

The impact of a delay to early intensive behavioral intervention on educational outcomes
for a cohort of Medicaid-enrolled children with autism

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Dedication

This dissertation is dedicated to my grandfather, Dr. Fawzi G. Dimian and my grandmother, Ivonne Dimian for setting the example in our family that anything is possible and for their unconditional love. I miss you both dearly and hope you know that this would not have been possible without you.

Abstract

Introduction. Early Intensive Behavioral Interventions (EIBI) is an applied behavior analysis approach that can be effective for remediating autism spectrum disorder (ASD) symptoms for some individuals (Reichow, 2012). From a population perspective, timely access to early intervention services is assumed to be important for facilitating long term positive educational outcomes. Stakeholders report, however, long waitlists for services. The range of effects of EIBI service delay on educational outcomes for children with ASD is unknown. The purpose of the study was to examine how EIBI service delays relate to later educational and placement outcomes for Medicaid-enrolled children diagnosed with ASD. Three research questions guided the analyses conducted in this study: 1) what is the main effect of delay to EIBI on educational outcomes, 2) what is the main effect of average hours of EIBI per week on educational outcomes and 3) does the average delay to start EIBI differ by county or region within Minnesota?

Method. The study utilized cross-systems administrative data to create a cohort of 3 to 5 year olds who received a diagnosis of ASD between 2008 and 2010. This cohort was matched with Minnesota Department of Education (MDE) records from the 2010-2014 academic year (94.5% match rate). Delay to EIBI services in months was calculated by subtracting the date of ASD diagnosis (ICD-9 CM 299.0) from the first billing date associated with an EIBI service provider. Educational outcomes evaluated included primary educational ASD diagnosis, instructional placement, Minnesota Comprehensive Assessment-III (MCA) scores and special education service hours. Descriptive analyses, Generalized Estimating Equations regressions models (GEE), and Geographic

Information Systems (GIS) were used to evaluate data from 667 children with ASD (82% Male, 72% White).

Results. The average delay to EIBI was 8.99 months ($SD=10.63$ mos). At follow-up, 94% of the cohort qualified for special education with 70% of them receiving an ASD diagnosis in school. About 40% of the children received a general education placement. The GEE models calculated showed that the main effect of delay to EIBI was significant and the odds of receiving a general education placement and participating in the MCA-tests was decreased if the child experienced a longer delay to start EIBI. Additionally, the odds of receiving a primary educational diagnosis of ASD increased for every increase in delay. The results further suggest that the main effect of average hours of EIBI per week was significantly associated with ASD diagnosis in school, MCA participation, and special education service hours. Finally, children who resided in the metro area ($M=9.89$ mos, $SD=11.24$ mos) had a larger average delay to EIBI compared to children who resided in the non-metro area ($M=7.00$ mos, $SD=8.78$ mos).

Discussion. With increases in diagnoses of ASD over the past decade, it is imperative that children and families have early access to high quality services. Children who were diagnosed younger and experienced a shorter delay had better educational outcomes overall. This study is limited in that the reason a delay may have occurred is unknown and the educational outcomes are limited. In sum, there are waitlists and delays to services which may be detrimental to children's educational outcomes. Future research should investigate if a telehealth delivery model (i.e., video-conferencing) could supplement the gap in services early on and the cost-effectiveness of timely service.

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CHAPTER 1: INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disability that is estimated to impact 1 in 68 children nationwide and roughly 1% world-wide (Center for Disease Control and Prevention [CDC], 2016). In Minneapolis, Minnesota, the estimates among 7 to 9 year olds are closer to 1 in 48 children (Hewitt et al., 2013). Children diagnosed with ASD have impairments in communication and social functioning, and engage in repetitive and/or restricted behavior (CDC, 2016). Symptom presentation is heterogeneous and is considered along a continuum. Some individuals experience more difficulties in only one or some of the core features associated with ASD (American Psychiatric Association [APA], 2013). For example, some individuals may avoid social contact while others could be overly social; some individuals may be nonverbal and others may have communication strengths or live independently with very little supports needed. ASD is almost five times more common among boys than girls (CDC, 2016). Comorbid conditions are also common with ASD and may include intellectual disability, attention deficit disorder, and/or epilepsy to name a few, which in turn can contribute to ASD symptom severity (Gurney, McPheeters, Davis, 2006; APA, 2013).

The etiology of ASD is idiopathic in most cases, but for a very small percentage an identified chromosomal abnormality, single gene disorder, or an environmental agent is known to contribute to ASD (Rogers, Wehner, & Hagerman, 2001). ASD is clinically diagnosed based on behavior and can be detected as early as 18 months in some cases and reliably diagnosed by 24 months (Lord et al., 2006). The disorder emerges early and is a lifelong disability. There is no cure for ASD; the impairments associated with ASD can

have deleterious effects on the individual's and families' quality of life (e.g., engagement in serious problem behavior harmful to self or others, limited communication and independence).

The identification of ASD among individuals up to 21 years old in Minnesota has increased more than 300% since 2001 (Minnesota Department of Education, 2011). With the increase in diagnoses of ASD in the past decade, it is imperative that children and families in Minnesota have access to high quality services early on (Chasson, Harris, & Neely, 2007). Treatment for ASD, while costly, is essential to increase the quality of life for individuals and families. The long-term cost to society attributed to the needs of a person with ASD is estimated at upwards of \$3.2 million (Ganz, 2007). The research to date, however, suggests that these costs can be significantly reduced with effective early diagnosis and early intervention services (Jarbrink & Knapp, 2001). There is currently no standard treatment recommended for all individuals with ASD.

Early Intensive Behavioral Intervention

The extant literature indicates that early intensive intervention can have ameliorating effects and is associated with positive long-term outcomes for children diagnosed with ASD (Sallows & Graupner, 2005; Reichow, 2012). Addressing areas of impairment and increasing adaptive behavior early on for children with ASD is critical to increase independence in daily living and quality of life throughout the lifespan. Early intensive behavioral intervention (EIBI) in particular has demonstrated promising results in terms of positive outcomes (Lovaas, 1987; Sallows & Graupner, 2005). EIBI programs promote acquisition in deficit skill areas by utilizing evidence-based practices, such as

discrete trial training/ individualized skills training (Lovaas, 1987). Interventionists deliver one-on-one teaching to children at a high dose of hours per week (recommended at 40 hours per week) typically in the child's home or a center-based environment (Lovaas, 1987; Sallows & Graupner, 2005). EIBI is based on the principles of applied behavior analysis and is usually an intensive home-based program (e.g., one on one services for up to 40 hrs per week for 2 yrs) (Reichow, 2012). EIBI effectiveness studies conducted to date suggest that the approach is among the top evidence-based behavioral treatments for young children with ASD (Matson & Smith, 2008).

The majority of intervention and remediation for children with ASD comes in the form of special education. The effectiveness of special education's eclectic and varied intervention approaches for children with ASD in particular has been limited (Smith, Groen, & Wynn, 2000). The Individuals with Disabilities Education Act (IDEA) was reauthorized in 2004 and mandates that all children have the right to a free and appropriate education. IDEA provides services for students with disabilities 3-18 years old under Part B, and early intervention services for children birth–2 years old under Part C. In Minnesota, the Department of Human Services (DHS) and the Minnesota Department of Education (MDE) provide a majority of early intervention services for children diagnosed with ASD (Hewitt et al., 2013). Researchers have conducted meta-analyses that specifically compared the effects of EIBI to special education services in the schools and found that children who received EIBI outperformed the other children on tests of intelligence, adaptive behavior, social skills, communication, autism symptoms and overall quality of life (Reichow, Barton, Boyd, & Hume, 2014).

It is important to ensure that families have access to high quality and effective evidence-based interventions early on. EIBI has been shown to reduce special education placement (Lovaas, 1987; Bibby, Eikeseth, Martin, Mudford & Reeves, 2002; Cohen, Amerine-Dickens & Smith, 2006). Furthermore, cost-benefit analyses have been done to weigh the cost of treatment with the savings in special education. An estimated total savings of \$208,500 per child was found for children who received 3 years of EIBI treatment compared to the special education costs that would be accrued with 18-years of special education services (Chasson, Harris, & Neely, 2007).

There have been 9 meta-analyses/systematic reviews of EIBI for young children with ASDs published in peer-reviewed journals to date that altogether include over 50 studies (Caron, Berube, & Paquet, 2017; Eldevik et al., 2009; Howlin, Magiati, & Charman, 2009; Makrygianni & Reed, 2010; Reichow, 2012; Reichow & Wolery, 2009; Spreckley & Boyd, 2009; Virués-Ortega, 2010; Warren et al., 2011). The meta-analyses on the effectiveness of EIBI as a treatment for ASD indicate that there is evidence of significant gains in adaptive behavior, communication, socialization, daily living skills, and intelligence among children that receive EIBI (Caron et al., 2017; Eldevik et al., 2009; Howlin et al., 2009; Makrygianni & Reed, 2010; Reichow, 2012; Reichow & Wolery, 2009; Spreckley & Boyd, 2009; Virués-Ortega, 2010; Warren et al., 2011). The meta-analyses suggest that strength of the evidence ranges from low to moderate due to a lack of high-quality randomized controlled trials (considered the gold standard for causal inference) and small sample sizes reported in some of the studies. Taken together, there is a large literature base on EIBI for young children with ASD that has limitations (i.e., use

of parent reported measures, small sample sizes, lack of high quality RCTs, lack of no treatment control groups due to ethical reasons) but overall has yielded positive results across different demographics.

Delayed Access to Autism Treatment Services

There is a need to investigate the effects of early service delays on outcomes for individuals with ASD. There are reported waitlists for initial ASD diagnosis and early intervention service start up by stakeholders (Hewitt et al., 2012). Research has focused on access to services disparities in terms of specific racial differences (Mandell et al., 2010) as well as age of ASD diagnoses for Medicaid-enrolled children (Liptak et al., 2008; Mandell et al., 2010) but the effects of a delay to community-based services on academic achievement and educational outcomes has not been examined. Researchers in Canada published some data on wait times for child developmental and rehabilitation services but limited data severely constrained their conclusions and more documentation was recommended (Miller et al., 2008).

In a 2012 report conducted by the University of Minnesota's Institute on Community Integration (ICI; Hewitt et al., 2012), a community sample of stakeholders was surveyed. The stakeholders not only reported wait lists for services and EIBI in particular throughout Minnesota but reported a persistent lack of services within Minnesota's diverse communities (i.e., culturally and linguistically). Furthermore, stakeholders and an ASD advisory council within Minnesota pointed out the pronounced lack of longitudinal data on outcomes for children with ASD in Minnesota who received EIBI services (Hewitt et al., 2012). Development of data sets that follow and monitor the

outcomes of children with ASD was recommended by the council and stakeholders to ensure effectiveness of interventions. The current proposed project fulfills the aforementioned recommendation.

Rationale and Significance

Timely access to high quality early intervention services may improve quality of life for both children and families (Boyd, Odom, Humphries, & Sam, 2010), and EIBI specifically can be effective for remediating ASD symptoms (Lovaas, 1987; Reichow, 2012). The EIBI studies conducted to date suggest that the approach is among the top evidence-based behavioral treatments for young children with ASD (Matson & Smith, 2008). The current project's goal is to help elucidate the educational outcomes associated with delayed access to EIBI services within Minnesota and provide critical evidence for policy planners and practitioners when it comes to the wait times related to service start.

In the current investigation, a cohort of young children who received a diagnosis of ASD were studied after they entered Minnesota public schools 4 to 6 years following diagnosis. EIBI has been and is covered in Minnesota by Medical Assistance with the recent implementation of Minnesota's early intensive developmental and behavioral benefit (EIDBI; Minnesota Department of Human Services, 2016). The findings of this study will be policy-relevant specific to service allocation in Minnesota and begin to clarify who, when, and where children in Minnesota are receiving timely services.

Purpose, Research Questions, and Hypotheses

The overall purpose of the study was to examine how EIBI service delays relate to later educational and placement outcomes for Medicaid-enrolled children diagnosed with

ASD. At issue was whether delayed EIBI services for children with ASD aged 3-5 was associated with later educational outcomes and school placements. EIBI in the form of individualized and family skills training was examined by documenting onset of services (date started) and average number of hours per week each child completed from the ages 3 and 5 years old. The educational outcomes included the Minnesota Comprehensive Assessment outcomes as well as instructional placement, whether an ASD educational diagnosis was given in the school setting, and special education service hours. The study utilized cross-systems administrative data sets from the state of Minnesota Department of Human Services and Minnesota Department of Education.

The specific research questions were:

1. What is the main effect of a delay in EIBI services for Medicaid-enrolled children with ASD on later educational outcomes?
 - a. Specifically, are there differences in school/instructional placement, ASD diagnoses, special education service hours, and standardized test completion/performance (if the student took the Minnesota Comprehensive Assessment-III (MCA) starting in 3rd grade)
 - b. *Hypothesis:* Children with ASD that experienced a longer delay to service will retain an ASD diagnosis in school, have more restrictive instructional placements, have more special education service hours, and will be less likely to participate in the MCA.
2. What is the main effect of average EIBI hours per week on later educational outcomes?

- a. *Hypothesis:* Children with ASD that received more hours a week on average will be in less restrictive placements, receive less special education service hours, and will be more likely to participate in the MCA.
3. Does average delay to start EIBI differ by county or region within Minnesota?
 - a. *Hypothesis:* The metro area will have less service delay compared to other regions of the state; this difference will be accounted for by differences in service provider density.

Advance Organizer

The dissertation is organized into four subsequent chapters. The second chapter will review the existing literature on treatment for ASDs, EIBI efficacy, and waitlists for ASD services and their assumed effects. The third chapter provides detailed information on the methods and data analyses. The fourth chapter will present the results and the final chapter will review the research questions, main findings, and discuss the implications for future research.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews the extant peer-reviewed literature and empirical work in the following areas to give context and background information on 1) the effectiveness and efficacy of early intensive behavior intervention (EIBI) for children with autism spectrum disorder (ASD), 2) barriers to service such as waitlists for ASD services and access disparities, and 3) educational outcomes for children with ASD. The first section is a systematic literature review and the following two sections are scoping reviews of the extant literature. The conclusion of this chapter will revisit the rationale for the study, the study purpose, and the study research questions.

Early Intervention and Evidence-Based Practice

The purpose of early intervention is to improve the behavioral and academic development of young children with disabilities to minimize special education placement in school and improve long-term educational and social outcomes (IDEA, 2004; Lipkin & Okamoto, 2015). IDEA authorizes federal funding for early intervention services to states for infants/toddlers (Part C) and special education for youth with disabilities (Part B) (IDEA, 2004; Lipkin & Okamoto, 2015). The overall evidence from the extant literature suggests that early intervention optimizes outcomes for children with autism. More specifically, improvements in developmental domains are evident, as well as decreases in maladaptive behaviors (Rogers & Vismara, 2008). Based on the literature, the American Academy of Pediatrics specified nine critical components of effective early intervention for children with ASD and include the following: 1) intervention should start as soon as an ASD diagnosis is being considered as opposed to waiting for a definitive

diagnosis, 2) intervention should be systematic and intensive (at least 25 hours per week, 12 months a year), 3) 1:1 and small group instruction, 4) family or parent training, 5) promotes interaction with typically developing peers, 6) continued measurement/documentation of progress towards educational objectives and appropriate adjustment of programming is done, 7) structure is incorporated (e.g., visual schedules or routines), 8) generalization and maintenance is promoted and, 9) assessment-based curricula are used to address functional communication, social skills, adaptive skills, cognitive skills, academic skills, and maladaptive or destructive behavior (Myers & Johnson, 2007). The components highlighted are integral to effective early intervention, but tend to vary in terms of implementation by setting and program.

There are additional guidelines from other agencies as well. The National Autism Center (NAC) created the National Standards Project to provide guidelines for effective evidence-based practices for individuals with ASD (National Autism Center, 2015). The National Standards Project classifies ASD treatments/interventions into established, emerging, and unsubstantiated categories of evidence. The goal is to elucidate and facilitate the integration of evidence-based interventions into programming for individuals by providing a guide for caregivers, professionals, and educators (NAC, 2015). The National Standards Project reviews peer-reviewed treatment and intervention studies for persons with ASD published from 2007 to 2012. Interventions that received an established level of evidence rating included the following: behavioral interventions, comprehensive behavioral treatment for young children (e.g., EIBI), cognitive behavioral intervention package, language, parent, and peer training, modeling, natural teaching

strategies, schedules, scripting, self-management, social skills package, story-based intervention, and pivotal response training. Behavioral intervention was the largest category of established interventions and included 155 articles with participant samples ranging from ages 3 to 21 years old.

Many of the interventions listed by the National Autism Center are based in behavior analytic principles such as reinforcement, function-based intervention, chaining, and prompting (NAC, 2015). The comprehensive behavioral treatment for young children interventions included EIBI components like intensive service delivery (over 25 hours per week for 2 to 3 years), data-based decision making targeted at symptoms of ASD, applied behavior analysis strategies and principles (i.e., discrete trial training, errorless learning, modeling, etc.), and individualized instruction across settings (NAC, 2015). Taken together, a large literature base on behavioral treatment for ASD has accrued over time.

In contrast, there are fewer effective biomedical or pharmacological treatments that are safe and widely accepted to treat ASD (LeClerc & Easley, 2015). There are two drugs that are approved by the U.S. Food and Drug Administration (FDA) to treat symptoms or behaviors associated with ASD. Risperidone (i.e., Risperdal) is an antipsychotic medication and is approved to treat irritability and aggression in individuals with ASD that are 5 years old or older (FDA, 2006; LeClerc & Easley, 2015). Aripiprazole (i.e., Abilify) is a psychotropic drug approved to treat irritability in children 6 to 17 years old with ASD (Bristol-Myers Squibb, 2009; LeClerc & Easley, 2015). Although there are ongoing clinical drug trials to test the effectiveness of other drugs

types to treat ASD, behavioral interventions are the primary effective treatment for the core deficits associated with ASD (social-communication and repetitive behavior).

Surveys given to parents (Green et al., 2006) and community service providers for ASD (Stahmer et al., 2005) indicated that EIBI in particular is among the most commonly delivered and requested treatment. There are currently 45 states within the U.S. that mandate insurance coverage for autism treatment (Autism Speaks, 2017) with most having statutes that specifically cover ABA-based treatments including EIBI (Roane, Fisher, & Carr, 2016). The U.S. Surgeon General and the National Academy of Sciences recognize EIBI as an effective treatment for ASD (National Academy of Sciences, 2001; Satcher, 1999). The core tenets of EIBI and the different types will be presented next followed by a review of the empirical work to date on the efficacy and effectiveness of EIBI for children with ASDs.

