (training dose) was measured in hours. The average hours of treatment in this analysis was 12.28 (SD 18.13) hours for caregivers. The results of the random-effects meta-regression indicate the mean effect sizes did not differ significantly for studies with communication partners who had an increase of training by one hour. Although the meta-regression did not indicate statistically significant results for this variable, studies with communication partners who had an increase in training by one hour were predicted to produce, on average, higher effect sizes of expressive language outcomes by 0.0104 (0.008 for meta-regression with RVE). This information contributes to the overall debate about the amount of training necessary for caregivers to make positive changes in expressive language outcomes for children birth to 6 with developmental disabilities who do or do not use AAC.

Roberts and Kaiser (2011) completed a meta-analysis to systematically evaluate the effects of parent-implemented language intervention on language skills of children ages 18 to 60 months with primary and secondary language delay. The results indicated parent-implemented language interventions have a significant positive impact on receptive and expressive language skills of children with and without intellectual disabilities. Previous research indicates a significant positive impact on receptive and expressive language skills of children with and without intellectual disabilities (Roberts & Kaiser, 2011). The critical features of parent-implemented language interventions...
included the triadic interventions of parent training, parent implementation of intervention strategies, and child language outcomes (Roberts & Kaiser, 2011).

In addition, family-centered AAC services have supported parents in implementing the communication goals with their children and have reported better outcomes for children who use AAC devices (Kaiser et al., 2001; Ruble et al., 2008). A predictor of successful implementation of AAC use was the amount of support provided at home by family members (Parette & Angelo, 1996). Outcomes for families and children with complex communication needs who used an AAC device improved when the communication partner was provided specific instruction on adapting responses to the child, the environment, and specific communication opportunities (Beukelman & Mirenda, 2013; Cress & Marin, 2003). Communication partner instruction for caregivers, teachers, and siblings has been recognized as important to successful outcomes for individuals who use AAC (Kent-Walsh & Mcnaughton, 2005; Kent-Walsh et al., 2015).

The family has played a critical role in the development of language and communication skills for the young child, and research has supported this evidence, suggesting parents and other communicative partners can use AAC strategies with young children (Romski et al., 2015). Also, family participation has been mandated in US early intervention programs, and defining that role for AAC early interventions is essential to the long-term success of AAC (Romski et al., 2015). Presently, private insurance and Medicaid do not reimburse for formalized caregiver education (i.e., *It Takes Two To Talk*, by Pepper & Weitzman, 2004) related to speech-language interventions.
**Group Design**

The last control variable within the meta-analysis was study design. Two types of designs were used to include group designs and SSED. The results of the meta-regression indicate a significant relationship of study design with expressive language outcomes. The study design coefficient was -1.0863 with a p value of < 0.0001. Controlling for covariates, the model predicted that group studies, on average, observed treatment effects 1.086 standard deviations smaller than SSED on expressive language outcomes. In other words, average effects from SSED were estimated to be larger than those from group designs. This trend is consistent with theoretical expectations and the single-case research community specifically that effect sizes from SSED may be generally larger than those for group designs (Barton, Pustejovsky, Maggin, & Reichow, 2017), as a strong publication preference exists for studies with larger effects (Shadish et al., 2015). This is consistent with the publication bias results, specifically the asymmetry within the funnel plot and the Egger’s regression test, suggesting publication bias against studies with small samples and non-significant results.

**Research Question 4**

What is the quality of the speech-language intervention research studies that are included in the meta-analysis?

All studies within the meta-analysis met or met with reservations the study design standards as specified by the WWC. The majority of previous reviews and meta-analyses completed within the field of AAC have reported a high number of research studies with quality limitations. The quality limitations included: limited reporting of treatment fidelity, inadequate description of intervention for replication, inconsistent reporting of
treatment intensity and duration, and lack of complete and comparable participant
descriptions (Branson & Demchak, 2009; Ganz et al., 2012; Light & Drager, 2007;
Mirenda, 2003; Schlosser & Lee, 2000; Schlosser & Sigafoos, 2006; Snell et al., 2006;
Walker & Snell, 2013). The field of AAC and early intervention has demonstrated within
the last 10 years some improvement in the quality of SSED and group research designs
from which to pull for the support of evidence-based practice.

**Future Research**

**Small Sample Size**

The meta-analysis is limited as a result of the small effect size sample. The effect
size sample was limited for a number of reasons: the quality of studies was limited to
WWC criteria and search results likely did not find all of the articles in the universe that
relate to this analysis; and a smaller research base existed for this population, given the
level of heterogeneity between the participants. A percentage of the studies reviewed for
the meta-analysis were excluded due to not meeting quality standards as indicated by the
WWC. Future research should support the advancement of the field by adhering to the
WWC SSED and group design standards for rigorous research.

In addition, SSED are recognized within the field of evidence-based practice as a
viable source of evidence especially within heterogeneous populations (Howard et al.,
2015). There has been a call for standardization in the use of SSED within the field to
allow for comparison across studies. Two examples of standardization are the
recommendation to replicate SSED within studies (e.g., multiple-baseline designs) and
across studies (Shadish & Sullivan, 2011). If researchers use SSED to replicate findings
across studies, the studies could be combined using meta-analysis (Maggin et al., 2011).
Both the increase of SSED and the use of meta-analysis of SSED would help to meet the need for future research within heterogeneous populations, such as with children with disabilities.

As future research studies are published, the new results could be compared or combined with this meta-analysis to increase the sample of the effect sizes. With a larger sample of effect sizes, additional variables could be modeled to improve the results of the meta-regression and provide insight into moderators or predictors of the expressive language outcomes to inform future research, policy, and practice.

**Publication Bias**

The asymmetry both from the funnel plot and Egger’s regression test suggests publication bias against studies with small samples and small-observed effects. As a result of publication bias, the current average effect size most likely is inflated; with the addition of future studies that include results from small samples and small-observed effects, the effect size overall would be lower.

**Scope of the Intervention for Child Participants**

This meta-analysis compared two types of speech-language interventions (i.e., naturalistic and responsive). Future meta-analyses comparing the different types of speech-language interventions with AAC (i.e., intervention to increase multiple symbol use on AAC device, peer interventions with AAC, expressive communication interventions delivered only by the SLP, mentoring to AAC users by experienced seasoned AAC users, video modeling to teach AAC, and behavioral interventions that incorporate AAC) are warranted to further determine the effect of each type of intervention on expressive outcomes for children with disabilities ages birth to 6.
The NS-CH (2010) indicated that there was a necessity for speech-language therapy and communication aids and devices as there was an unmet need of 4.3% to 14.9% of families that were not able to or were not accessing communication devices and speech-language therapy. The results of the meta-analysis did not provide insight into the overall level of unmet need for families specifically in regard to speech-language pathology services as all of the studies had speech-language therapy services provided as part of the inclusion criteria, but descriptive statistics provided insight into the allocation of AAC devices for children with disabilities ages birth to 6 within the studies of the meta-analysis. Out of the 16 studies included within the meta-analysis, 10 (63%) used unaided AAC. Aided AAC was reported for 6 (37%) studies included within the meta-analysis. This information compared to previous reviews and meta-analysis indicated that unaided AAC was still the preference for early intervention populations as 10 out of 16 studies used unaided AAC (Branson & Demchak, 2009; Ganz et al., 2012; Light & Drager, 2007; Mirenda, 2003; Schlosser & Lee, 2000; Schlosser & Sigafoos, 2006; Snell et al., 2006; Walker & Snell, 2013). Although there has been a slight increase in the use of aided AAC for early intervention populations as 7 out of 10 studies used aided AAC, future research is warranted to determine the effects of aided AAC compared to unaided AAC for this population.

In addition, the age group for this meta-analysis included studies of children birth to 6. Although this analysis looked at a larger age group, future analyses could disaggregate the ages and compare the use of the speech-language interventions for children birth to 3 compared to children ages 4 to 6. In addition to determining the effect of speech-language interventions on subcategories of child participants with disabilities,
determining the effect of AAC with speech-language interventions would also add to the evidence-base for this population.