The foundations of EIBI. Early intensive intervention based on behavior analytic strategies/principles are related to positive outcomes for children with ASD (Harris & Handleman, 2000) as well as for families (Remington et al., 2007). EIBI is based on the principles and technologies of ABA, grounded in B.F. Skinner's pioneering empirical work on operant conditioning in which reinforcement processes were studied and codified (reinforcement schedule effects, extinction effects, shaping by successive approximation) (Skinner, 1938). For example, Skinner utilized reinforcement within an environmental context to show that behaviors that produce favorable outcomes will be repeated in the future and continue to occur (Skinner, 1938). Skinner also provided empirical evidence that breaking down a behavior or a task and providing reinforcement

for successive approximations of the behavior (i.e., shaping) can result in behavior change and acquisition over time (Skinner, 1938).

From the foundational operant conditioning and basic research on learning mechanisms, the field of applied behavior analysis (ABA) emerged in which the principles of behavior and learning were extended and applied to systematically change human behavior in socially important ways (Baer, Wolf, & Risley, 1968; Cooper et al., 2007). ABA methodology provides a powerful tool to increase (and maintain) adaptive behaviors and decrease maladaptive behaviors by teaching new skills and promoting generalization of these skills across settings and contexts (Cooper et al., 2007). The conditions under which maladaptive behaviors (e.g., self-injurious behavior such as head banging) occur are systematically (and experimentally, in some cases) assessed and used to create a targeted intervention. Modeling and prompting a response are also ABA strategies with operant learning roots and are evident within EIBI (Cooper, Heron, & Heward, 2007). A cornerstone of research, assessment, and intervention within the field of ABA is the focus on reliable and objective measurement of observable behaviors within a context like home, school, and or the community (Cooper et al., 2007). Baer, Wolf, and Risely (1968) suggested that ABA needs to be applied, behavioral, technological, systematic, effective, generalizable, and analytic. ABA-based intervention, like EIBI, has five decades of single-case experimental design research strategies and some randomized and nonrandomized controlled studies supporting it as a treatment of ASD (Myers & Johnson, 2007).

Overall, ABA and EIBI focus on remediating delays in communication, social and emotional skills, and emphasize integrating children with typically developing peers in least restrictive settings (Eikeseth, 2009). ABA-based interventions/programs in general, and EIBI specifically, include the following important components for treatment of ASD: 1) early intervention (starting as early as possible and before 3.5 years old), 2) parent involvement to facilitate generalization and maintenance of skills, 3) mainstreaming children with ASD with typically developing peers, 4) intensive 1:1 teaching, 5) comprehensive programming to target and teach skills that are functional (i.e., communication, play, self-help skills, and social-emotional skills), and 6) individualized programming based on the child's strength and weaknesses (Eikeseth, 2009). There are several types of EIBI that will be discussed next in to provide context for the current study.

Types of EIBI. EIBI is a comprehensive treatment for ASD that is sometimes referred to as intensive behavioral intervention, Lovaas therapy, ABA therapy or early behavioral treatment (Reichow, 2012). In a review of EIBI conducted by Eldevik and colleagues (2009) common elements of EIBI programs were identified and included the following: 1) individualized and comprehensive programming to address all skill domains, 2) ABA based strategies to reduce challenging behavior that may interfere with learning and programming to build new behavioral repertoires (i.e., discrete-trial training, differential reinforcement, prompting, task analyses), 3) personnel with advanced training in ABA such as a board certified behavior analyst, 4) developmentally appropriate intervention targets are used, 5) parents participate as co-therapists/implementers, 5)

intervention is delivered 1:1 with generalization to others programmed for, 6) generalization of skills is considered for other settings like school and the community, and 7) program intensiveness, (20-40 hrs a week for 2 or more years starting at between 3 and 4 years of age). Taken together, EIBI is a comprehensive behavioral treatment that aims to improve adaptive functioning and decrease maladaptive autism related symptoms like repetitive stereotypical behavior and challenging behavior. There are three general EIBI models reviewed briefly below.

UCLA. Three decades ago, Ivar Lovaas pioneered and developed the first EIBI program for children with ASD at the University of California Los Angeles (UCLA; Lovaas, 1987). The UCLA/Lovaas model (also known as the UCLA Young Autism Project model), as originally conceived, provided 40 hours of treatment in home per week on a 1:1 basis for over 2 years with the goal of increasing functional skills (e.g., communication, joint attention, imitation, and play) and decreasing maladaptive behavior (Lovaas, 1987; Roane, Fisher, & Carr, 2016). Lovaas' seminal empirical work utilized trial-by-trial data collection and discrete-trial training (DTT); brief teaching opportunities that are repeated and signaled by a specific discrete instruction (Lovaas, 1987; Roane, Fisher, & Carr, 2016). Correct answers or approximations are reinforced with praise, access to a preferred item or activity, like an edible or 'tickles.' Prompts and error correction strategies were also used to ensure skill acquisition and contact with reinforcement for the target/correct responses. Punishment was used to decrease aberrant behavior when Lovaas initially created the program, however, as his work/behavior analysis evolved and our understanding of the negative side effects of punishment

emerged (e.g., interventionist becoming a conditioned punisher), reinforcement-based strategies are now primarily used and tried before resorting to any punishment strategies (Cooper et al., 2007). Finally, data-based decision making regarding programming is a cornerstone of EIBI in general and the UCLA/Lovaas model in particular.

ESDM. The Early Start Denver Model (ESDM; University of Washington) uses ABA strategies embedded explicitly in a developmental framework with relationship-based approaches (Smith, Rogers, & Dawson, 2008; Dawson et al., 2010). ESDM is recommended for children with ASD as young as 12 months; the curriculum is typically implemented by an interdisciplinary team which focuses on increasing imitation, verbal and nonverbal communication, play, and social-emotional skills (Smith, Rogers, & Dawson, 2008). Additionally, ESDM employs teaching strategies that incorporate real-life materials/activities, adult responsivity, following the child's lead and cues, and emphasizes interpersonal exchanges (Smith, Rogers, & Dawson, 2008; Roane, Fisher, & Carr, 2016).

PRT. Pivotal Response Training (PRT) is a trademarked program from Koegel, O'Dell, and Koegel (1987) that focuses on naturalistic teaching strategies and targets motivation, self-management, self-initiation, and responsiveness to different cues. Important components of training include reinforcement of attempts at appropriate responding (shaping), turn-taking, following the child's choice of activities, and using natural consequences for instance (Koegel et al., 1987). Finally, PRT utilizes play-based activities to increase language skills in children with ASD along with the strategies already mentioned.

The ‘Lovaas’ model of EIBI has been adapted over the years to accommodate more naturalistic learning opportunities for children with ASD in the Early Start Denver Model and Pivotal Response Training. Each of the EIBI models use teaching strategies that are consistent with the principles of ABA (i.e., using positive reinforcement, shaping, chaining) and individual programming for each child. The EIBI research literature on ASD outcomes is reviewed in the following section.

Review of the Literature

I reviewed and synthesized the meta-analyses conducted to date on the empirical work specific to EIBI for young children with ASD. The results of the combined meta-analyses are presented in the next section (and Table 1) and are followed by a narrative review of the potential barriers to access early intervention/EIBI services for families as well as the available research on educational outcomes for children with ASD.

Method

An electronic search of the literature was conducted for this review using three databases. PsychINFO, Google Scholar, and PubMed were searched for articles with the terms *meta-analysis, review, early intensive behavioral intervention/EIBI (variations include intensive behavioral intervention, early behavioral intervention, applied behavior analysis intervention), efficacy, autism/autism spectrum disorders, and or young children* (e.g., “*review of EIBI AND autism*”). Ancestral searches were subsequently conducted with publications that met the selection criteria.

Electronic searches were also conducted with a combination of the following search terms for the other sections of this literature review including barriers to /or wait

lists for autism services, educational or achievement outcomes for young children with *autism*, and or *early intervention*, and *Medicaid autism services*. Ancestral searchers were also conducted.

Selection criteria. The abstracts of articles identified through the above search procedures were evaluated to determine relevance. Studies were included if they met the following criteria: a) the article was peer-reviewed and in English, b) included children with autism who received early intensive behavioral intervention (regardless of model; also called applied behavior analysis intervention, intensive behavioral intervention or, early intensive intervention for children with autism), and c) the article was a meta-analysis or systematic literature review. Articles were excluded if they did not examine the effectiveness of EIBI in the form of a review of early intervention services in general for children with ASD.

Thirteen articles were identified. Of those articles, nine were included for review. A second coder (a graduate student in a Ph.D. level program in educational psychology) independently reviewed the thirteen abstracts. Inter-observer agreement (IOA) was calculated (number of agreements divided by number of agreements plus disagreements and multiplying by 100%) and was 90%.

Review of the Effectiveness of EIBI

Inclusion Criteria. Six meta-analyses (Eldevik et al., 2009; Makrygianni & Reed, 2010; Reichow, 2012; Reichow & Wolery, 2009; Spreckley & Boyd, 2009; Virués-Ortega, 2010) and three systematic reviews (Caron, Berube, & Paquet, 2017; Howlin, Magiati, & Charman, 2009; Warren et al., 2011) were included in this review. Table 1

provides information from all 56 articles (spanning 1987-2015) that were included in the reviews including main review results, models, EIBI dosage, and comparison groups. There were a variety of primary research questions and inclusion criteria employed in each of the meta-analyses/reviews evaluated. Each review and overall results will be presented in the following section.

Reichow and Wolery (2009) provided a synthesis of studies on EIBI and examined the experimental methods, intervention program, and the participants included. The effects and outcomes of the participants were also evaluated in terms of descriptive, effect-size, and meta-analyses. The inclusion criteria utilized were: 1) the study had to use the UCLA YAP model by Lovaas, 2) the participants needed to be diagnosed with either ASD or pervasive developmental disorder not otherwise specified (PDD-NOS), 3) mean age was 84 months (7 years old) or less at the start of treatment, 4) the mean duration of EIBI was 12 months or more, 5) child outcomes were included, 6) an experimental design was used, and 7) the publication was in a peer-reviewed journal and in English. Based on this inclusion criteria, 14 articles were included in this meta-analysis (Anderson et al., 1987; Bibby et al., 2002; Birnbrauer & Leach, 1993; Boyd & Corley, 2001; Cohen et al., 2006; Eikeseth et al., 2007; Eldevik et al., 2006; Harris et al., 1991; Lovaas, 1987; Magiati et al., 2007; Sallows & Graupner, 2005; Sheinkopf & Siegel, 1998; Smith et al., 1997; Smith, Groen, & Wynn, 2000).

Eldevik and colleagues (2009) extended Reichow and Wolery's (2009) meta-analysis by restricting inclusion for review only to comparative group experimental designs (i.e., need a control or comparison group) as well as including changes in

adaptive behavior to the outcome measures examined. Additional inclusion criteria different from Reichow and Wolery were: 1) the study needed an intelligence and/or adaptive behavior measure at intake and after treatment, and 2) the study could not be a case study or a series of case studies. The authors included 9 articles in their meta-analysis (Birnbauer & Leach, 1993; Cohen et al., 2006; Eikeseth et al., 2002; Eldevik et al., 2006; Howard et al., 2005; Lovaas, 1987; Remington et al., 2007; Smith et al., 1997; Smith, Groen, & Wynn, 2000).

Spreckley and Boyd (2009) aimed to review the effectiveness of EIBI (what they called applied behavior intervention programs) for preschool children with ASD in their meta-analysis. The authors limited the studies included to randomized controlled trials, quasi-randomized controlled trials and controlled trials in comparison to the other meta-analyses reviewed. The EIBI intervention studies examined also included children 18 months to 6 years old and had to have cognitive, language or adaptive behavior outcomes reported. In contrast to Reichow and Wolery (2009) and Eldevik et al. (2009), PRT models of EIBI were included. Overall, 13 studies met eligibility (Bernard-Optiz, Ing, & Kong, 2004; Cohen et al., 2006; Eikeseth et al., 2002; Eikeseth et al., 2007; Eldevik et al., 2006; Howard et al., 2005; Jocelyn et al., 1998; Koegel et al., 1996; Magiati et al., 2007; McEachin et al., 1993; Sheinkopf & Siegel, 1998; Smith, Groen, & Wynn, 2000; Sallows & Graupner, 2005).

Howlin and colleagues (2009) conducted a systematic review and had similar inclusion criteria to Reichow and Wolery (2009) and focused on the UCLA model but included only case-control studies. The results included 13 studies and overlapped with

the other meta-analyses published in 2009 (Cohen et al., 2006; Eikeseth et al., 2002; Eikeseth et al., 2007; Eldevik et al., 2006; Howard et al., 2005; Lovaas, 1987; Magiati et al., 2007; McEachin et al., 1993; Remington et al., 2007; Sallows & Graupner, 2005; Sheinkopf & Siegel, 1998; Smith et al., 1997; Smith, Groen, & Wynn, 2000).

Makrygianni and Reed (2010) only included longitudinal studies and excluded single case and case studies research on EIBI for children with ASD. Characteristics of the children in the studies (e.g., intellectual, language, and adaptive behavior) and the characteristics of the programs (e.g., intensity, duration, and staff training or parent training) were also analyzed. Fourteen studies were examined (Anderson et al., 1987; Ben-Itzchak & Zachor, 2007; Cohen et al., 2006; Eldevik et al., 2006; Howard et al., 2005; Lovaas, 1987; Magiati et al., 2007; Reed et al., 2007a; Reed et al., 2007b; Remington et al., 2007; Sallows & Graupner, 2005; Smith, Groen, & Wynn, 2000; Smith et al., 1997; Weiss, 1999).

Virués-Ortega's (2010) focused primarily on the effects of intervention on skill domains and also evaluated dose-dependent effect sizes. Similar inclusion criteria were used by Virués-Ortega as the previous meta-analyses but PRT and Group Intensive Family Training were also included, which are different that the UCLA model. Twenty-five studies were evaluated by Virués-Ortega (Anan et al., 2008; Anderson et al., 1987; Baker-Ericzen et al., 2007; Ben-Itzchak et al., 2008; Ben-Itzchak & Zanchor, 2007; Bibby et al., 2002; Birnbrauer & Leach, 1993; Cohen et al., 2006; Eikeseth et al., 2002; Eikeseth et al., 2007; Eldevik et al., 2006; Harris et al., 1991; Harris & Handleman, 2000; Howard et al., 2005; Lovaas, 1987; Magiati et al., 2007; Matos & Mustaca, 2005; Reed et

al., 2007a; Reed et al., 2007b; Remington et al., 2007; Sallows & Graupner, 2005; Sheinkopf & Siegel, 1998; Smith et al., 1997; Smith, Groen, & Wynn, 2000; Weiss, 1999).

Reichow (2012) gave an overview and evaluated the findings of five meta-analyses on the effectiveness of EIBI for children with ASD published since 2009 (Eldevik et al., 2009; Makrygianni & Reed, 2010; Reichow & Wolery, 2009; Spreckley & Boyd, 2009; Virués-Ortega, 2010). Differences in the meta-analyses and potential confounders were presented and included 26 studies across the five meta-analyses (Anan et al., 2008; Anderson et al., 1987; Baker-Ericzen et al., 2007; Ben-Itzhak et al., 2008; Ben-Itzhak & Zanchor, 2007; Bibby et al., 2002; Birnbrauer & Leach, 1993; Boyd & Corley, 2001; Cohen et al., 2006; Eikeseth et al., 2002; Eikeseth et al., 2007; Eldevik et al., 2006; Harris et al., 1991; Harris & Handleman, 2000; Howard et al., 2005; Lovaas, 1987; Magiati et al., 2007; Matos & Mustaca, 2005; Reed et al., 2007a; Reed et al., 2007b; Remington et al., 2007; Sallows & Graupner, 2005; Sheinkopf & Siegel, 1998; Smith et al., 1997; Smith, Groen, & Wynn, 2000; Weiss, 1999).

Warren and colleagues (2011) systematically reviewed the evidence regarding EIBI and parent training programs for children with ASD. All but single case studies were included in this review. Also included were participants with ASD that were 13 year olds and younger, which is an older age range than the other reviews. EIBI, ESDM, and PRT models were all a part of this review. Thirty-four studies met Warren et al.'s (2011) inclusion criteria, however, only twenty-two studies were specifically EIBI, ESDM, or PRT models and those are reported in Table 1 (Baker-Ericzen et al., 2007; Beglinger &

Smith, 2005; Ben-Itzhak & Zachor, 2007; Ben-Itzhak et al., 2008; Bibby et al., 2001; Boyd & Corley, 2001; Cohen et al., 2006; Dawson et al., 2010; Eikeseth et al., 2002; Eikeseth et al., 2007; Eldevik et al., 2006; Granpeesheh et al., 2009; Harris & Handleman, 2000; Hayward et al., 2009; Howard et al., 2005; Luiselli et al., 2000; Mudford et al., 2001; Perry et al., 2008; Reed et al., 2007a; Remington et al., 2007; Smith et al., 2000; Zachor et al., 2007).

The final systematic review examined is Caron et al. (2017). In Caron et al., the inclusion criteria was similar to the other reviews but extended the focus to EIBI studies conducted over the past ten years. Twenty-eight experimental and quasi-experimental studies that measured the effects of EIBI on preschool children with ASD were evaluated by Caron et al. (Ben-Itzhak & Zachor, 2007; Beglinger & Smith, 2005; Cohen et al., 2006; Dawson et al., 2010; Eapen et al., 2013; Eikeseth et al., 2012; Estes et al., 2015; Fava et al., 2011; Fernell et al., 2011; Flanagan et al., 2012; Granpeesheh et al., 2009; Howard et al., 2005; Howard et al., 2014; MacDonald et al., 2014; Magiati et al., 2007; Perry et al., 2008; Perry et al., 2011; Remington et al., 2007; Rivard et al., 2014; Sallows & Graupner, 2005; Smith et al., 2010; Smith et al., 2015a; Smith et al., 2015b; Stock et al., 2013; Strauss et al., 2012; Virués-Ortega & Rodriguez, 2013; Vivanti et al., 2013; Vivanti et al., 2014).

Effectiveness of EIBI. The multiple meta-analyses and systematic reviews examined indicate improvements in multiple areas of development for young children with ASD. The effectiveness of EIBI was the main focus of the reviews analyzed. Overall, there is evidence in the empirical literature that EIBI, compared to treatment as

usual or control groups, improves the following for children with ASD:

intellectual/cognitive functioning (Anan et al., 2008; Anderson et al., 1987; Beglinger & Smith, 2005; Ben-Itzhak et al., 2008; Birnbrauer & Leach, 1993; Cohen et al., 2006; Dawson et al., 2010; Eikeseth et al., 2002; Eldevik et al., 2006; Estes et al., 2015; Flanagan et al., 2012; Granpeesheh et al., 2009; Harris et al., 1991; Hayward et al., 2009; Howard et al., 2005; Howard et al., 2014; Lovaas, 1987; Luiselli et al., 2000; Matos & Mustaca, 2005; McEachin et al., 1993; Mudford et al., 2001; Perry et al., 2008; Reed et al., 2007a; Reed et al., 2007b; Remington et al., 2007; Rivard et al., 2014; Sallows & Graupner, 2005; Sheinkopf & Siegel, 1998; Smith et al., 1997; Smith et al., 2000; Smith et al., 2015a; Stock et al., 2013; Vivanti et al., 2014), *adaptive behavior* (Anan et al., 2008; Anderson et al., 1987; Baker-Ericzen et al., 2007; Ben-Itzhak & Zachor, 2007; Bibby et al., 2002; Cohen et al., 2006; Dawson et al., 2010; Eikeseth et al., 2007; Eikeseth et al., 2012; Estes et al., 2015; Fernell et al., 2011; Flanagan et al., 2012; Granpeesheh et al., 2009; Hayward et al., 2009; Howard et al., 2014; Perry et al., 2008; Remington et al., 2007; Rivard et al., 2014; Vivanti et al., 2014; Weiss, 1999), *communication/ language* (Ben-Itzhak & Zachor, 2007; Eapen et al., 2013; Eldevik et al., 2006; Fava et al., 2011; Harris et al., 1991; Hayward et al., 2009; Howard et al., 2014; Jocelyn et al., Lovaas, 1987; MacDonald et al., 2014; Matos & Mustaca, 2005; Smith et al., 1997; Smith et al., 2000; Smith et al., 2010; Smith et al., 2015a; Stock et al., 2013; Strauss et al., 2012; Vivanti et al., 2014; Zachor et al., 2007), *social behavior* (Anderson et al., 1987; Eikeseth et al., 2007; Hayward et al., 2009; Koegel et al., 1996; MacDonald et al., 2014; Matos & Mustaca, 2005; Remington et al., 2007; Rivard et al., 2014; Vivanti

et al., 2014; Zachor et al., 2007), *decreases in severity of ASD symptoms* (Ben-Itzhak et al., 2008; Dawson et al., 2010; Eapen et al., 2013; Eikeseth et al., 2012; Estes et al., 2015; Flanagan et al., 2012; Lovaas, 1987; Matos & Mustaca, 2005; Perry et al., 2008; Rivard et al., 2014; Smith et al., Strauss et al., 2012; 2010; Weiss, 1999), *and decreases in challenging behavior* (Ben-Itzhak et al., 2008; Eikeseth et al., 2012; Estes et al., 2015; Fava et al., 2011; Lovaas, 1987; MacDonald et al., 2014; Smith et al., 1997; Smith et al., 2010; Stock et al., 2013; Strauss et al., 2012).

Reichow (2012) aggregated the five meta-analyses included in this review and reported that four out of five meta-analyses concluded that EIBI was an effective intervention for many children with ASD (Eldevik et al., 2009; Makrygianni & Reed, 2010; Reichow, 2012; Reichow & Wolery, 2009; Virués-Ortega, 2010). For the four meta-analyses that indicated EIBI was effective, the mean effect sizes for IQ ranged from $g = .57-1.19$ and $g = .42-1.09$ for adaptive behavior (Reichow, 2012). The meta-analysis concluding EIBI was not more effective than treatment as usual (Spreckley & Boyd, 2009) reported mean effect sizes of $g = .38$ for IQ and $g = .30$ for adaptive behavior (Reichow, 2012). All mean effect sizes were weighted and are moderate.

Outcomes do vary, however, across children with ASD. Heterogeneity among individuals with ASD in terms of severity may contribute to the variability. For example, Eldevik et al. (2009) indicated that about 30% of some of the children included in Sallow and Graupner (2005) follow-up study after EIBI caught up to their typically developing peers academically. Although others also make gains, they do not reach 'normative' levels (e.g., Smith et al., 2000). Therefore, there were several studies

that did conduct analyses to identify the predictors of later success for children with ASD that received EIBI. Sallows and Graupner (2005) reported that pretreatment imitation, language, and social responsiveness skills predicted later treatment outcomes. Similarly, children that were younger and less impaired at pretreatment showed the most improvement at follow up in several studies (Baker-Ericzen et al., 2007; Bibby et al., 2002; Flanagan et al., 2012; Granpeesheh et al., 2009; Harris & Handleman, 2000; MacDonald et al., 2014; Perry et al., 2011; Smith et al., 2015b; Virués-Ortega & Rodriguez, 2013). Additionally, Flanagan et al. (2012) reported that children with higher initial adaptive skills predicted better outcomes. Finally, treatment duration, intensity, and quality have also been found to be related to outcomes (e.g., Eikeseth et al., 2009; Lovaas, 1987).

A common criticism, however, of the research on the effectiveness of EIBI is the limited number of randomized controlled trials conducted to date. The strength of the evidence is considered by some to be low (Spreckley & Boyd, 2009; Warren et al., 2011). On average, however, EIBI produces significant gains in IQ and or adaptive behavior for many children with ASD (Reichow, 2012). Taken all together, most of the meta-analyses examined concluded that EIBI is an effective intervention despite different inclusion criteria. Next, the potential barriers to timely EIBI services will be presented.

Barriers to Service

In this section, a scoping review of the common barriers to accessing timely services for children with ASD and their families is presented. The cost of services, age of diagnosis, access to services, and waitlists are reviewed.

Cost. Specialized services are needed for individuals with ASD. The lifetime cost to care for an individual with ASD with a comorbid intellectual disability in the United States is estimated to be \$2.4 million and \$2.2 million in the United Kingdom, respectively (Buescher, Cidav, Knapp, & Mandell, 2014). For individuals without a comorbid intellectual disability, the cost is estimated at \$1.4 million in both countries (Buescher et al., 2014). Implementation costs of EIBI are expensive due to the intensity and duration of the treatment (i.e., 20 to 40 hours per week for approximately 2 years) (Peters-Scheffer, Didden, Korzilius, & Matson, 2012). The cost per year for EIBI is estimated at up to \$60,000 (Amendah, Grosse, Peacock, & Mandell, 2011; Chasson, Harris, & Neely, 2007). For an individual with ASD, 3 to 65 years old in the Netherlands, EIBI has a long-term savings of about \$1,180,282 (€1,103,067; Peters-Scheffer et al., 2012). EIBI cost-savings, however, range from \$187,000 to \$203,000 for individuals 3 to 22 years old and \$656,000 to \$1,082,000 for 3 to 55 year olds (Jacobson, Mulick, & Green, 1998; Lovaas, 1987; McEachin et al., 1993; Peters-Scheffer et al., 2012). Chasson and colleagues (2007) estimated that with EIBI the state of Texas would save approximately \$208,500 for each child with ASD over 18 years of education. The overall cost, including indirect, medical, and nonmedical service costs for individuals with ASD is estimated to be \$3.2 million per child in the United States (Ganz, 2006). Furthermore, a child with ASD has seven times greater health care costs than a child without (Liptak, Stuart, & Auinger, 2006). Taken together, even though EIBI can be costly up front, it has a cost-benefit and can improve cognitive, adaptive, and social skills and decrease autism severity and challenging behavior in children with ASD. Therefore, it is imperative that

children with ASD and their families have timely access to services after a diagnosis is given.

Diagnosis. Early diagnosis is crucial for facilitating positive outcomes for children with ASD. ASD can reliably be diagnosed as early as 24 months (Lord et al., 2006; Wetherby et al., 2004) and considering the literature indicates that children who get diagnosed earlier often have better outcomes (Rogers & Vismara, 2008), screening and early diagnosis needs to be a priority. Previous research reports variability in the age of diagnosis by race and socioeconomic status (Liptak et al., 2006; Mandell et al., 2002; Mandell et al., 2010). In one study in the state of New Jersey, Thomas et al. (2012) found that ASD was diagnosed at younger ages among higher income tracts, based on census data. Further, Mandell and colleagues (2010) reported that the average age of diagnosis for Medicaid-enrolled children was 64.9 months (5.4 years old) and that children that were Asian were diagnosed earlier than other racial groups.

Other studies indicate that Black and Hispanic/Latino children with ASD were more likely to be diagnosed later or not at all (Mandell et al., 2009). Mandell et al. (2009) also found that children with ASD that were Black were three times more likely to be misdiagnosed or receive a diagnosis other than ASD (e.g., conduct disorder) and were diagnosed 1.4 years later, on average, than White children. Epidemiological studies indicate though that there is no difference in terms of race or ethnicity and ASD incidence or prevalence (Bertrand et al., 2001). There are differences, however, when it comes to recognition/ diagnosis by race (Bertrand et al., 2001; Mandell et al., 2002). Age of diagnosis is affected by degree or severity impairment as well (Wiggins, Baio, & Rice,

2006). Finally, delays between first report of parental concern and when a diagnosis of ASD has also been reported (Wiggins, Baio, & Rice, 2006; Zuckerman, Lindly, & Sinche, 2015). In summary, disparities are apparent in the early detection, diagnosis, and treatment of ASD. Disparities could be a function, in part, of access to services.

Access. Medicaid (a jointly funded state and federal health insurance program for people with disabilities and people who are economically disadvantaged) is the primary source of health care insurance for one in four children in the United States (Mandell et al., 2010). Having Medicaid was associated with better access to some services for children with ASD (Liptak et al., 2006). Conversely, being Black, Hispanic, or having a lower socioeconomic status/income was associated with decreased access to services (Liptak et al., 2006). Lower income families, racial minorities, and those with lower levels of education overall tend to report difficulty with accessing early intervention services than more educated or higher income families (Bailey et al., 2004). Stigma and lack of familiarity with the system could contribute to access issues for families that are racial minorities (Mandell et al., 2002). Unfortunately, families with a child with ASD are more likely to have difficulty accessing services in general compared to caregivers of children with other types of developmental delays or special health care needs (Krauss, Gulley, Sciegaj, & Wells, 2003; Ruble, Heflinger, Renfrew, & Saunders, 2005; Siklos & Kerns, 2007) and often have unmet therapy needs (Chiri & Warfield, 2012).

Thomas and colleagues (2012) examined the role of state residence and Medicaid reimbursement rates in relation to access to care for children with ASD using 2005 National Survey of Children with Special Health Care Needs data. Thomas et al. reported

the mean percentage of children with ASD experiencing problems accessing care by state. The average across all the states for children with ASD experiencing problems getting referrals was 31%, delayed care was 14%, unmet care coordination needs was 43%, and difficulty using services was 28%. Within Minnesota (the source of the current study's data) Thomas et al. (2012) reported that 29% of children with ASD had problems getting referrals, 9% had delayed care, 43% had unmet care coordination needs, and 24% difficulty using services. Another potential barrier for families to access services is geography. Residing in an urban area is associated with earlier autism diagnosis possibly due to access to more resources (Mandell, Novak, & Zubritsky, 2005). Conversely, limited access to care for autism-related services is associated with residing in non-metropolitan areas (Thomas, Ellis, McLaurin, Daniels, & Morrissey, 2007).

Access to EIBI also has specific barriers associated with implementation. In a study in the United Kingdom, Johnson and Hastings (2002) examined facilitating factors and barriers to implementation of EIBI programs (specifically Lovaas/UCLA type model) for children with ASD. Parents reported the most common barrier was problems recruiting and maintaining a treatment team due to staff shortages or lack of appropriate training (Johnson & Hastings, 2002). Program funding was the second most common barrier reported. Parents reported the most common factor facilitating EIBI implementation was having a supportive, stable, and complete team (Johnson & Hastings, 2002). In summary, access to services is difficult for many families of children with ASD and disparities in access are unfortunately common across various racial/ethnic groups,

socioeconomic status, and geographic locations. One barrier in particular that families often have to deal with are waitlists, discussed next.

Waitlists. The primary focus of the current study is to examine if a delay to EIBI affects later educational outcomes for children with ASD. Studies specific to waitlists for autism-related services is limited, despite caregivers and stakeholders reported concerns (e.g., Hewitt et al., 2012; Johnson & Hastings, 2002). Families report dissatisfaction with long wait lists for ASD-related services (Keating, Syrmis, Hamilton, & McMahon, 1998; Kohler, 1999). Long waits for services are a significant concern of both parents and providers, particularly given the evidence on the efficacy of early intervention services, the time sensitive nature of developmental periods, and the perception that prolonged waiting will add to caregiver stress (Miller et al., 2008). There are several potential factors that could contribute to waitlists for ASD services.

First, the lack of capacity may be because of the increased prevalence of ASD. The CDC estimates that 1 in 68 children have a diagnosis of ASD (CDC, 2016). Second, there are shortages of qualified service providers, such as Board Certified Behavior Analysts (BCBA), Speech-Language Pathologies (SLP), and occupational therapists (Wise et al., 2010). In 2014, for instance, there were only approximately 16,000 BCBA certificates in the United States to serve individuals ASD (Deochand & Fuqua, 2016). Further, Wise and colleagues (2010) reported that over 80% of states had shortages of ASD-related personnel including behavioral therapists and SLPs. A third possible factor is delay to diagnosis. In a nationally-representative sample, for example, Zuckerman et al. (2015) reported that ASD diagnosis was delayed by almost 3 years after a caregiver's

first conversation about concern about their child. Finally, funding and access to in-network service providers could also add to waitlists for ASD services.

There are few estimates of current wait times to start ASD services in general and EIBI in particular. Piccininni and colleagues (2017) conducted a study on the cost-effectiveness of wait time reduction for EIBI services in Ontario, Canada. This study reported a mean wait time for EIBI across Ontario of 2.7 years (Piccininni, Bisnaire, & Penner, 2017). The authors also reported that in Canada, increases in waiting lists exceed increases in program funding with eligible children not starting EIBI until age 6 or older (Piccininni et al., 2017). Starting age for EIBI was modeled and compared current wait time (mean EIBI start age = 5.24 years), reduced wait time (mean EIBI start age = 3.89 years) and no wait time (mean EIBI start age = 2.71 years) based on the Children's Hospital of Eastern Ontario IBI Center data. Piccininni et al. (2017) calculated the economic effect of wait times and found that if wait times were eliminated the lifetime savings would be Can\$267,000 per individual compared to the current wait times (Can\$1=USD\$0.78). Overall, the results suggested that providing timely access to optimize EIBI outcome could lessen costs and improve future independence (Piccininni et al., 2017).

In summary, waitlists, access to services, and costs are a problem for many families with children with ASD across the world. Future research needs to focus on how families are navigating the various service systems (i.e., school and community-based/private) and how to make the process less stressful, more efficient, and less cumbersome for families.

Educational Outcomes of Children with ASD

In the last section of this scoping literature review, the educational outcomes for children with ASD were examined in terms of instructional placement and academic achievement to provide context for the current study's findings. In general, there is limited research on academic achievement and predictors of achievement for individuals with ASD. One possible reason may be that Individualized Education Plans (IEPs) are based on individual student's needs which makes aggregating and using it as an outcome measure difficult. In the research to date, academic achievement is most commonly measured by standardized achievement/IQ testing (i.e., Woodcock-Johnson Tests of Achievement) and instructional placement setting (Keen et al., 2016).

IQ. Overall, research indicates a strong correlation between IQ and academic achievement, academic progress, and response to intervention for individuals with ASD (Keen et al., 2016; Mayes-Dickerson & Calhoun, 2003). Individuals with ASD with higher IQ tend to have better academic achievement and students with challenging behavior and or less social skills tend not to do as well academically (Eaves & Ho, 1997; Keen et al., 2016; Manti et al., 2011; Miller et al., 2017). Autism severity has been reported to be related to achievement in school (Eaves & Ho, 1997). Better social functioning at age six has also been found to be significantly associated with greater achievement later (Estes et al., 2011). Under-achievement of students with ASD is reported in comparison to typically developing peers in some studies (Ashburner, Ziviani, & Rodger, 2010).

Reading and Mathematics. Keen and colleagues (2016) conducted a literature review on the academic achievement of students with ASD. In the review, Keen et al. reported that reading achievement was commensurate with IQ for individuals with an IQ of 80 or greater. Among individuals with an IQ of below 80, reading achievement was a relative strength (Keen et al., 2016; Mayes-Dickerson & Calhoun, 2003). Reading comprehension skills frequently appear to be impaired among students with ASD (Miller et al., 2017; Minshew, Goldstein, Taylor, & Siegel, 1994; Nation et al., 2006; Troyb et al., 2014). For mathematics, similar results were found with individuals with ASD with higher ability were either average or below average on math performance (Estes et al., 2011; Keen et al., 2016; Mayes-Dickerson & Calhoun, 2003; Troyb et al., 2014). Mathematic achievement was reported to be positively correlated with IQ as well (Assouline et al., 2012; Keen et al., 2016; Mayes-Dickerson & Calhoun, 2003). Greater impairment in tasks requiring inferential processing or reasoning are evident in comparison to simple mathematic calculations for some individuals with ASD (Minshew et al., 1994; Miller et al., 2017; Troyb et al., 2014). There is significant variability apparent across both reading and mathematics achievement and discrepancies between predicted achievement based on IQ in some studies (e.g., Estes et al., 2011).

Miller et al. (2017) characterized academic functions and predictors of achievement among twenty-six children with ASD. Multiple regression analyses indicated weaknesses in reading comprehension relative to word reading. Mathematic skills were better for the group, but math reasoning was lower than numerical operations. Miller and colleagues also found that preschool verbal abilities significantly predicted

school-age reading comprehension and early motor functioning predicted later math skills (controlling for IQ). The authors concluded that early intervention should target language and motor skills for children with ASD to improve later achievement possibly (Miller et al., 2017).

Instructional placements. In the United States, IDEA mandates that education for students with disabilities should be in the least restrictive environment possible (IDEA, 2004). Of the EIBI studies identified, ten included school placement at follow-up. When compared to children that received treatment as usual, more children with ASD that received EIBI were placed in a regular/general education classroom with or without support (Cohen et al., 2006; Lovaas, 1987; Magiati et al., 2007; McEachin et al., 1993; Remington et al., 2007; Sheinkopf & Siegel, 1998; Smith et al., 2000). Special education or self-contained classroom placements were the second most common instructional placements for children with ASD receiving EIBI (e.g., Remington et al., 2007). Additionally, higher IQ and younger age at EIBI intake was predictive of being placed in a regular education classroom at 4-6 years of follow-up (Harris & Handleman, 2000). Finally, lower IQ and being older at EIBI intake was predictive of special education classroom placement as well (Harris & Handleman, 2000). In summary, the literature on academic achievement and school-based performance of children with ASD warrants more research.