**Scope of Intervention for Communication Partner Participants**

This analysis broadly defined intervention for communication partners as time invested by the SLP with the primary communication partner. The specific type of intervention or communication partner training was coded but the small sample size did not permit for each type of training technique implemented by the clinician to be used within the meta-analysis as moderators. This potentially sacrificed a more fine-grained set of categories and comparisons, which should be further explored with additional studies and larger sample sizes allowing for pinpointing the most effective communication partner strategy or strategies to increase expressive language outcomes for this population. The specific types of strategies that are used to provide intervention or communication partner training to adult participants specific to a triadic model (Roberts & Kaiser, 2011) will be important to use in future meta-analyses. Future research is needed to determine the efficacy of the current business as usual practice, compared to formalized caregiver education programs currently funded through grants and charitable funders specific to responsive interventions, as well as naturalistic interventions with and with out the use of AAC. This information will provide support for the evidence base and practical application of specific instructional techniques to be used by clinicians to support implementation of expressive language outcomes for children with developmental disabilities.
Expressive Language Outcome Domain

This analysis used a broad definition of expressive language outcomes that were collapsed within one larger domain. Each of the outcomes fit within the larger domain of expressive language, however future analysis with a larger effect size sample will allow for more narrower categories (i.e., direct observation compared to standardized assessment) to determine the impact on the type of outcome measure. The specific expressive language outcome or target will be important to determine for future research as the meta-analysis indicated that larger effect sizes were reported when naturalistic intervention was used for specific expressive language targets. The importance of a SLP determining the appropriate expressive language target and teaching communication partners how to elicit the target will aid in the prescriptive nature of administering speech-language pathology services to children with disabilities within the early intervention population.

In addition, group design studies within the meta-analysis typically used standardized assessments compared to SSED that typically used direct observation outcomes. The standardized measures used within the group designs produced smaller effect sizes compared to SSED that produced larger effect sizes. This discrepancy between the sensitivity of the type of expressive outcome should be analyzed further in future meta-analysis to continue to determine the impact of the type of the expressive outcome related to intervention for this population. In addition, the importance and relevance of using the most appropriate type of expressive outcome (i.e., direct observation or standardized assessment) will aid in future clinical practice and research
studies specific to this population and speech-language interventions with and without AAC.

In addition, the expressive outcome used within this analysis was the immediate post intervention measure (i.e., direct observation measure or standardized measure). The maintenance and generalization of the effects from the speech-language intervention were attempted to be coded in the analysis but not all research studies included this data within the results. The short-term (maintenance) and long-term (generalization) effects of the speech-language interventions for this population should be reported in future research studies as well as analyzed in future meta-analyses to provide a broader view of the impact of this type of intervention on expressive outcomes for this population.

Implications

Research

A primary purpose of this review was to apply new methods for calculating a between-case effect size for SSED and using that data within a meta-analysis with group design research to summarize an overall effect of speech-language interventions with and without AAC for children with disabilities ages birth to 6. This type of meta-analysis has not been completed within the field of speech-language pathology as of the present date; although limitations exist in the meta-analysis, this method can be used alongside more conventional methods to contribute to the evidence base within the field of speech-language pathology, AAC, and early intervention. The use of this type of meta-analysis is important to the advancement of information within the field of early intervention and speech-language pathology. Until recently, no method has combined SSED and group designs. The majority of studies that combined the use of AAC, early intervention, and
speech-language pathology have typically used SSED. The ability to combine more of the current research, SSED and group designs, in a meta-analysis is applicable and a significant contribution to the field of AAC, early intervention, and speech-language pathology.