Study Purpose

Previous studies have focused primarily on the delay to diagnosis but not on the delay to services. There is evidence to suggest that the earlier children with ASD start

intervention/therapy services, the better the outcomes. Evidence on the effectiveness of EIBI consistently indicates that children who received EIBI at younger ages make greater gains. As we learn more about early brain development, there are also compelling data from neuroscience about early experience and programming effects on learning and memory. Therefore, to improve long-term outcomes for children with ASD, timely access to services is imperative. The effects delay (i.e., waitlists) have on outcomes has not been evaluated and the research to date on educational outcomes is limited. Therefore, the purpose of this study was to examine how EIBI service delays relate to later educational outcomes for children diagnosed with ASD. The specific research questions are:

1. What is the main effect of a delay in early intensive behavioral intervention services for Medicaid-enrolled children with ASD on later educational outcomes?
2. What is the main effect of average early intensive behavioral intervention hours per week on later educational outcomes?
3. Does average delay to start early intensive behavioral intervention differ by county or region within Minnesota?

The methods utilized to answer the research questions are presented in the following chapter.

CHAPTER 3: METHOD

Sample

A secondary data analysis of Minnesota Department of Human Services (DHS) and the Minnesota Department of Education (MDE) was conducted. The study was a population-based (state-wide) observational study. Administrative data were utilized to answer the research questions specified in Chapter 1. De-identified data from Medicaid-enrolled families were used to identify a cohort of approximately 3 to 5 year olds with a diagnosis of ASD. The ICD-9-CM billing code 299.0 for autistic disorder was used to identify EIBI service recipients anytime between January 1st, 2008 and December 31st, 2010. During this time within Minnesota, Medicaid was one of the only entities that covered EIBI services through Children's Therapeutic Services and Supports (CTSS), a DHS division. Figure 3 outlines inclusion and exclusion criteria for the data needed to support the analyses to answer the research questions. All children included in the sample received EIBI services before entering elementary school and had a diagnosis of autism ($n=667$).

Data Sources

Minnesota Linking Information for Kids (Minn-LInK) is a multi-disciplinary community of experts from child welfare, education, health, juvenile justice and children's mental health that provides support for conducting research in the area of child well-being. Minn-LInK uses a cross-systems approach and provides fully-linked longitudinal, child-level administrative data from the fields of child welfare, education, health, juvenile justice and children's mental health within Minnesota. The Minn-LInK

Project is housed at the University of Minnesota's Center for Advanced Studies in Child Welfare in the School of Social Work and holds statewide administrative datasets received from the state departments of health, education, and human services. All data used in this project were secondary and were provided under data sharing agreements with each of the agencies. The University of Minnesota's institutional review board approval was obtained as of November, 2015 (project number: 1510E79342) to conduct the study. Requested data were received from DHS in March, 2016.

Data storage. Identified personal health information (PHI) data were stored on a secure Minn-LInK server housed at the University of Minnesota's Office of Information Technology. Access to the server is limited to authorized users, and access to study data containing PHI is restricted to only those researchers listed on the IRB application. The computers used for data analysis are password-protected and require a dual log-in to access the server and study data. All analyses occur in a secure office to which only Minn-LInK staff members have access. Identifiers are only used for linking data purposes. Once data were linked across systems, identifiers are stripped from the data prior to analysis.

MMIS data. The Medicaid Management Information System (MMIS) is Minnesota's automated system for payment of medical claims and capitation payment for Minnesota Health Care Programs (MHCP) (i.e., Medical Assistance and Medicare Supplement Programs). In Minnesota, Medicaid is known and Medical Assistance (MA) and ensures healthcare coverage and services for people with disabilities, children, low-income adults, and the elderly. MMIS billing and demographic data were requested from

DHS for a cohort of 3 to 5 year olds who received a diagnosis of ASD between January 1st, 2008 and December 31st, 2010. The data years were chosen because Minn-LInK already had education data from 2010 to 2014 at the time of the request. The specific billing code used to identify the cohort was ICD-9 CM 299.0 for autistic disorder. EIBI billing claims were identified by children's therapeutic services and supports (CTSS) codes for individualized skills training and family skills training (H2014 UA/HR). Individualized or family skills training are general billing codes used for direct service by EIBI service providers. The list of providers from the dataset was cross referenced with DHS' list of EIBI eligible service providers. Comorbid intellectual disability and communication disorder codes were also included, as well as billing claims from speech, occupational, and physical therapy for the sample. A complete list of the variables utilized are in Table 2 and Figure 1.

MARSS data. Minnesota Department of Education's (MDE) Minnesota Automated Reporting Student System (MARSS) includes data from all the school districts on every student enrolled during the school year. The data system contains information on students' academic experience including attendance, special education service, primary disability diagnosis, district numbers, and eligibility for free or reduced lunch/meals. Table 2 and Figure 2 show the variables in the MARSS dataset that were utilized in this study from school years 2010-2014. The MARSS dataset was used to evaluate the other educational outcomes of interest including instructional placement setting and special education service hours by school year.

MCA data. The Minnesota Comprehensive Assessments (MCA) are state tests that help districts measure student academic progress towards standards specified under the Elementary and Secondary Education Act. At 3rd grade, students take the reading and math sections of the test until they get to 5th grade where a science section is also given. Students receiving special education services for cognitive disabilities are exempt from the MCA and can take the Minnesota Test of Academic Skills (MTAS), an alternative assessment. The MTAS data for this cohort were not available at the time of the study. The MCA-II was used by Minnesota school districts in school/academic year 2011. The version was updated the following year and so the MCA data for school years 2012 to 2014 were from the MCA-III.

Linking. Minn-LInK staff linked the two data systems together and matched the data records using first name, last name, middle name, and date of birth. Link plus (an open source software created by the CDC) was used to match the data using probabilistic matching. Matching and cleaning by hand was then conducted by the staff on the probabilistic matches. For the two data systems, the match rate was 94.5% (see Figure 3). Data were all de-identified after matching was completed and each participant was given a numeric identifier.

Cohort Demographics. The Medicaid-enrolled cohort of 667 children analyzed in this study was 82.2% male, and 71.7% White (Table 3). Within the cohort, approximately 15% of the children were Black, 6% Hispanic, 5% Asian, and 2% American Indian. A majority of the children were diagnosed with ASD at age 4 (35.4%; range 2 to 6 years old) and 92% had a comorbid intellectual disability, language disorder, or developmental

delay between 3 and 5 years of age. Language disorder was the most common (39%) comorbid impairment followed by unspecified intellectual disability (20.4%). Upon entry into elementary school (i.e., between 2010 and 2014), 64.5% of the cohort qualified for free or reduced priced lunch, 1% were homeless, and 6% had limited English proficiency. Table 25 shows the cohort attrition rates by demographics for the dataset compiled. Approximately 9% of the sample participants had missing data during follow up in one or more of the school years evaluated.

Data Analysis

Independent variables (predictors). The independent variables included in the data analyses are presented in the following section. Table 1 displays all the variables used from the MMIS, MARSS, and MCA datasets.

Delay to EIBI. The primary independent variable was delay to start EIBI services from the date of diagnosis to the start of EIBI date. The first billing date in the MMIS dataset with an autistic disorder diagnosis (billing code 299.00) was used as the date of diagnosis. To confirm the date of diagnosis, the MMIS dataset was examined for the ASD diagnostic billing code 12 months prior. If an earlier date of diagnosis was found, outside the date range of January 1st, 2008 to December 31st, 2010, that was the date used for the date of diagnosis. Date of ASD diagnosis was then subtracted from the first billing code date for individualized skills training and/or family skills training (H2014 UA/HR) to yield number of months until services started. If EIBI services were received before an ASD diagnosis was given, the data were coded as a zero. Figure 5 shows the recoded

distribution of delay to EIBI in months. All data analyses used the distribution in Figure 5 ($M= 8.99$, $SD=10.63$).

Average hours of EIBI service per week. Research question 2 used data from the MMIS dataset (i.e., time 1 data from January 1st, 2008 to December 31st, 2010). The average hours of EIBI service per week was derived by taking each unit billed for (e.g., 1 unit of IST= 15 min) and taking the sum of the units for each participant and multiplying them by 15 to get total minutes EIBI services were received in the date range examined. Total minutes billed were then divided by 60 to get total number of hours of service. Figure 7 shows the distribution of average EIBI per week and was treated as a dosage variable ($M= 20.23$ hours per week, $SD= 14.68$ hours per week).

Age, gender and race. Age of diagnosis (date of billing code 299 subtracted by date of birth to get age of diagnosis in years), gender, and race were not recoded and were based on billing claims in the MMIS dataset. The distribution of the age when diagnosis was given is displayed in Figure 6. Approximately 18% of the cohort was female. Racial groups identified were American Indian (2.4%), Asian (5.1%), Hispanic (6.1%), Black (14.7%), and White (71.7%; Table 3).

Residence. County of residence was identified based on the MMIS claims data. County data were then recoded into a binary variable for residence in the metro area ($n=460$) or non-metro areas ($n=207$) within the state of Minnesota. The metro area is made up of 7 of the 87 counties in Minnesota including: Hennepin, Anoka, Carver, Scott, Dakota, Washington, and Ramsey counties. Figure 16 displays the county names and

location of each county within Minnesota. A black boundary line was used in each map created to delineate the metro from the non-metro areas (Figures 16-18).

Comorbid services. Participation in rehabilitative services was also examined. Billing claims from the MMIS dataset for occupational therapy, physical therapy, and speech language therapy were recoded into a binary variable. The billing codes are listed in Figure 1 and included 92507 GN, 97110 GO, 97110 GP and 97530 GP. Overall, approximately 52% of the cohort received speech services, 43% received occupational therapy, and 12% received physical therapy.

Intellectual disability status. ICD-9-CM billing codes for mild, moderate, severe, profound, and unspecified intellectual disability from the MMIS dataset (i.e., time 1) were also examined (317, 318, 318.1, 318.2, and 319). Mild intellectual disability is classified as an intellectual quotient (IQ) of 50 to 70. Moderate consists of an IQ between 35 and 49. Severe classification is an IQ of 20-34 and profound is less than 20. Comorbid codes for language disorders (315.3) and developmental delay (315.8) were also included and all codes utilized are displayed in Figure 1. For the descriptive analysis of the cohort, each classification was used as a categorical variable. In the statistical analyses conducted, a binary variable was created for intellectual disability status (0= no intellectual disability, 1=mild, moderate, severe, profound, and unspecified intellectual disability) to aggregate the data.

Free or reduced lunch receipt. The only economic indicator available for the cohort was free or reduced lunch receipt from the MARSS dataset. The U.S. Department of Agriculture sets the annual eligibility criteria for the National School Meal Program

based on family income and size. Families qualified for reduced price meals if their income was 131-185% of the poverty level. Incomes at or below 130% of the poverty level qualified for free price meals. At entry to elementary school, free or reduced lunch receipt was coded as a binary variable and used in the descriptive and statistical data analyses conducted. Approximately 65% of the cohort received free or reduced lunch in school.

Dependent variables (outcomes). The dependent variables included an educational diagnosis of ASD (yes or no), the instructional placement (general education, special education resource room, separate classroom, or a separate school for special education (i.e., a Level 4 restrictive setting), special education service hours, and MCA participation/scale scores for reading, math, and science subscales. Table 2 and Figure 2 display the educational outcomes examined at follow up and over time.

Instructional placement setting. Instructional placement setting is an educational placement setting examined at each year of follow up. Four categories of placement from least to most restrictive were used from the MARSS dataset. A placement in general education included students who received the majority of their special education and related services in a regular class. General education placement consisted of children with disabilities receiving special education and related services outside the regular classroom for less than 21% of the school day. Resource room placement included students who received special education and related services outside the regular classroom for 21% to 60% of the school day. A separate class placement (i.e., self-contained classroom) consisted of children with disabilities receiving special education and related services

outside the regular classroom for more than 60% of the school day. Finally, a separate school placement included students with disabilities receiving special education and related services for greater than 50% of the school day in separate facilities in a public or private facility. Figure 9 displays the instructional placements by school year.

For a subgroup of students from 2010 to 2013, early childhood special education (ECSE) instructional placement data were available in the MARSS dataset. For those placements, the classification for primary disability instructional setting varies from the 6 to 21-year-old instructional placements. Early childhood programs included in the MARSS dataset are Head Start, Kindergarten, private preschool programs, school readiness, early childhood family education, group child care, and reverse mainstream classrooms that included at least 50% children without disabilities. There were four instructional placements for ECSE which included regular early childhood program or general education for at least 80%, general education for less than 79% up to or less than 40% of the time, separate classroom, or home/service provider location. Due to the limited data available, general education placements of 40-79% and less than 40% were combined to create one placement category of general education <70%. ECSE services that were received at home or at a service provider location were also aggregated to create one categorical placement. Figure 8 presents the ECSE instructional placement settings by school year.

ASD diagnosis in school. Students that were assessed and identified by the school as needing special education services, or had a signed Individualized Education Plan (IEP), Individual Family Service Plan (IFSP), or Individual Learning Plan (IILP), or were

receiving special education services, had a primary disability reported in the MARSS dataset. There are 13 possible disability categories that a student could qualify under for special education services from 6 to 21-years old and 14 categories for early childhood special education, which included Developmental Delay diagnoses (used for birth to 6 years old only). A binary variable was created for each school year evaluated based on if a primary ASD diagnosis (yes, no) was given in elementary school. Overall, 70% retained an ASD diagnosis in elementary school.

MCA participation and scores. A binary variable was created for all eligible (3rd grade or above) students for each school year for whether they took the MCA or not. There were three subscales: reading, mathematics, and science. As stated earlier, only 5th graders were eligible to take the science subscale. Due to the limited sample size within the cohort that took the science subscale, this scale was excluded from statistical analyses. The science subscale was included, however, for descriptive purposes for each school year evaluated at follow up. The math and reading scale scores were used for the statistical analyses. The scale score cuts to assess proficiency varied by grade and were set by MDE. Proficiency categories included: did not meet, partially met, met, and exceeded the standard. Figures 11 through 16 display the distribution of scale scores and proficiency for each subscale and school year examined.

Special education service hours. Special education service hours are used in generating tuition billing for special education in the MARSS dataset. Licensed special educational teacher administered direct and indirect special education services were included. Not included were one-to-one para professional or other professional time as

well as hours for programs. Special education service hours were restricted in the statistical analyses conducted by removing any zero hours from the distribution. The distribution utilized is displayed in Figure 9 and is shown by school year.

Statistical analyses. SPSS version 22 was used to conduct all analyses. All statistical tests were two-sided and an alpha level of 0.05 was used. Descriptive analyses of demographic information for all children included in the cohort are reported. To investigate the relationship between delay in months to start EIBI services and educational outcomes at 4-6 years of follow up (at each school year time point), Generalized Estimating Equations regression analyses were conducted. An outline of the analyses conducted are listed in Appendix A. The first research question was specific to the effect of a delay to EIBI services on later educational outcomes. The second research question was specific to the effect of average EIBI hours per week (i.e., EIBI dosage) on later educational outcomes. Both research questions were addressed by conducting Generalized Estimating Equations regression models.

Generalized Estimating Equations (GEE). GEE is a marginal (population-average) approach used to model longitudinal data generated from repeated measures (Zeger & Liang, 1986). GEEs are an extension of generalized linear modelling and take into account the correlation among outcomes measured repeatedly over time (Ballinger, 2004). Taking the correlation among outcomes into account produces more efficient estimates and improves standard error estimates (Zeger & Liang, 1986). GEE can also be used with different distributions such as binomial and Poisson (Ballinger, 2004). Another advantage of GEE is that it has very few assumptions that need to be met; it does not

require meeting the assumption that random effects or residuals be normally distributed (Ballinger, 2004). Cases need to be dependent within subjects, independent between subjects, and the correlation matrix needs to be specified because it is estimated in the model and represents the within subject dependencies (IBM, 2016). Ultimately, GEE provides information about how much the average response would change for every one-unit increase in a covariate across the population and yields robust estimates (Ballinger, 2004).

GEE was used to test and estimate the effects of a delay in EIBI services on educational outcomes and academic achievement (research question 1). GEE was also used to estimate the effects of average hours per week of EIBI on the same educational outcomes (research question 2). Intellectual disability status, gender, race, county/region of residence, comorbid service receipt (SLT, OT, or PT), free/reduced lunch receipt, and school year were included as covariates/predictors in each model calculated. The models, link functions, response distribution, and correlation matrix needed for all GEE analyses specific to each research question are in Appendix A. The assumptions were met for each GEE model conducted (sample size large enough, and observations independent) and multicollinearity of the predictor variables was assessed. Variance inflation factors (VIF) indicated acceptable levels of multicollinearity (<10) and bivariate correlations ($<.80$). Spearman rank correlation coefficients are presented in Tables 25 to 29 for each dependent variable (i.e., educational outcome) evaluated by school year.

To test the sensitivity of the results to the correlation structure, I conducted robustness checks with alternative specifications. The results of the robustness checks

yielded similar estimates across unstructured, autoregressive (AR(1)), and exchangeable working correlational matrices. An unstructured correlation structure does not have constraints across observations and are estimated from the data without restriction. Autoregressive differs in that the correlation over time diminishes exponentially with time. Lastly, exchangeable correlation structure co-varies equally across all observations (see Zorn, 2001 and Garson, 2013 for more information on correlation structures). Quasi-likelihood under independence criterion (QIC) is a goodness-of-fit measure and is an adaptation of AIC for repeated measures. The QIC coefficient was used to select the best working correlation structure for each model implemented (lower values indicate better fit; Garson, 2013).

GEE for a binomial distribution with a logistic regression were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for a general education placement (yes, no), an ASD diagnosis (yes, no), and MCA-reading or math participation (yes, no). GEE linear regression with a Gamma distribution was used to estimate coefficients and 95% CIs for special education service hours and MCA-reading or math scale scores. Based on the QIC values, unstructured correlational matrices were used for general education placement and math scale score outcomes. Autoregressive correlation structure was used for ASD diagnosis, special education hours, MCA-math participation, and reading scale score outcomes. Lastly, an exchangeable correlational matrix was used for MCA-reading participation. Robust standard errors were used in all models to account for correlation across the school years.

Unstandardized beta- weight coefficients, odds ratios, 95% confidence intervals, Type- III Wald chi-square tests for the null hypothesis (test of model effects) and Wald chi-square test for each parameter (predictor) estimate are reported in Tables 30-43. The Type- III Wald chi-square tests for the null hypothesis that none of the parameter estimates for a predictor are different from 0. The other Wald chi-square test if significant, means the parameter is significantly different from 0 (Garson, 2013). The results of each GEE model are presented and explained in chapter 3.

Potential confounding adjustment. The present project is an observational (non-experimental) study. The gold standard for evaluating and estimating the effects of treatments and interventions are randomized controlled trials. Randomization is an effective strategy to control for confounding variables. Confounders are defined as extraneous variables that are associated with both the independent variable and the dependent variable that can lead to biased or skewed results (Aschengrau & Seage, 2014). Administrative data sets, however, preclude randomizing participants into treatment groups. When randomization is not possible other strategies such as stratification, matching, regression analyses, and restriction can be used to adjust for confounders.

In terms of this study, the target sample included young children with ASD. The core diagnostic features of ASD include deficits in social-emotional skills and communication, as well as the presence of repetitive and/or restrictive behaviors (CDC, 2015). Autism is a heterogeneous neurodevelopmental disorder, therefore, no two children with autism will have the same exact profile or symptoms. Deficits in the core

domains related to ASD can vary from person to person and that is why it is called a spectrum disorder. The heterogeneity associated with ASD can make it difficult to compare or generalize results across studies and must be addressed in the current study.

The three criteria that a variable need to meet to be a confounder are: 1) the variable is associated with the exposure (independent variable), 2) the variable is associated with the outcome (dependent variable), 3) and the variable is not on the causal pathway between the exposure and outcome (Aschengrau & Seage, 2014). The severity of ASD (i.e., the extent of deficits in one domain or all) can be associated with when and how many hours of services each week are allocated. Severity can also be associated with the educational outcomes (e.g., more deficits, the more likely the child is to qualify for special education services).

Intelligence (IQ) and the presence of a comorbid intellectual disability (ID) is an established confound with respect to the severity of ASD (Matson & Smith, 2008). Lower intellectual functioning is highly associated with more severe autism (Schopler, Reichler, & Renner, 1986). In terms of studies previously conducted, individuals with less severe autism symptoms has been found to be related to better outcomes (Bartak & Rutter, 1976; DeMeyer et al., 1973; Lotter, 1974). In prior EIBI studies higher IQ was predictive of better response to EIBI (Lovaas & Smith, 1988; Smith, Groen, & Wynn, 2000). The extant literature indicates that an IQ of 50 or higher among children with ASD is also associated with more positive long-term outcomes (Eaves & Ho, 1996; Gillberg & Steffenburg, 1987; Kobayashi, Murata, & Yoshinaga, 1992). Age of diagnosis is also a potential confounder as well according to the literature on EIBI reviewed in the previous

chapter. The research to date suggests that children with ASD that receive a diagnosis earlier and start EIBI at a younger age have better outcomes (Baker-Ericzen et al., 2007; Bibby et al., 2002; Flanagan et al., 2012; Granpeesheh et al., 2009; Harris & Handleman, 2000; MacDonald et al., 2014; Perry et al., 2011; Smith et al., 2015b; Virués-Ortega & Rodriguez, 2013).

To address the potential for severity of the ASD features and age of diagnosis as confounders, I created a Directed Acyclic Graph (DAG) or causal diagram (see Figure 4). DAGS are used widely in epidemiology to help identify causal pathways. The following billing codes on intellectual functioning were included to adjust for the potential confounder of severity of ASD symptoms in the models conducted: 317, 318, 318.1, 318.2, and 319 (see Figure 1). Not all the EIBI service providers in Minnesota use the same intake measures or assessments, so billing codes were used as a proxy assessment for IQ. Age of diagnosis was also included to control for severity and differential outcomes associated with earlier diagnosis.

Geographical Information System (GIS) analysis. Research question 3 addressed whether the average delay to start EIBI differed by county or region within Minnesota. To answer the question, geographical information system (GIS) was used. GIS is a spatial analysis technique that utilizes a computer data system to store, analyze, and display geographic information (Folger, 2011). GIS can integrate data to analyze spatial relationships by electronically layering information, such as the population within a specific region and other variables of interest (Folger, 2011). By compiling various data layers, different features of the geospatial data can be analyzed (Folger, 2011).

GIS is an approach commonly used by local and state governments for public services like local planning, zoning, land records, and property taxation (Folger, 2011; Brown, 2013). GIS is also starting to be used in the fields of community integration and mental health to track neighborhood and geographic factors such as drug-use, depression, stress, and disability (Brown, 2013). Within Minnesota, the city of Minneapolis provides electronic public access to GIS data and applications that show information such as election results, construction, property, dangerous dogs, farmers markets, and parks (Hennepin county, 2016). In terms of autism specific research studies, GIS has been utilized to evaluate the spatial structure of autism in California (Mazumdar, King, Liu, Zerubavel, & Bearman, 2010) and the autism related residential proximity to freeways (Volk, Hertz-Picciotto, Delwiche, Lurmann, & McConnell, 2011). Delay to service in conjunction with prevalence of autism estimates along with number of service providers available for young children has not been examined in Minnesota with GIS.

For the current study, GIS was used to layer 4 different types of geospatial information. ArcMAP (version 10.3) was the software platform. The four types of information were as follows: 1) sample size of individuals from the cohort 2) by county, 3) number of EIBI service providers (based on the NPI numbers provided in the MMIS data set) and the 4) average delay to EIBI service in months from the sample being analyzed. Figures 17-19 graphically depicts the layers within a choropleth map. Descriptive statistics, an ANOVA (for regions), and an independent sample *t*-test (metro vs. non-metro areas) were also conducted to examine if average delay to EIBI differed by county of residence and region within Minnesota. Not all assumptions were met

(dependent variable was not normally distributed), therefore the results of the t -test and ANOVA are interpreted with caution in chapter 4.

CHAPTER 4: RESULTS

The purpose of this chapter is to report the results of the data analyses. Descriptive analyses of the cohort by demographic characteristics, service provision, and educational outcomes are reported first. The GEE models fitted for the first and second research questions are presented next. Finally, the results of the GIS analysis and differences in delay to EIBI by Minnesota county and region are presented.

ASD Diagnoses

The average age of an ASD diagnosis (Table 4 and Figure 6) was similar across females ($M=3.87$ years; $SD=0.94$; range=1.58-5.83 years) and males (3.99 years old; $SD=0.89$; range=1.42-5.92 years). Across the five racial groups reported in the dataset, Black children were diagnosed the earliest, on average, at 3.82 years (range 1.67-5.92 years; $SD=0.87$ years old), followed by White children at 3.97 years old, (range=1.42-5.92 years; $SD=0.91$ years). Children who were identified as being American Indian received a diagnosis the latest on average at 4.46 years old (range= 3.00-5.67 years; $SD=0.81$). Hispanic ($M=4.00$ years; $SD=0.85$; range=2.83-5.75 years) and Asian ($M=4.07$ years; $SD=0.84$ years; range=2.50-5.75 years) children were in the middle. Age of diagnosis did not differ by residence when metro (range= 1.42-5.92 years) versus non-metro (range= 1.83-5.92 years) counties were compared (3.97 years; $SD=0.90$ years). Finally, children who had an unspecified comorbid intellectual disability received a diagnosis ($M=3.78$ years; $SD=0.82$ years; range=1.67-5.67 years) before children with language disorders ($M=3.90$ years; $SD=0.90$ years; range=1.42-5.92 years), developmental delay ($M=3.92$ years; $SD=0.93$ years; range=1.67-5.92 years), and other

degrees of intellectual disabilities (Mild $M=4.33$ years, $SD= 0.80$ years, range=3.00-5.92 years; Moderate $M= 4.08$ years, $SD=0.76$ years, range=2.42-5.33 years; Severe $M= 3.85$ years, $SD= 0.77$ years, range=1.42-5.92 years; Profound $M= 4.33$ years, $SD=0.44$ years, range=3.67-5.00 years), on average.

Services Received

EIBI. All Medicaid-enrolled children included in the cohort received EIBI services between 2008 and 2010. The average delay to begin EIBI was 8.99 months (range= 0 to 45 months; $SD= 10.63$ months). The average hours of EIBI per week received by the cohort was 20.23 hours ($SD=14.68$ hours). Table 4 shows the average delay to EIBI in months and the average hours per week of EIBI by gender, racial group, residence, and comorbid disability. Figure 5 presents a histogram of the distribution of delay to EIBI service.

Delay to EIBI. Males experienced a slightly greater average delay to EIBI between diagnosis and the start of EIBI ($M= 9.14$ months; $SD=10.65$ months; range=0-44 months) than females ($M=8.29$ months; $SD=10.48$ months; range=0-45 months). Average delay to EIBI varied by race. Children who were Black experienced the largest average delay ($M=10.96$ months, $SD=11.84$ months, range=0-44 months), followed by children who were White ($M=8.90$ months, $SD=10.67$ months, range=0-45 months). Children who were identified as American Indian had the least delay to EIBI ($M=5.13$ months, $SD=5.85$ months, range= 0-20 months). Asian and Hispanic groups had an average delay to start EIBI of 8.15 ($SD=8.96$ months, range= 0-30 months) and 7.59 months ($SD=8.76$ months, range=0-31 months), respectively. Additionally, children who resided in the metro area

($M=9.89$ months, $SD=11.24$ months, range= 0-45 months) had a larger average delay to EIBI compared to children who resided in the non-metro area ($M=7.00$ months, $SD=8.78$ months, range= 0-44 months).

Among children with comorbid disabilities, or a previous classification before an ASD diagnosis was given, children with developmental delay received EIBI services with an average delay of approximately 9 months ($SD=10.84$ months, range=0-43 months). Children with severe ID experienced the longest delay with an average delay to start EIBI of 16.22 months ($SD=12.82$ months, range=0-40 months). For the other disorders or disability groups reported, average delay to EIBI ranged from 10.17 months for children with language disorders to 12.92 months for children with moderate ID; see Table 4.

EIBI dosage. The average hours per week of EIBI was calculated to get an estimate of EIBI dosage different cohorts received. The distribution of the average hours of EIBI per week are displayed in Figure 7. Among males and females, average hours of EIBI per week were similar at approximately 19-20 hours per week (male $SD=11.92$; female $SD=12.42$). When the cohort was divided by race, Asian ($M=23.12$ hours; $SD=11.05$ hours) and White ($M=19.57$, $SD=11.92$ hours) children received the most hours per week, on average. Children who were American Indian received almost half the hours the other groups did with an average of 10.44 hours per week ($SD=6.42$). Black and Hispanic children received similar average hours per week ($M=17.81$, $SD=12.39$; $M=15.76$, $SD=12.40$). Children with comorbid disabilities received similar average hours per week of EIBI, ranging from approximately 18 (language disorders; $SD=11.85$ hours) to 20 hours (severe ID, $SD=12.81$ hours). Of the 5 children with ASD and profound ID

($IQ < 20$), only about 15 hours per week ($SD = 8.07$ hours) was received, on average.

Finally, children who resided in the metro area of Minnesota received slightly more hours per week ($M = 19.36$ hours, $SD = 12.45$ hours), than children who resided in non-metro areas ($M = 18.33$ hours, $SD = 10.94$ hours).

EIBI service provision. There were 59 EIBI service provider companies, 27 located in the metro area and 29 in the non-metro area providing EIBI services to the cohort. The average age to start EIBI services was 4.70 years ($SD = 1.24$ years). In the metro area, the average start age was 4.79 years. In the non-metro area, children started EIBI at a younger age, 4.50 years, on average. Table 5 displays the setting or place of service that the cohort received EIBI, and the service professionals' credentials who implemented EIBI. Most children received EIBI services in home (60.27%). The remaining children received EIBI in offices (34.83%), schools (2.70%), community health centers (2.55%), or in a mobile unit (0.30%). When EIBI service provision was compared by residence, 59.35% of the children that resided in the metro area received services at home compared to 62.32% of children that resided in the non-metro area. For 37.83% of metro residence children and 26.09% of non-metro residence children, offices were the primary place of service.

Psychologists were the most common type of service professional to implement EIBI services for the total sample (64.47%), metro (66.96%), and non-metro (58.93%) residents. Social workers and marriage and family therapists were the next common service professionals for the cohort (overall 20.09%, 13.19%, respectively), for children in the metro (17.39%, 14.35%), and children in the non-metro area (26.09%, 10.63%).

Other mental health providers, licensed clinical counselors, and undefined staff also provided EIBI services, but with much less frequency than psychologists, social workers, and marriage/family therapists.

Speech and language therapy (SLT). Over half of the cohort received SLT along with EIBI. Table 4 shows SLT receipt by demographic group. Males (53%) and females (49%) had similar rates of participation in SLT. Among racial groups, children that were Black had the highest rates of SLT receipt (65%), followed by Hispanic children (59%), American Indian (50%), and White (49%). Children that were Asian had the lowest rates of SLT receipt (44%). A greater number of children in the metro area received SLT (59%) than children in the non-metro area (37%). Among children with comorbid disabilities, children with language disorders (84%) and developmental delay (74%) received SLT. Finally, approximately 54% (Moderate ID) to 66% (Mild ID) of children with intellectual disabilities also received SLT.

Occupational therapy (OT). Approximately 43% of the sample received OT. Males (55%) received OT more than females (47%). Half of Black and Asian children and 44% and 41% of Hispanic and White children participated in OT. Only 25% of children who were American Indian received OT. OT services were received by more children in the metro area (48%) than in the non-metro area (31%). Eighty percent of children with profound ID participated in OT. Children with language disorders (63%) and developmental delay (59%) had similar rates of OT receipt. Among the other children with various degrees of intellectual disabilities, OT receipt was around 50% or more.

Physical therapy (PT). Twelve percent of children in the cohort received physical therapy. Approximately the same proportion of females (13%) and males (12%) participated in PT. Across the different racial groups, PT receipt ranged from 9% (Black) and 15% (Asian). Metro compared to non-metro areas exhibited similar PT receipt with 13% and 11% of children, respectively. Thirty percent of children with severe ID received PT, whereas only 8% of children with moderate ID did. PT receipt was similar across the other comorbid disabilities and ranged from 16% (language disorder, mild ID) to 23% (developmental delay).

Early childhood special education (ECSE). Data were available for a subset of the cohort ($n=493$; Tables 6-9) that received ECSE and EIBI during 2010 and 2013. The subset of children was 79% male, 70% White, and 65% resided in the metro area. Of the children with a comorbid disability, a majority had a language disorder (42%). The primary educational diagnoses (i.e., special education label or qualification for special education services) given in the school setting were developmental delay (36.5%) and ASD (50.5%). Within the subset of children that ECSE data were available, 35% received free or reduced meals at school. Average special education service hours received in a school year ranged from 273 hours (SY2013) to 409 hours (SY2012). Overall, the greatest percentage of children received ECSE in a self-contained classroom (SY2010= 38.3%, SY2011=45.3%, SY2012= 37.1%, SY2013= 33.3%). The primary diagnoses, special education service hours, and instructional placement will be discussed by demographic group for each school year next. Free and reduced meal eligibility status (i.e., socioeconomic status) are presented in Tables 6 through 10.

Primary ECSE diagnoses. For the 2010 school year, 40% of the children had a primary educational diagnosis of developmental delay and 47% had a diagnosis of ASD. Forty-seven percent of males had an educational ASD diagnosis whereas 43% of females had a developmental delay label. Approximately 40% of children had a primary educational diagnosis/label of developmental delay across all the racial groups reported. The non-metro area had a higher percentage of developmental delay labels (44.2%) compared to the metro area (37.8%). Conversely, the metro area had a higher percentage of children with an ASD label in ECSE (51.1%) compared to the children who resided in the non-metro areas (38.4%). Comorbid language disorders were the most common; 40.7% of children with a developmental delay label and 52.2% of children with ASD had a language disorder. Half of the children with mild or moderate ID had a primary developmental delay label and about 30-40% of them had an ASD label.

Similar patterns in terms of the primary educational diagnoses/labels for ECSE eligibility were apparent in SY2011 ($n=148$). Over half had a primary ECSE label of ASD and approximately 32% received a primary diagnosis of developmental delay. A higher percentage of females (58.1%) compared to males (55.6%) had a primary educational diagnosis of ASD. Among children with developmental delay, 33% of males and 26% of females were given the educational label. In terms of the racial groups, over half for all groups except for children that were American Indian (0%) had an ASD educational label/diagnosis. All four of the children that were American Indian had a developmental delay label, whereas approximately 20-33% of the other racial groups were receiving ESCE for developmental delay. A higher percentage of children who

resided in the metro (66.3%) area had an ASD label than the non-metro area (39.3%).

Among children with a developmental delay diagnosis, there was a higher percentage of non-metro area residents (46.4%). Like the SY2010 ECSE findings, comorbid language disorders were the most common with more children with ASD diagnoses than developmental delay had language deficits.

School years 2012 ($n=62$) and 2013 ($n=9$) had less ECSE records due to the age and date restrictions of the data. Similar patterns were observed in terms of the gender distribution for the primary diagnoses given for SY2012. Over half of males had an ASD diagnosis and a quarter of females had a developmental delay diagnosis in SY2012. Children that were Black had the highest percentage of ASD diagnoses. There was only one student that was identified as American Indian and one student that was identified as Asian in the SY2012 data. Both were given a primary diagnosis of developmental delay for ECSE. A greater percentage of children in the metro area received a diagnosis of ASD (61.1%), and the non-metro area had a greater percentage of developmental delay diagnoses (53.8%) like the other school years reported. Unspecified ID and comorbid language disorders were the most common for children with a primary diagnosis of ASD. For the children with a primary diagnosis of developmental delay, the mild and severe ID subgroups were the most prevalent. Finally, SY2013 data are presented in Table 9. Due to the limited sample size ($n=9$), the primary diagnoses across the demographic groups reported will not be discussed.

Special education service hours. Figure 10 shows the distribution of special education service hours by school year. Average total special education service hours for

SY2010 (Table 6) was 322 hours ($SD= 385.52$). School year 2011 (Table 7) was similar with 345 hours for the year ($SD= 306.16$). The highest special education service hours received was in SY2012 ($M=409.15$ hours, $SD=308.55$ hours). The following year, with a limited sample ($n=9$), the average was 273.29 hours ($SD= 241.20$ hours). Males, on average, received more special education hours for SY2011 and SY2012. Furthermore, for two of the four school years (SY2010 and SY2011), children that were Black received more total special education service hours, on average. In comparison, children that were American Indian were given less special education service hours on average for SY2011 ($M= 339.68$ hours, $SD= 353.73$ hours) and in SY2012, children that were Hispanic had more total special education hours ($M=584.68$ hours, $SD= 371.53$ hours). Children with comorbid intellectual disabilities overall experienced higher total special education service hours with children with severe ID receiving the most for two out of the four school years reported (SY2010 and SY2012).