**Practice**

The secondary purpose of the study was to summarize the effect of speech-language interventions with or without the use of AAC with children with disabilities ages birth to 6. The results of the meta-regressions were not statistically significant for speech-language interventions with or without AAC. Although the results are not statistically significant, the data from the meta-analysis provide insight into the positive small to moderate effects of naturalistic interventions on expressive outcomes for children with disabilities within the early intervention population. In addition, the analysis of the effect sizes of both the model estimates and the univariate results provides evidence in the form of data to support the use of AAC for this population. In other words, the results of the analysis provide an evidence base that using AAC with traditional speech-language pathology interventions produce a positive small effect, although not statistically significant, on expressive outcomes for children with disabilities ages birth to 6. Interventions that had specific directive expressive language targets in conjunction with naturalistic speech-language interventions (multicomponent interventions), using AAC or without AAC, were more effective than general responsive speech-language interventions. More work is needed to determine the specifics of the type of communication partner strategy and expressive language targets, but the results of the analysis provide sufficient evidence that AAC does not harm but helps more than just
traditional intervention alone to improve expressive language outcomes for this population.

Policy

The analysis provided insight into the impact of early intervention services, specifically speech-language pathology services, on children with significant expressive language disabilities or delays. The analysis indicates the intervention is less effective as the child participant ages. The data support the importance of starting early with speech-language interventions that address expressive language delays with children with disabilities, and the use of AAC in conjunction with naturalistic (and responsive) interventions improves these expressive outcomes more than responsive speech-language intervention alone. The use of AAC with early intervention populations has improved slightly over the last 10 years according to the meta-analysis. Although the research base has begun to grow in regard to the use of AAC with early intervention populations, more research is needed and should be supported to determine the specific types of intervention for child participants, as well as the primary adult communication partners of these children. In addition, a larger research base would allow for more fine-grained analysis of optimal intervention intensity (dose form, dose frequency, total intervention duration, session duration, cumulative intervention intensity; Warren et al., 2007) to further advance the necessary prescriptive elements of speech-language pathology services needed for children with disabilities ages birth to 6.

Also, the involvement of caregivers has been mandated by early intervention policy for children with disabilities ages birth to 6. The amount of training necessary for caregivers to make a positive change in expressive language outcomes for this population
relates to the current early intervention policy within the US. Although the meta-regression did not indicate statistically significant results for this variable, studies with communication partners who had an increase in training by one hour were predicted to produce, on average, higher effect sizes on expressive language outcomes. Previous research indicates a significant positive impact on receptive and expressive language skills of children with and without intellectual disabilities (Roberts & Kaiser, 2011). The family has played a critical role in the development of language and communication skills for the young child, and research has supported this evidence, suggesting parents and other communicative partners can use AAC strategies with young children (Romski et al., 2015).

Although the early intervention policy within the US mandates caregiver involvement in the development and implementation of goals, private insurance and Medicaid in Colorado do not reimburse for formalized caregiver education related to speech-language interventions. The results of the meta-analysis, although not statistically significant, indicated higher effect sizes when the caregiver was involved in the implementation of the speech-language interventions. Future meta-analysis and research studies determining the effect of formalized caregiver programs compared to business as usual practices related to speech-language interventions will help to aid to the overall debate about the importance of caregiver involvement and the impact caregiver involvement has on expressive outcomes for this population. In addition, a research study or meta-analysis determining the discrepancy between caregivers and children with disabilities that are able to access caregiver education programs compared to families that are not will also add relevance and overall understanding of the impact of the current
early intervention policy. The NS-CH (2010) indicated that there was a necessity for speech-language therapy and communication aids and devices with an unmet need of 4.3% to 14.9% of families to access communication devices and speech-language therapy. Determining the barriers to accessing services, system wide or locally, for some families will help to first shed light on the inconsistencies or constraints and then to work with stakeholders in starting initiatives to rectify or minimize the identified barriers to allow for all families to access mandated services that have demonstrated positive effects on expressive outcomes for this population.