Instructional placements. Figure 8 displays the ECSE instructional setting placements across the school years evaluated. Most children received ESCE services in a self-contained classroom (range= 33.3%-45.3%). General education for greater than 80% of the time (range= 25%-33.3%) and general education less than 70% of time (range=15.3%-33.3%) had similar percentages of children across school years. Home or service provider placements overall had the smallest percentage of children receiving ECSE (range= 0%-17.9%).

Educational Outcomes

Cohort results. The grade levels represented in this sample include kindergarten to

6th grade (Table 10). In the first year of educational outcomes evaluated (SY2010), there were 57% kindergarteners, 35% 1st graders, and 8% 2nd graders from the cohort ($n=326$). In the last school year included in this study (SY2014, $n=607$), kindergarteners made up 3% of the sample along with 11% 1st graders, 16% 2nd graders, 23% 3rd graders, 26% 4th graders, 18% 5th graders, and 4% 6th graders.

Over 94% of the cohort qualified for special education services across the school years examined (Table 10). School year 2010 yielded the highest percentage of children in the cohort that qualified for special education services. The primary educational label or diagnosis given for special education qualification was ASD for over 70% of the cohort. Average special education service hours ranged from 116 hours (SY2013) to 220 hours (SY2010). The most common instructional placement setting across the school years was general education, followed by self-contained classrooms. Instructional placements in separate restricted schools (i.e., the most restrictive placement) was the least common placement. Additionally, 46% to 59% of eligible students participated in MCA reading and mathematics standardized tests. Among eligible 5th grade students, 36% participated in the MCA science test in SY2013, and 53% in SY2014. Figures 12 and 15 display the distribution of reading scale scores by school year and proficiency. Figures 11 and 14 show the mathematic scale scores and proficiency by school years. Finally, for school years 2013 and 2014, MCA science scale scores and proficiency level for the children that participated in the assessments are presented in Figures 13 and 16.

Educational Outcomes by School Year and Demographic Groups

SY2010. During 2010 (Table 11; $n=326$), 98% of males and 94% of females

qualified for special education services. Over half of the female students were given a primary educational diagnosis of ASD to qualify for special education services compared to 75% of males. In terms of the race demographics reported, 100% of students that were Asian qualified from special education services, with 90% having a primary educational diagnosis of ASD. For the rest of the groups, over 91% of the students qualified for special education, however, primary ASD diagnosis rates varied. Only 37% of the children that were American Indian had a primary educational diagnosis of ASD, whereas 74% of children that were White did. Among Hispanic and Black demographic groups, 61% and 67% were given a primary diagnosis of ASD, respectively.

The percentage of children who lived in the metro area that qualified for special education was the same as children that lived in non-metro areas of the state (97%). A higher percentage (74%) of children who resided in the metro area had a primary diagnosis of ASD in the school setting compared to 66% of children in non-metro areas. Over 97% of children with comorbid disabilities qualified for special education services and children with comorbid moderate ID had the highest percentage of primary ASD diagnoses. Children with severe ID had the lowest percentage of ASD educational diagnoses.

Average special education service hours were slightly higher for females than males in 2010. Students that were Hispanic or Black received the most and students that were American Indian received the least in comparison, on average. Students who resided in non-metro areas had more average hours of service than the students in the metro area. Children with comorbid profound ID had the most special education hours on average

and children that were identified with developmental delay in the MMIS dataset received the least.

SY2011. Table 12 displays the educational outcomes for SY2011 ($n=451$). Approximately 93% of females and 95% of males qualified for special education services. Three quarters of males had a primary diagnosis of ASD, like in the previous school year. Fifty-five percent of females had a primary diagnosis of ASD, also like the previous school year and tended to have more special education services hours on average ($M=194.23$, $SD=437.78$). Of the limited number of students that were eligible to participate in the MCA-III (i.e., standardized achievement test starting at 3rd grade), only half of the females and 44% of the males took the test.

When the educational outcomes were examined by racial group, over 92% of the cohort in SY2011 qualified for special education with students that were Asian having the highest percentage (100%). Children that were Asian also had a higher percentage of educational diagnoses of ASD in school (85.7%), followed by students that were White (72.0%). The lowest percentage (41.7%) of ASD diagnoses was observed in the students that were American Indian. The lowest amount of special education service hours was also allocated to the students that were American Indian. Students that were Black received the most special education service hours, on average. Of the limited number of eligible students, 44% of White and 33% of Black students participated in the MCA.

In regards to residence, children that lived in the metro area and children that lived in the non-metro areas had the same percentage of special education qualification (95%). More students in the metro area (73%) had a primary diagnosis of ASD than in the non-

metro area (67%) and had more special education service hours on average. Of the eligible student, 47% participated in the MCA in the metro area whereas the non-metro areas had 40%.

Over 95% of the children with comorbid disabilities qualified for special education. Children with moderate ID had the highest percentage of educational diagnoses of ASD, and children with severe ID had the lowest percentage of educational diagnoses of ASD. The most special education service hours on average were received by students with profound ID and the least by students with moderate ID. About 17% to 33% of children with a comorbid disability participated in the MCA.

SY2012. School year 2012's educational outcomes are listed in Table 13 ($n=543$). Approximately 95% of males and 94% of females from the cohort qualified for special education in SY2012. The percentage of educational ASD diagnoses were like the previous two years with 56% of females having the primary diagnosis and 74% of males. Females received more special education service hours on average than males, but males had a higher percentage of MCA participation among eligible students.

More than 93% of children across each racial group qualified for special education during SY2012. Of those, students that were Asian had the highest percentage of ASD educational diagnoses followed by students that were American Indian. Black students received the most special education service hours on average. Students that were Hispanic received the least amount of special education service hours on average. Seventy-five percent of Hispanic students participated in the MCA. Fifty-eight percent of White students participated in the MCA, whereas only 33% of eligible students that were

American Indian participated.

A higher percentage of children who resided in the metro area qualified for special education (96%) compared to children who resided in non-metro areas (93%) unlike the previous two years. The percentages of children within each area that had a primary diagnosis of ASD was similar to the previous two school years. Children who resided in the metro area had a higher percentage of primary ASD diagnoses (73%) than children who resided in non-metro areas (66%). Children in the metro area also participated in the MCA (55%) more than children in the non-metro areas (50%).

Finally, in terms of children with comorbid disabilities per the MMIS dataset, over 97% qualified for special education and children with moderate ID had the highest percentage of ASD diagnoses in the school setting (77%). Again, children with severe ID had the lowest percentage of primary ASD diagnoses (58%). Children with profound ID had the most special education service hours on average ($M=327.90$ hours, $SD=612.97$ hours) and children with severe ID had the least ($M=196.68$ hours, $SD=355.74$ hours). For MCA participation, no children with severe or profound ID participated but 35% of children with unspecified ID, 40% with moderate ID, and 37% with mild ID did participate. Thirty-eight percent of children with a language disorder and 39% of those previously with developmental delay also participated in the MCA.

SY2013. Table 14 presents SY2013's educational outcomes by demographic group ($n=609$). As with the previous three school years, slightly more males qualified for special education (95%), compared to females (93%). Percentages of ASD diagnoses in the school setting were also like the previous years, 74% males and 57% females. More

special education service hours on average ($M=162.97$, $SD=327.78$) were given to females, but more males (60%) than females (51%) participated in the MCA.

In regards to race demographics, the percentage of children that qualified for special education ranged from 93% (White) to 100% (Asian). Children that were Asian (82.8%) had the highest percentage with a primary diagnosis of ASD followed by children that were White (72.4%). Children that were American Indian had the lowest percentage (43.8%) of ASD diagnoses. As in the previous school years examined with this cohort, students that were Black received the most special education service hours on average ($M=148.93$ hours, $SD=285.87$ hours) and students that were American Indian received the least ($M=80.16$ hours, $SD=225.45$ hours). Of the eligible students, Hispanic students had the highest percentage participating in the MCA (63.2%) followed by White (61.7%), American Indian (60%), and Asian (58.3%) students. Only 37.8% of students that were Black participated in the MCA.

As with the previous school years, a higher percentage of children who resided in the metro area (95.7%) qualified for special education services than children that resided in the non-metro areas (91.7%). Further, primary ASD diagnoses were more frequent in the metro area (74.1%) than the non-metro areas (63%). Children that lived in the metro area received more special education service hours on average ($M=125.02$ hours, $SD=293.78$) than children in the non-metro areas ($M=95.77$ hours, $SD=218.50$ hours). Over 59% of children in the metro area that were eligible participated in the MCA compared to 55.8% of children that resided in non-metro areas.

Of the children with comorbid disabilities, over 95% qualified for special education

services. Children with mild ID had the highest percentage of children with a primary ASD diagnosis in the school setting (72.9%) and children with severe ID had the lowest percentage (55%). The other categories reported ranged from 60%-70% in terms of primary ASD diagnoses. Children with profound ID received the most special education service hours on average ($M=310.68$ hours, $SD=651.39$ hours) and children with moderate ID received the least ($M=65.10$ hours, $SD=159.53$ hours). Children with mild ID had the highest percentage of participation in the MCA (45.7%) with children with language disorders (44.7%) and developmental delay (43.9%) having similar rates of participation. No children with profound ID participated, however, children with moderate ID (38.1%) and unspecified ID (38.2%) had similar percentages of children that participated in the MCA. About 7% (1 out of 15) of the children with severe ID took the MCA.

SY2014. The last year of follow up was SY2015. Table 16 shows the educational outcomes from 2014 for the cohort ($n=607$). The distribution of males and females that qualified for special education and who had a primary diagnosis of ASD in the school setting was similar to the previous school years evaluated. Males had a higher percentage than females that qualified for special education, but males also had more primary diagnoses of ASD (73% compared to 55%) yet received less special education service hours on average ($M=114.97$, $SD=289.199$) compared to females ($M=132.05$, $SD=299.42$). Males also had a slightly higher percentage of MCA participation (53.9%) compared to females (52.2%) in SY2014, again.

In terms of qualification for special education services, all students in the cohort

that were American Indian or Asian qualified in SY2014. Over 98% of students that were Black qualified, and approximately 93% of White and 91% of Hispanic students also qualified in this school year. Students that were Asian (82.1%) had the highest percentage of ASD diagnoses in the school setting followed by White (72.1%), and Black (67.8%) demographic groups. Children that were Hispanic (51.4%) and American Indian (37.5%) had the lowest percentages of primary ASD diagnoses. Students that were Black received the most special education service hours on average again in SY2014 ($M=179.89$ hours, $SD= 380.17$ hours). Conversely, students that were Hispanic received the least number of special education service hours on average ($M=46.34$ hours, $SD=155.82$ hours). Students that were American Indian received the second least amount of special education service hours on average ($M=66.39$ hours, $SD= 248.20$ hours), but had the highest percentage of MCA participation (58.3%). Students that were White received 112.96 hours on average of special education service hours and 58% participated in the MCA in SY2014. Of the students that were Hispanic, 54% participated in the MCA whereas 41% of Black and 29% of Asian students also participated.

Over 95% of children in the metro area from the cohort qualified for special education in 2014 and 74% had a primary diagnosis of ASD. Of the children that resided in the non-metro areas, approximately 90% qualified for special education with 61.3% having a primary diagnosis of ASD. Children that lived in the metro area received more special education service hours on average ($M=147.71$ hours, $SD=327.48$ hours) than children in the non-metro area ($M=53.23$ hours, $SD=171.49$ hours). However, children in the non-metro area participated in the MCA at a higher percentage (55.6%) than children

in the metro area (52.8%).

Across all the children with comorbid disabilities per the MMIS dataset, over 95% qualified for special education services in 2014. Children that had mild ID and language disorders had the highest percentage of primary ASD diagnoses (71.4%, 69.7%).

Children with severe ID had the lowest percentage of primary ASD diagnoses (55%) and received the fewest special education service on average ($M=240.30$ hours, $SD=490.84$ hours). Children with profound ID received the most special education services hours on average in 2014 ($M=240.30$ hours, $SD=490.84$ hours). Of the students that were eligible, approximately 40% of children with language disorders or mild ID participated in the MCA. Children with moderate (30%), severe (11.8%), profound (0%), or unspecified ID (34.1%) had the lowest percentages of participation in the MCA in 2014.

Instructional Placements

Instructional placement setting was another educational outcome evaluated by school year for the EIBI recipient cohort (Figure 9). Each school year's distribution of placements by demographics will be presented in the following section. General education is the least restrictive placement and a separate school placement is the most restrictive placement that child in the cohort would be receiving their education.

SY2010. The most frequent placement for females in 2010 (Table 16) were self-contained classrooms for special education services (42.3%), whereas males were most frequently placed in a general education setting (45.6%). Resource room placements (approximately 15%) and separate school placements (4-5%) were similar across both males and females.

Across race demographics, the highest percentage of children were either placed in general education or a self-contained classroom. Separate school placements had the overall lowest percentage of children across all groups. Of the placements in general education, children that were White (46.8%), Asian (45%), or Hispanic (42.9%) had the highest percentages of placement in general education. Conversely, children that were Black (27.9%) or American Indian (36.4%) had the least in comparison. Among resource room placements, percentages of student placement by racial group varied from 5% (Asian) to 27% (American Indian). Within self-contained classroom placements, children that were Black had the highest percentage of placements (53.5%) and children that were White had the smallest percentage (27.3%) of self-contained classroom placements. Finally, separate school placements ranged from 0% for students that were Hispanic to 9% of children that were American Indian.

Regarding the distribution of placements by residence, general education placements had the highest percentage of children across both metro (41.9%) and non-metro areas (50.5%). The second most common placement was self-contained classrooms with children in the metro area having a higher percentage of placements in this setting (38.8%) than children living in the non-metro areas (27.3%). Children in the non-metro areas had a slightly higher percentage of resource room placements (16.2%) however than in the metro area (15.4%). Finally, 6% of the children that resided in the non-metro area had a separate school placement compared to 4% of children in the metro area.

Over 41% of children with comorbid disabilities received special education services in self-contained classrooms. Three quarters of children that had severe ID or profound

ID were placed in a self-contained classroom. Further, less than half of children with a language disorder, developmental delay, mild ID, and unspecified ID had a self-contained classroom placement. Additionally, 35% of children with language disorders had a general education placement. No children with severe or profound ID were in general education placements, but approximately 27% to 30% of children with developmental delay, mild ID, and moderate or unspecified ID did have a general education placement. Resource room placements were below 22% across the comorbid disability categories. Overall, separate school placements were the least common, but children with profound ID or mild ID had the highest percentage of placements in this category in 2010.

SY2011. The instructional placements for 2011 are presented in Table 17. General education placements across males and females were both 44% and were the most common overall. Self-contained classroom setting placements also had the same distribution across females and male (36%). Males had a higher percentage of resource room placements (15.1%) compared to females, but females had a higher percentage of separate school placements (6.8%) than males (4.5%).

The distribution of instructional placements across racial groups was similar to the previous year with most of the children in a self-contained classroom or general education. Students that were American Indian, Hispanic, or White had the highest percentage of children in general education compared to the other settings. Conversely, students that were Asian or Black had the highest percentage of children in the self-contained classroom instructional setting. All groups, except for children that were American Indian, had a higher percentage of children in resource room settings in

comparison to separate school settings.

Across both the metro and non-metro areas, children were most commonly placed in general education settings. There was a higher percentage of children in the non-metro areas (48.6%) that were in general education than children in the metro area (42.2%). The metro area had more children in a self-contained classroom instructional setting though than the non-metro areas (28.3%). Resource room and separate school instructional placements were similar across both areas. There was a marginally higher percentage of children in the non-metro in resource rooms and more children in the metro area in a separate school placement.

Like the previous school year, most of the children with a comorbid disability were in a self-contained instructional setting. Again, no children with severe or profound ID were placed in general education, however, approximately 11% to 38% of children with other disabilities were in general education. Children with severe ID had the highest percentage of resource room (26.7%) placements and no children with profound ID received special education in a resource room. Additionally, children with profound ID (25%) and severe ID (13.3%) had the highest percentages of separate restrictive school placements. Those with developmental delay or unspecified ID had the lowest percentage of separate school placements.

SY2012. Table 18 displays the 2012 distributions of instructional placements. Males, again, had a higher percentage of general education placements (41.6%) compared to females (37.6%). Self-contained classroom placements had a higher percentage of females (43%) than males (36.2%). In contrast, both resource room and separate school

placements had a higher percentage of males (16.2%, 6%) in comparison to females (14%, 5.4%).

For all racial groups, except for students that were White, a higher percentage of children were in self-contained classrooms (range=32.2%-55.8%) than a general education instructional setting (range= 22.1%-45.3%). The next most common placement, as in the previous two years, was a resource room instructional placement (range= 6.7%-17.6%). No children that were Hispanic were placed in a separate school. Approximately 4% of students that were Asian and about 6% of children in the other racial groups had separate school placements. Overall, children that were White had the highest percentage of general education placements (45.3%) and children that were Hispanic had the highest percentage of resource room instructional placements (17.9%). Finally, over half of children that were Black (55.8%) received special education in self-contained classrooms. A small percentage of children received the most restrictive instructional placement (separate schools). American Indian students had the percentage of separate school placements (6.7%).

A higher percentage of children in the non-metro areas (46.2%) than children in the metro area (38.5%) had a general education setting placement. In contrast, a higher percentage of children who lived in the metro area were in a self-contained classroom placement (42%) than children in the non-metro areas (27.2%). Instructional placements in resource rooms and separate schools were similar between metro and non-metro areas, with the non-metro areas having marginally higher percentages.

As in the previous years, self-contained classrooms had the highest percentage of

children with comorbid disabilities across all the categories (range= 46.4%-80%). For self-contained instructional settings, approximately half of the children with language disorders, developmental delay, mild ID, and unspecified ID received special education services in this placement. Over half of the children with moderate ID, severe ID, and profound ID also received services in self-contained classrooms. General education placements had a similar distribution of children with comorbid disabilities as in the previous years with no children with profound ID in the setting and about a quarter of children with developmental delay, mild ID, and language disorders in the instructional placement. Between 14% of children with language disorders and 21% of children with severe ID had an instructional placement in a resource room. Overall, children with language disorders were in a separate school, and 1 out of 5 children with profound ID received their education in a separate school placement.

SY2013. Instructional placements from 2013 are presented in Table 19. A marginally higher percentage of males (41.4%) compared to females (40.5%) were in a general education placement, as in the previous school years. More males than females were in a resource room placement, but separate school placements were similar in terms of percentage of females and males (5.4%).

Again, as with the previous years, children identified as American Indian, Hispanic, and White had the highest percentage within their respective groups of placements within general education followed by self-contained classrooms, resource rooms, and separate schools. The distribution of placements for children identified as Asian or Black differed in that most of those children were in a self-contained room and the second common

placement was general education, followed by resource rooms, and separate school instructional placements. Overall, the highest percentage of children in general education were Hispanic (46.2%) and the lowest percentage was children that were Black (22.2%). Within resource room placements, the highest percentage observed were students that were American Indian (18.8%) and the lowest was Asian (13.8%). For self-contained classrooms, children that were Black had the highest percentage of placements and children that were American Indian (31.3%) had the lowest. Finally, in terms of the most restrictive placement, children that were Black had the highest percentage within the group and children that were Hispanic had no separate school placements.

A higher percentage of children in the non-metro areas had placements in general education (45.8%), resource rooms (20.8%), and separate schools (5.7%) compared to children in the metro area. The highest percentage of placements among children who resided in the metro area was in self-contained rooms (42%). The least number of students for both locations were instructional placements in separate schools.

For children in the cohort that had a comorbid disability, a similar pattern was observed with children with language disorders, developmental delay, mild ID, and unspecified ID where the highest percentage of placements among the groups was in self-contained rooms followed by general education, resource rooms, and separate schools. Children that had moderate ID and severe ID had the highest percentage of placements for each respective group in self-contained rooms followed by resource rooms, general education, and separate school instructional placements. There again was a limited sample of children with profound ID ($n=5$), but 4 out of 5 of the children were placed in a

self-contained instructional placement and 1 was in a separate school.

SY2014. The final year of instructional placement data are displayed in Table 20. Overall similar patterns in the distributions were observed across each demographic category examined in comparison to the previous school years. For females and males, however, a higher percentage of females were placed in general education in 2014 (43%) compared to males (40.2%). The pattern of the distribution, though, was similar to the previous years with general education placements having the most children followed by self-contained classrooms, resource rooms, and separate schools. A higher percentage of males had placements in resource rooms and separate schools whereas females had the highest percentage of self-contained classroom placements.

Among the racial groups identified, children that were American Indian, Hispanic, and White had the highest percentage of placements within the groups in general education followed by self-contained rooms, resource rooms, and separate schools. Students that were Asian and Black had a different distribution pattern where the most common placements was self-contained rooms, general education, resource rooms, and finally separate school instructional placements. The most common placement overall was general education with children that were Hispanic having the highest percentage (45.7%), and the least common was separate school placements with children that were Black having the highest percentage of placements (12.6%).

When children that lived in the metro area were compared to children that lived in the non-metro areas, a different pattern of the distribution of placements was evident. The non-metro areas had higher percentage of placements in general education and

resource rooms than the children in the metro areas, whereas children in the metro area had the highest percentage of placements in self-contained classroom followed by general education, resource rooms, and separate school placements.

For children with comorbid disabilities, children with language disorders, developmental delay, and unspecified ID had a similar pattern in that the most common placement was self-contained classrooms, followed by general education, resource room, and separate school instructional placements. For children with mild ID, moderate ID, and severe ID, the most common placement was self-contained classrooms followed by resource rooms, and either general education (mild and moderate ID) or separate school (severe ID) instructional placements. For children with profound ID, 4 out of 5 of the children had a placement in self-contained classrooms and 1 was receiving education in a separate school instructional placement. Children with language disorders had the highest percentage of general education placements and children with profound ID had none. For resource room placements, children with moderate ID had the highest percentage and children with profound ID had none. Among children that had self-contained classroom placements, children with profound ID had the highest overall percentage and children with language disorder had the lowest percentage of self-contained classrooms. Finally, among separate school placements, children with profound ID and severe ID had the highest percentage and children with mild ID had the lowest percentage in this placement.

Minnesota Comprehensive Assessment (MCA)

Tables 21 through 23 display the frequency of children by demographic category

that met or exceeded proficiency in each subject area for each school year. Figures 10-15 show the distribution of standard scores across each subject area and school year. The MCA- subtests will be presented in the following section.

Math. Figure 11 shows the distribution of scale scores in a histogram of the MCA-math subscale by school year. In 2011 ($n=10$), the mean math score was 36.30 ($SD=18.80$) and ranged from 15 to 63. The distribution of proficiency in math for 2011 is displayed in Figure 14. Most children that participated in the MCA math subtest did not meet the standard for proficiency. No children exceeded the standard, however, more children met the math standard than partially met it. Presented in Table 21 are the frequency of children whose MCA- scores met or exceeded proficiency. Only 3 out of 10 children that participated in the math MCA in 2011 met proficiency. Two of the three children were male and all were White and lived in the metro area. One of the children did have comorbid moderate ID.

In 2012 ($n=72$), the mean math score was 46.81 ($SD=19.07$) with a range of 13 to 81. Most children did not meet the standard for proficiency in math but the more exceeded than met or partially met it (Figure 11). Almost half (47%) of the children that took the Math subtest on the MCA did meet or exceed proficiency. More males than females met or exceeded the math standard and most were White (40%) and lived in the metro area (31%, Table 21). Of the children that met or exceeded the math standard, 10% had language disorder, 8% had an unspecified ID, 6% had developmental delay, 4% had mild ID, and 1% had moderate ID.

For school year 2013 ($n=171$), the mean of the math scale score was 43.17 ($SD=$

20.94) with a range of 9 to 99. As in the previous two years, most of the children did not meet the math standard, however, more children met or exceeded the standard than partially met it (Figure 14). Approximately 44% did meet or exceed math proficiency in 2013. Again, more males (38%) than females (6%) meet or exceeded proficiency and most of them were White (36%) and lived in the metro area (30%). Like the previous school year, approximately 9% of children that had a language disorder met or exceeded proficiency. Only 4% of children with developmental delay, 2% with mild ID, and 1% with moderate ID also met or exceeded math proficiency in 2013 (Table 21).

School year 2014 was the last year of follow-up and 228 children took the math MCA-subtest. The mean math scale score was 43.29 ($SD=20.40$) and ranged from 9 to 97. Most children did not meet the proficiency standard in math in 2014 and more met or partially met it than exceeded it (Figure 14). Less than half (40%) of the children's math scale scores met or exceeded proficiency with 36% of males and 4% of females achieving proficiency. Children that were White and lived in the metro area had the highest percentage of children that met or exceeded proficiency in math on the MCA. Children with language disorders (11%) again met or exceeded the standards more than children with developmental delay (3%), or the various degrees of ID (0-9%).

Reading. Figure 15 shows the distribution of scale scores in a histogram of the MCA reading subscale by school year. In 2011 ($n=10$), the mean scale score was 42.20 ($SD=20.48$) with a range of 14 to 70. Most children's scale scores did not meet the reading proficiency standard in 2011, however, more children exceeded it than partially met or met it. Only 30% did meet or exceed proficiency with 20% of males and 10% of

females meeting the standard. All the children were White and lived in the metro area whose scores met or exceeded the standard. Only 1 child with a comorbid disability met the reading standard (Table 22).

In school year 2012 ($n=72$), the mean of scale scores was 48.53 ($SD=19.57$) with a range of 1 to 97. The distribution displayed in Figure 12 indicates that most of the children's reading scores did not meet the proficiency standard but that more met or exceeded than partially met it. Half of the children did meet or exceed the reading standard, of which 42% of males and 8% of females were proficient. Most children that were proficient in reading on the MCA were White (43%) and from the metro area (35%) as in the previous year. Of the children with a comorbid disability, 11% of children with language disorders, 7% with an unspecified ID, 6% with developmental delay, and 3% of children with mild or moderate ID were proficient in reading.

For school year 2013, 169 children from the cohort participated in the MCA-reading subtest. The mean reading scale score was 35.92 ($SD=20.09$), which less than the previous two years, and ranged from 1 to 88. Most of the children's scores did not meet the reading proficiency standard and more met or partially met the standard than exceeded it (Figure 14). Only 27% of the children that took the reading subtest met or exceeded the reading standard. More males (23%) than females (4%) that were White (22%) and living in the metro area (18%) met the reading standard than the other racial groups (0-2.4%) and the non-metro areas (8%). No more than 4% of children with comorbid disabilities' scores met or exceeded proficiency in reading.

In the final year of follow up, 230 children participated in the reading MCA-

subtest. The mean of the scale scores was 38.42 ($SD=19.32$), and ranged from 1 to 87.

The distribution was the same as the previous year with most children not meeting the standard and more children meeting or partially meeting it than exceeding it.

Approximately 31% of the children that participated in the reading subtest met or exceeded proficiency. Additionally, 27% of males and 4% of females met or exceeded the standard in reading, however, most were again White (27%) and lived in the metro area (20%). Overall, less than 6% of children with comorbid disabilities' scores met the proficiency standard in reading.

Science. Figure 13 displays the distribution of science scale scores from the MCA-III for the children that were in 5th grade and participated in the assessment. In 2013, only 9 of the 25 eligible students participated in the science subtest. The mean of science scale scores was 34.89 ($SD=14.50$) and ranged from 20 to 67. Figure 16 presents the achievement levels and shows that most children did not meet the science proficiency standard and the rest of the children met or partially met the standard. Table 23 displays the percentage of children that met or exceeded proficiency in the science subtest. Only 1 student's score out of the 9 (11%) that took the subtest met the standard. The student was male, White, and lived in the metro area and did not have a comorbid disability.

In the final year of follow up, 57 fifth graders participated in the MCA-III science subtest. The mean scale score was 41.42 ($SD=17.09$) and scores ranged from 1 to 73. Most children's scores did not meet the science proficiency standard and more children met or partially met the standard than exceeded it. Approximately 35% of the children that took the science MCA-III subtest met or exceeded the standard. Again, more males

(33%) than females (2%) were proficient and most of the students were White (32%). The same number of students in the metro and no-metro areas were proficient (18%). Finally, less than 5% of children with comorbid disabilities' scores met proficiency in science.

Research question 1: What is the main effect of a delay in EIBI on educational outcomes at follow up?

To control for the dependence between the repeated measurement of each educational outcome (i.e., dependent variables), generalized estimating equation (GEE) models were used to evaluate the longitudinal associations of delay to EIBI in months, age of diagnosis, gender, race, intellectual disability status, residence, free/reduced lunch receipt, and other services received with educational outcomes from 2010 to 2014 for the cohort.

General education placement. A GEE logistic regression model was conducted to determine the main effect of delay to EIBI in months on general education instructional placement at follow up (i.e., school years 2010-2014) with age of diagnosis, gender, intellectual disability status, race, residence, other types of service receipt, free/reduced lunch receipt and school year as covariates. Table 30 presents the odds ratios (OR) with 95% confidence intervals. The odds of a general education placement decreased with every unit increase in delay to EIBI ($OR=0.97$; 95% $CI=0.95-0.98$; $p < .001$). Odds of general education placement also decreased if the student had a comorbid intellectual disability ($OR=0.31$; 95% $CI=0.23-0.44$; $p < .001$) and if the child was diagnosed at an older age ($OR=0.71$; 95% $CI=0.60-0.83$; $p < .001$). Race was statistically significant with

students that were Black having lower odds than students that were White to receive a general education placement ($OR= 0.45$; 95% $CI= 0.30, 0.69$). Children that received speech therapy services had lower odds of a general education placement than children that did not receive speech therapy ($OR=0.70$; 95% $CI = 0.50, 0.97$; $p=.03$). School year was also statistically significant, indicating there was a decrease in the odds of a general education placement with each subsequent school year ($X^2= 19.71$; $p =.001$). Gender, residence, other service receipt, and free or reduced lunch receipt were not significantly associated with general education placement at follow-up.

ASD diagnosis in school. A GEE logistic regression model was also conducted to determine the main effect of delay to EIBI on whether or not a child was given a primary educational diagnosis of ASD in school. Table 31 presents the ORs with 95% confidence intervals for the GEE model. The odds of an ASD diagnosis in school increased if delay to EIBI was greater ($OR=1.02$; 95% $CI=1.01-1.04$; $p =.001$), the child was male ($OR=2.25$; 95% $CI=1.50-3.38$; $p =.001$), or was White ($X^2= 9.74$; $p =.05$). Odds of an ASD diagnosis decreased if the child received a diagnosis at an older age ($OR=0.72$; 95% $CI=0.59-0.86$; $p =.001$) and resided in the non-metro area ($OR=0.68$; 95% $CI=0.47-0.98$). There was a decrease in the odds of an ASD diagnosis in school at follow-up if children received physical therapy ($OR=0.46$; 95% $CI=0.28-0.75$; $p =.002$) or free/reduced lunch receipt ($OR=0.42$; 95% $CI=0.29-0.61$; $p <.001$). Intellectual disability status, speech/occupational therapy receipt, and school year were not statistically significantly associated with educational ASD diagnoses.

MCA-reading scale participation and scores. The main effect of delay to EIBI

was examined in two different GEE models for each MCA subscale. A GEE logistic regression model was conducted for MCA reading participation and is presented in Table 32. Delay to EIBI was statistically significant with the odds of taking the MCA reading subscale at follow-up decreasing with greater delay ($OR=0.98$; 95% $CI=0.96-0.99$; $p=.03$). Children without comorbid intellectual disability had greater odds of participating in the MCA- reading assessment compared to children with comorbid intellectual disability ($OR=0.33$; 95% $CI=0.21-0.50$; $p<.001$). The last school year (2014) was significantly different than the previous school years with the odds of taking the reading subscale decreasing ($OR=0.55$; 95% $CI=0.31-0.97$; $p=.04$). Children that received speech therapy before entering elementary school, compared to those that did not, had lower odds of participating in the MCA reading subscale in 3rd to 5th grade ($OR=0.55$; 95% $CI=0.35-0.87$; $p=.01$). Race was also statistically significant with students that were Black having lower odds than students that were White ($OR=0.48$; 95% $CI=0.27-0.86$). Finally, age at diagnosis, gender, residence, OT and PT services received, and free/reduced lunch receipt were not significantly associated with MCA reading participation in school.

For reading scale scores, a GEE linear regression model was fitted (Table 34). The main effect of delay to EIBI on MCA- reading scale scores was not significant. Intellectual disability status, race, OT service receipt, and school year were significantly associated with reading scale scores at follow-up. Children with comorbid intellectual disability that took the MCA scored lower than children without intellectual disability ($B= -0.20$; 95% $CI= -0.38, -0.03$; $p=.02$). Children who were Black scored significantly

lower compared to students who were White (reference), $B=-0.42$; 95% $CI= -0.67,-0.18$; $p=.001$. Additionally, children receiving OT services before elementary school scored higher on average on the reading subscale than children not receiving OT services before elementary school ($B= 0.18$; 95% $CI= 0.04-0.32$; $p=.01$). School years 2013 and 2014 were significantly associated with lower reading scale scores than 2011. Diagnosis age, gender, speech and physical therapy, residence, and free/reduced lunch were not statistically significantly associated with MCA- reading scale scores at follow-up.

MCA-mathematics scale participation and scores. A GEE logistic regression model was conducted for MCA- mathematics participation and is presented in Table 33. Delay to EIBI was significantly associated with the odds of participating in the MCA-math subscale. The odds of MCA- math participation decreased with greater delay to EIBI ($OR=0.98$; 95% $CI=0.96-0.99$; $p=.01$). Intellectual disability status, speech therapy service receipt, and school year were also statistically significant. The ORs for the association between intellectual disability, speech service recipients, and school year with MCA-math participation were 0.33 (95% $CI=0.21-0.50$, $p<.001$), 0.54 (95% $CI= 0.34-0.85$; $p=.01$) and 0.62 (95% $CI=0.38-0.99$, $p=.05$) for school year 2014, respectively. These ORs indicate that children with intellectual disabilities, and those who received speech services before elementary school had lower odds of participating in the MCA-math subscale assessment. Similarly, the final school year evaluated, compared to 2011, resulted in lower odds of participation. Race was also statistically significant with students who were Black having lower odds compared to students who were White ($OR= 0.49$; 95% $CI= 0.28-0.87$). Gender, age of diagnosis, residence, OT or PT receipt, and

free/reduced lunch receipt was not significantly associated with MCA-math participation.

A GEE linear regression was fitted for MCA-mathematics scale scores (Table 35). The main effect of delay to EIBI was statistically significant ($B=-0.006$; 95% $CI= -0.01-0.001$; $p=.03$). Age of diagnosis, intellectual disability status, race, and school year were found to be significantly associated with MCA math performance. Children with comorbid intellectual disability scored lower, on average, compared to children without ($B= -0.16$; 95% $CI= -0.30, -0.01$, $p=.02$). Children that received a diagnosis of ASD at a younger age had lower scores than older counterparts ($B=-0.08$; 95% $CI=-0.14, -0.02$). Children who were Black also scored, on average, lower than students who were White ($B=-0.45$; 95% $CI= -0.67, -0.23$; $p<.001$). School years 2013 and 2014 resulted in lower scores compared to 2011. Gender, residence, other services, and free/reduced lunch receipt were not statistically significant predictors.

Special education service hours. A GEE linear regression model was conducted to determine the main effect of delay to EIBI on special education service hours at follow up. Table 36 presents the beta-weights and 95% confidence intervals. Delay to EIBI was statistically significant with special education service hours, decreasing with greater delay to EIBI ($B=-0.01$; 95% $CI= -0.02-0.003$; $p=.01$). Non-metro residence ($B=-0.30$; 95% $CI=-0.50, -0.10$; $p=.004$), males ($B=-0.33$; 95% $CI=-0.58, -0.07$; $p=.01$), and the 2013 ($B=-0.56$; 95% $CI=-0.78, -0.34$; $p<.001$) and 2014 ($B=-0.40$; 95% $CI=-0.64, -0.17$; $p=.001$) school years were also significantly associated with reduced special education service hours. Finally, age of diagnosis, intellectual disability status, other service receipt, and free/reduced lunch receipt were not statistically significant predictors of average

special education service hours at follow-up.

Research question 2: What is the main effect of average hours of EIBI received per week on later educational outcomes?

GEE models were used to evaluate the longitudinal associations of average hours of EIBI received (i.e., dosage), delay to EIBI, age of diagnosis, gender, race, intellectual disability status, residence, free/reduced lunch receipt, school year, and other services received with educational outcomes from 2010 to 2014 for the cohort. Each of the educational outcome results are presented in the following section. The models are different from research question 1 in that the EIBI dosage variable has been added to investigate its main effect on educational outcomes at follow up.

General education placement. A GEE logistic regression model was conducted to determine the main effect of average hours of EIBI received on general education instructional placement at follow-up (i.e., school years 2010-2014) with delay to EIBI, age of diagnosis, gender, intellectual disability status, race, residence, other types of service receipt, free/reduced lunch receipt and school year as covariates. Table 37 presents the ORs with 95% CIs. Average hours of EIBI per week was not statistically significant ($OR=1.00$; 95% $CI=0.99-1.01$; $p=0.85$). Delay to EIBI, diagnosis age, race, intellectual disability status, speech services, and school year were statistically significant as in the previous model presented in Table 30.