**Conclusion**

Existing meta-analyses completed within speech-language pathology, AAC, and early intervention have been either group designs or systematic reviews SSED that have employed non-parametric methods. The increased accountability of early intervention policy and evidence-based practice movements with requirements for data-driven interventions and investigations has heightened the need for stakeholders to evaluate literature and conduct clinical research to determine the most effective speech-language interventions with and without the use of AAC in order to improve outcomes. The primary purpose of this review was to use meta-analytic procedures across both SSED and group designs to examine the effectiveness of speech-language pathology interventions with and without the use of AAC strategies and technology on speech-language outcomes of individuals ages birth to 6 with developmental disabilities. This type of meta-analysis has not been completed within the field of speech-language pathology as of the present date; and although there were limitations to the meta-analysis, this method can be used with more conventional methods to contribute to the evidence
base within the field of speech-language pathology, AAC, and early intervention. While the results were not statistically significant, the data from the meta-analyses provide insight into the positive large effects of naturalistic interventions on expressive outcomes for children with disabilities within the early intervention population.

Effective AAC provisions for children and families will become extended to the larger medical, early intervention, and speech-language pathology community only with supporting knowledge, research, and clinical evidence. With access to appropriate assistive technology at the early stages of development, young children with complex communication needs may be able to maximize language and communication development and achieve their full potential (Constantino & Bonati, 2014). Although the research base has improved regarding the use of AAC with early intervention populations, additional research is needed and should be supported to determine the specific types of intervention for child participants, as well as the primary adult communication partners of these children.
REFERENCES

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


## APPENDIX A

### Intervention Descriptions

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aided AAC</td>
<td>Communication accomplished through the use of a tool or a device. Aided systems can be basic (i.e., pen and paper) or high-tech (i.e., speech-generating device; ASHA, n.d.a).</td>
</tr>
<tr>
<td>Applied Behavioral Analysis</td>
<td>A set of procedures (i.e., strict systematic application or more naturalistic) drawn from the discipline of behavioral psychology used to analyze and modify certain behaviors (ASHA, n.d.b).</td>
</tr>
<tr>
<td>Augmented Input</td>
<td>Communication partners use visual language by pointing to symbols on a child’s communication system while simultaneously talking to improve the child’s receptive language comprehension. The child is encouraged by not required to use symbols during the interaction (Senner, n.d.).</td>
</tr>
<tr>
<td>Discrete Trial Training</td>
<td>A method of teaching, originating from Applied Behavioral Analysis, in which the adult uses adult-directed, massed trial instruction, reinforcers chosen for their strength, and clear contingencies and repetition to teach new skills (ASHA, n.d.b).</td>
</tr>
<tr>
<td>Environmental Arrangement</td>
<td>The treatment technique of manipulating the physical, social, or programmatic aspects of a classroom, clinic, or intervention setting to improve a child’s engagement and behavior (Davis &amp; Fox, 1999).</td>
</tr>
<tr>
<td>Functional Behavioral Assessment</td>
<td>A collection of methods used for gathering information about the antecedents and consequences of a behavior to determine the function of a behavior. Once the function of the behavior is determined, this information is used to design interventions to reduce problem behaviors and facilitate positive behaviors as mandated through the Individuals with Disabilities Education Act (Gresham, Watson, &amp; Skinner, 2001).</td>
</tr>
<tr>
<td>Functional Communication Training</td>
<td>Functional communication training is a differential reinforcement procedure with three stages in which an individual is taught an alternative response resulting in the same class of reinforcement identified as maintaining the problem behavior. The alternative response is a recognizable form of communication (i.e., AAC or sign; Tiger, Hanley, &amp; Bruzek, 2008).</td>
</tr>
<tr>
<td>Incidental Teaching</td>
<td>Teaching in which the natural environment is arranged to attract the child to the materials and activities. The teacher is available to provide attention, praise, and instruction when the child initiates interaction with materials (Hart &amp; Risley, 1975).</td>
</tr>
<tr>
<td>Language Acquisition through Motor Planning</td>
<td>A therapeutic approach based upon neurological and motor learning principles. The goal is to give individuals who are nonverbal or with limited verbal abilities a method of independently and spontaneously communicating (The Center for AAC &amp; Autism, n.d.).</td>
</tr>
<tr>
<td>Milieu Approach</td>
<td>A variety of methods including incidental teaching integrated into a child’s natural environment and conversations which includes training in everyday environments and during activities that take place throughout the day (ASHA, n.d.b).</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Intervention</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture Supports</td>
<td>Visual supports (i.e., photographs or line drawings) used to improve behavior and communication skills for children with disabilities (Ganz et al., 2012).</td>
</tr>
<tr>
<td>Pragmatic Organization Dynamic Display</td>
<td>A method and a tool for developing and utilizing augmented input. Pragmatic Organization Dynamic Display utilizes strategies to support the design, production, and implementation of communication systems that enable communication for a variety of functions in all daily environments (Porter &amp; Cafiero, 2009).</td>
</tr>
<tr>
<td>Responsive Adult Interaction Patterns</td>
<td>Intervention procedures that focus on the quality of the interaction between a caregiver and his or her child (Mahoney &amp; Powell, 1986).</td>
</tr>
<tr>
<td>Total Communication</td>
<td>Total communication involves one or several modes of communication (manual, oral, auditory, and written), depending on the particular needs of the child. Communication partners are encouraged to use the communication method(s) most appropriate for a particular child at a particular stage of development (Hawkins &amp; Brawner, 1997).</td>
</tr>
<tr>
<td>Unaided AAC</td>
<td>Communication accomplished through the use of gestures, body language, facial expression, or sign language (ASHA, n.d.a).</td>
</tr>
</tbody>
</table>

Note. AAC = Augmentative and Alternative Communication.
APPENDIX B

Forest Plot of Standardized Mean Difference Effect Size Estimate for Studies

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Binger et al. (2008) 1.41 [0.38, 2.44]
Binger et al. (2009) 2.29 [0.98, 3.60]
McDuffie et al. (2016).1 1.21 [0.83, 1.59]
McDuffie et al. (2016).2 0.83 [0.46, 1.20]
Kent–Walsh et al. (2010).1 4.62 [2.93, 6.31]
Kent–Walsh et al. (2010).2 3.60 [2.07, 5.13]
Harjes–Walsh & Robbins (2012) 2.31 [1.28, 3.33]
Douglas et al. (2013) 0.55 [−0.41, 1.51]
Olive et al. (2007) 1.34 [0.55, 2.13]
Randolph et al. (2011) 0.58 [−0.43, 1.60]
Cabell et al. (2011).1 0.00 [−0.25, 0.26]
Cabell et al. (2011).2 0.51 [−0.25, 0.77]
Cabell et al. (2011).3 0.01 [−0.25, 0.27]
Kaiser & Roberts (2013).1 0.16 [−0.29, 0.60]
Kaiser & Roberts (2013).2 0.00 [−0.44, 0.45]
Kaiser & Roberts (2013).3 0.03 [−0.42, 0.48]
Kaiser & Roberts (2013).4 0.13 [−0.32, 0.58]
Kaiser & Roberts (2013).5 0.16 [−0.29, 0.61]
Kaiser & Roberts (2013).6 0.04 [−0.41, 0.48]
Fey et al. (2013).1 0.42 [−0.14, 0.70]
Fey et al. (2013).2 0.25 [−0.03, 0.45]
Duifhuis et al. (2017).1 0.80 [0.17, 1.77]
Duifhuis et al. (2017).2 0.21 [−0.72, 1.14]
Casenhiser et al. (2013) 0.22 [−0.34, 0.78]
Fey et al. (2006) 0.70 [0.14, 1.27]
Hardan et al. (2015).1 0.49 [−0.09, 1.07]
Hardan et al. (2015).2 0.35 [−0.23, 0.92]
Hardan et al. (2015).3 0.26 [−0.31, 0.84]
Hardan et al. (2015).4 0.07 [−0.50, 0.64]
Kasari et al. (2014).1 0.61 [0.07, 1.15]
Kasari et al. (2014).2 0.29 [−0.25, 0.82]
Kasari et al. (2014).3 0.43 [−0.10, 0.97]
FE Model 0.36 [0.20, 0.44]

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130