ASD diagnosis in school. A GEE logistic regression model was also conducted to determine the main effect of average EIBI hours per week received on whether or not a child was given a primary educational diagnosis of ASD in school. Table 38 presents the

ORs with 95% confidence intervals for the GEE model. Average EIBI hours per week was significantly associated with the odds of an ASD diagnosis in school. The odds of an ASD diagnosis in school increased with more hours per week, on average ($OR=1.04$; 95% $CI=1.02-1.06$; $p < .001$). As in the previous model, delay to EIBI, age of diagnosis, gender, physical therapy service receipt, residence, and free/reduced lunch receipt were statistically significant. Race, speech and OT services, and school year were not statistically significant when average EIBI hours were added to the GEE model.

MCA-Reading scale participation and scores. A GEE logistic regression model was conducted for MCA reading participation and is presented in Table 39. When holding all the other covariates constant, average EIBI hours per week were significantly associated with the odds of taking the reading subscale. Children with more EIBI hours per week had lower odds of taking the MCA -reading subscale ($OR=0.97$; 95% $CI=0.95-0.98$; $p < .001$). Delay to EIBI, intellectual disability status, race, speech service receipt, and school year as in the previous model, was significantly associated with the odds of MCA- reading subscale participation. Children living in the non-metro area had lower odds than children living in the metro area to participate in the MCA-reading subscale ($OR=0.63$; 95% $CI=0.41-0.99$; $p = .04$).

For reading scale scores, a GEE linear regression model was fitted and is presented in Table 41. The main effect of delay to EIBI on MCA- reading scale scores was again not significant and average EIBI hours was not either. Intellectual disability status, race, occupational therapy receipt, and school year were significantly associated with reading scale scores as in the previous model. Children with intellectual disabilities scored lower

than children without intellectual disabilities ($B = -0.20$; 95% $CI = -0.38, -0.03$; $p = .02$).

Additionally, children who were Black scored lower than children who were White ($B = -0.45$; 95% $CI = -0.69, -0.21$; $p = .001$). Children who received occupational therapy scored lower than those that did not ($B = 0.18$; 95% $CI = 0.04-0.32$; $p = .01$). Finally, school years 2013 and 2014 resulted in lower scores than the other years at follow-up.

MCA -Mathematics scale participation and scores. Another GEE logistic regression model was conducted for MCA -mathematics participation (Table 40). The main effect of average EIBI hours per week on MCA-math subscale participation was statistically significant ($OR = 0.97$; 95% $CI = 0.95-0.99$; $p = .001$). Delay to EIBI, age of diagnosis, intellectual disability status, race, residence, speech service receipt, and school year were also statistically significant predictors. There was a decrease in the odds of MCA math subscale participation if the child had a greater delay to EIBI ($OR = 0.97$; 95% $CI = 0.95-0.99$; $p = .001$), was older at diagnosis ($OR = 0.76$; 95% $CI = 0.60-0.98$; $p = .03$), had an intellectual disability ($OR = 0.33$; 95% $CI = 0.21-0.51$; $p < .001$), or received speech services ($OR = 0.51$; 95% $CI = 0.32-0.81$; $p = .004$).

A GEE linear regression was fitted for MCA- mathematics scale scores (Table 42). The main effect of average EIBI hours per week was not significantly significant. Delay to EIBI, age of diagnosis, intellectual disability status, race, and school year was statistically significant. Children with intellectual disabilities scored lower than children without intellectual disabilities ($B = -0.17$; 95% $CI = -0.30, -0.03$, $p = 0.02$). Children who were Black scored lower on average than students who were White ($B = -0.47$; 95% $CI = -0.68, -0.25$, $p < .001$) and as in the previous model school years 2013 and 2014 had lower

scores compared to 2011 ($X^2 = 23.78$; $p < .001$).

Special education service hours. A GEE linear regression model was conducted to determine the main effect of average EIBI per week (Table 43). Both average EIBI hours per week ($B = -0.01$; 95% $CI = -0.02, -0.003$; $p = .01$) and delay to EIBI were statistically significant for average special education service hours receipt. Age of diagnosis ($B = -0.12$; 95% $CI = -0.24, -0.01$; $p = .04$), gender ($B = -0.34$; 95% $CI = -0.60, -0.08$; $p = .01$), race ($X^2 = 9.58$; $p = .05$), residence ($B = -0.30$; 95% $CI = -0.50, -0.10$; $p = .004$), and school year were also statistically significant. Intellectual disability status approached significance, whereas receipt of other services and free/reduced lunch were not statistically significant.

Research question 3: Does average delay to start EIBI differ by county or region within Minnesota?

Figures 17 through 19 display GIS choropleth maps of average delay to EIBI in months by county. Medicaid-enrolled children with a diagnosis of ASD in this dataset resided in 64 of the 87 counties in Minnesota. Overall, approximately 70% of children in this study experienced a delay to EIBI services, with an average delay of approximately 9 months (range = 0-45 months). Figure 17 displays the county names and average delay to EIBI in a choropleth map. Average delay ranged from 0 months in 7 of the counties (Hubbard, Lincoln, Martin, Mille Lacs, Norman, Pine, and Wilkin), which were all located outside the metro area, to 28 months (Le Sueur in Southeast Minnesota). Figure 18 shows the number of children that lived in each county that had an ASD diagnosis. Similarly, in Figure 19, the proportion of service providers located in each county is displayed on the map. Hennepin county in the metro area had the most EIBI service

providers ($n=18$).

To investigate whether metro (Hennepin, Anoka, Carver, Scott, Dakota, Washington, and Ramsey; $n=460$) and non-metro ($n=207$) areas differ in mean EIBI delay in months, an independent samples t -test was computed. Due to the unequal variances and sample sizes associated with the locations, these results should be interpreted with caution. There was a statistically significant mean difference between the metro ($M= 9.89$, $SD=11.25$) and non-metro ($M= 7.00$, $SD= 8.80$) delay to EIBI services: $t(499.41) = -3.59$, $p=.001$, $g =.27$. The confidence interval for the difference between the means was -4.47 to -1.31 and the mean difference was -2.89 . Additionally, a one-way ANOVA was conducted to examine the mean difference among regions within Minnesota for delay to EIBI services. The mean and standard deviations are presented in Table 46. There was a statistically significant difference between regions as determined by a one-way Welch's ANOVA for unequal variances ($F(6,660) = 2.82$, $p=.01$).

CHAPTER 5: DISCUSSION

The current study aimed to evaluate the impact of delays to early intensive behavioral intervention (EIBI) services on educational outcomes for young children with autism spectrum disorder (ASD) enrolled in Medicaid (called Medical Assistance in Minnesota). Three research questions guided the analyses. The first question was what was the main effect of delay to EIBI on educational outcomes at follow-up? The second question asked what was the main effect of average hours of EIBI per week on educational outcomes. Finally, the third research asked whether the average delay to start EIBI differed by county or region within Minnesota. Two administrative datasets from the state of Minnesota were linked to identify children with ASD that received EIBI anytime between 2008 and 2010. The school records of these children were then matched and used to evaluate educational outcomes from school years 2010 to 2014. The sample included 667 children with a diagnosis of ASD residing in the state of Minnesota. The purpose of this chapter is to synthesize the study's main findings. Each research question and corresponding results are reviewed, limitations presented, and directions for future research proposed.

Descriptive Analyses

Overall, most of the sample was male, lived in the metro area of Minnesota, and were White (71.7%). For demographic comparison purposes, state-wide data from the National Center for Education Statistics (NCES) indicate that 73% of the student population in Minnesota in 2011 were White and 14.6% received special education (Bohrnstedt, Kitmitto, Ogut, Sherman, & Chan, 2015). In the current study, higher rates of

children qualified for free or reduced lunch in school (64.5%) than in the NCES data (37.1%). Also, limited-English learners made up 5.9% of the study sample, which was similar to the state-wide estimate of 7.2% (Bohrnstedt et al., 2015).

Approximately 70% of children in the study experienced a delay to EIBI services, with an average delay of nine months. It is promising that some (30%) children did start intensive services before receiving a diagnosis of ASD. Families may have been able to access services through IDEA Part C (birth to three services) with a diagnosis like Developmental Delay until an ASD diagnosis was given later. There were no data on how families navigated or accessed services, however, all were enrolled in Medical Assistance/Medicaid and would have had access to similar service providers. Longer delays overall were evident in the metro areas compared to the non-metro areas. Along with EIBI services, over half of the sample received speech and language therapy and were diagnosed with a comorbid language disorder. Additionally, approximately a quarter of the children had a comorbid intellectual disability and ASD.

The educational outcomes examined in this study at follow-up included instructional setting placement (e.g., general education), a primary educational diagnosis of ASD, special education service hours, participation and scores on standardized achievement tests. Grade levels kindergarten to 6th grade were included. Over 94% of the sample examined qualified for special education services, and 70% qualified for a primary diagnosis of ASD in elementary school. It is not surprising that most children qualified for special education services with an ASD diagnosis in school, given that ASD is a lifelong disability. The previous literature on the effectiveness of EIBI outlined in

Chapter 2, however, indicated that for some children, ‘normal’ functioning was achieved at follow up (e.g., Lovaas, 1987).

About 40% of the students received a general education placement whereas approximately 5% of the sample were placed in the most restrictive setting, a separate school. These results are similar to other studies comparing children receiving treatment as usual with those receiving EIBI (Cohen et al., 2006; Lovaas, 1987; Magiati et al., 2007; McEachin et al., 1993; Remington et al., 2007; Sheinkopf & Siegel, 1998; Smith et al., 2000). About half of the children participated in the MCA-III (standardized achievement test). Taken all together, among this sample of children receiving EIBI (with different rates of delay to service experienced), the distribution of children qualifying for special education, receiving an ASD diagnosis, the instructional placements, and participation in the MCAs was relatively stable across all five years of follow-up. The main findings for each research question are presented next, along with implications, limitations, and proposed future directions for research.

The Main Effect of a Delay to EIBI

Findings from the GEE models calculated for each educational outcome examined for school years 2010 to 2014 suggest that the main effect of delay to EIBI (in months) was significant. Specifically, the odds of receiving a general education placement and participating in the MCA-reading or math standardized achievement tests was decreased if the child experienced a longer delay to start EIBI. Additionally, the odds of receiving a primary educational diagnosis of ASD increased for every increase in delay. It was hypothesized that children who had longer delays to EIBI would have overall ‘worse’

outcomes at follow-up. More specifically, children experiencing a longer delay to service would have retained an ASD diagnosis in school, had more restrictive instructional placements, had more special education service hours, and were less likely to participate in the MCA. Overall, the results suggest that the time between when a diagnosis is made and the start of intensive services is important in optimizing outcomes for children with ASD. Although the educational outcomes evaluated were limited, the main effect of delay to EIBI was statistically significant for almost all outcomes examined, except for MCA reading scores. This study extends previous findings that children diagnosed younger and starting EIBI services earlier tend to have better outcomes (Baker-Ericzen et al., 2007; Bibby et al., 2002; Flanagan et al., 2012; Granpeesheh et al., 2009; Harris & Handleman, 2000; MacDonald et al., 2014; Perry et al., 2011; Smith et al., 2015b; Virués-Ortega & Rodriguez, 2013). There is no research to date isolating the effect a delay to EIBI has specifically on educational outcomes for children with ASD. Thus, the present study was important to fill in the gap in the autism and educational outcomes knowledge base.

Two potential confounders were adjusted for in each model for every outcome evaluated: age at ASD diagnosis (from the MMIS dataset) and intellectual disability status to control for severity of ASD symptoms. Age of diagnosis was statistically significant for general education placement, ASD diagnosis in school, and math scale scores. Age of diagnosis was important to include because the delay a 3-year old experiences may impact later outcomes differently than a 5-year old who experiences the same amount of delay. Comorbid intellectual disability status was a significant predictor

for general education placement and MCA-reading or math participation and scale scores over follow-up. Children with comorbid intellectual disabilities had lower odds of receiving a general education placement and to participate in the MCA-achievement test. These findings are in line with previous research on educational outcomes and developmental trajectories for children with ASD in which children with less impairment tend to do better over time than their peers (e.g., Fountain, Winter, & Bearman, 2012; Klintwall, Eldevik, & Eikeseth, 2015).

Gender, race, residence, previous services (i.e., speech, physical, and occupational therapy), free/reduced meals, and school year (time) were also included in each GEE model calculated. The odds that males received an ASD diagnosis in school was two times higher than their female counterparts. The Center for Disease Control (CDC) reports that ASD is 4.5 times more common among males and so these findings are consistent (CDC, 2017). Further, the study sample was primarily male. Race was a significant predictor for general education placement, MCA-participation, and special education hours. The reference group used was White since most of the sample was of this demographic. Significant differences were primarily found between White and Black students for the educational outcomes reported and were confirmed with post-hoc analyses. Within Minnesota, there are racial disparities evident in academic achievement. For instance, in 2015 Black students scored an average of 37-points lower than their White peers in reading and 30-points lower on mathematics on the MCA-III (NAEP, 2017). The findings of this study support the evidence on academic achievement and racial disparities within Minnesota.

Non-metro residence was significantly associated with reduced odds of an ASD diagnosis at follow-up. In terms of previous services received, children receiving speech and language therapy had lower odds of a general education placement and participating in the MCA than children that did not. Children receiving occupational therapy had higher scores on the reading subscale than children that did not. Finally, children receiving physical therapy had lower odds of an ASD diagnosis in school than children who did not. Over half of the sample did receive speech services along with EIBI, whereas about 43% received occupational therapy and 12% received physical therapy. Due to the heterogeneity associated with autism features, it is common for many children with ASD to receive co-occurring services.

Additionally, children receiving free/reduced meals had lower odds of receiving an ASD diagnosis in school than children who did not. Finally, school year was significant for all the models conducted, except for ASD diagnosis at follow-up. Again, ASD is a life-long disability but can co-occur with other disabilities and so school teams make a primary diagnosis determination (i.e., special education qualification) based on each student's individual needs. Once given an ASD diagnosis in elementary school, it is unlikely that the diagnosis will change over time even though goals and needs may be met. The other educational outcomes examined compared to ASD diagnosis within school are expected to change over time and this may be why school year was not significant for the ASD diagnosis outcome. Taken all together, delay to EIBI does impact later educational outcomes. The hypothesis that children experiencing a longer delay to service would retain an ASD diagnosis in school, have more restrictive instructional

placements, and would be less likely to participate in the MCA was corroborated. The second research question expanded on these GEE models and analyzed the main effect of average hours of EIBI per week on later educational outcomes for the cohort. The main findings from the ‘dosage’ analyses are discussed in the following section.

The Main Effect of Dosage

The second research question aimed to replicate the GEE models utilized in the first research question and add ‘dosage’ or average hours of EIBI per week to each model. Since the sample cohort was restricted to children that received EIBI services between January 1st, 2008 and December 31st, 2010, not all EIBI billing claim information was available for all the children. Therefore, average hours of EIBI was used as a potential proxy for a dosage variable and has been used in other studies to analyze EIBI dose-response (e.g., Klintwall et al., 2015; Virués-Ortega, 2010). More hours of service in general suggest more severe autism symptoms (i.e., children with more severe ASD may need more service hours/higher treatment intensity). For the outcomes in which the average hours of EIBI per week and delay to EIBI was significant, the pattern (and direction) was the same. For instance, the odds of MCA participation decreased for each unit increase for both average hours of EIBI and delay to EIBI.

The results of the GEE regression models indicated that the main effect of average EIBI hours per week (dosage) was significant for ASD diagnosis, reading and math subscale participation, and special education service hours. Children receiving more EIBI hours per week on average, and who experienced more delay to EIBI, had increased odds of an educational ASD diagnosis. More EIBI hours per week, on average, was

associated also with decreased odds of participating in the MCA. Severity of ASD may explain these findings in that children requiring more EIBI hours per week had more skill areas needing to be addressed by EIBI programming. These results are slightly different than previous research on intensity of EIBI. Klintwall et al. (2015) found that for every hour of EIBI treatment per week, learning rates increased. Further, younger children showed a greater benefit from increased EIBI hours, but overall there was a significant increase in new skill acquisition with increased treatment hours (Granpeesheh et al., 2009). Other research also indicates that language increases more based on EIBI duration (not measured in this study) whereas adaptive behavior increases more based on EIBI intensity (Virués-Ortega, 2010). In the current study, the results do not mean that gains in adaptive behavior did not occur with EIBI but maybe that they are not necessarily reflected in the educational ASD diagnosis and MCA participation outcomes.

For the other predictor variables also included in the dosage model, the results were similar to the previous GEE models. Gender, intellectual disability status, race, other services, free/reduced meals, and school year yielded the same results when average EIBI hours per week was added. The main effect of delay to EIBI was again significant for all outcomes, except reading scores. Age of diagnosis was also significant for general education, ASD diagnosis, and math subscale score outcomes as in the previous model, but also for MCA participation and special education service hours when dosage was added. Children that were diagnosed at an older age had lower odds of taking the MCA subscales. Age of diagnosis was also significantly associated with special education service hours on average. These findings correspond to previous research showing that

children with ASD who were younger and less impaired pre-EIBI treatment showed more improvement at follow-up (Baker-Ericzen et al., 2007; Bibby et al., 2002; Flanagan et al., 2012; Granpeesheh et al., 2009; Harris & Handleman, 2000; MacDonald et al., 2014; Perry et al., 2011; Smith et al., 2015b; Virués-Ortega & Rodriguez, 2013).

The overall results suggest that the main effect of average hours of EIBI per week was significantly associated with ASD diagnosis in school, MCA participation, and special education service hours. The hypothesis that children receiving more EIBI hours a week on average would be in less restrictive placements, receive less special education service hours, and would be more likely to participate in the MCA at follow-up did not hold up. The opposite was found, and could potentially be due to ASD severity. The results of the final research question are presented next.

Delay to EIBI by Residence

State-level data of the average delay to EIBI in months was also examined by county and region within Minnesota. The average delay was nine months to start EIBI services once a diagnosis of ASD was given. Some children did start EIBI before an ASD diagnosis. The seven-county metro area was compared to non-metro areas statewide. Overall, sample sizes and number of service providers varied by county with most of the children residing in the metro area ($n=460$).

In terms of service providers, Hennepin county in the metro area had the most EIBI service providers ($n=18$). There was a statistically significant mean difference between metro and non-metro delay to service estimates with the non-metro areas having

overall shorter delays. Although these results should be interpreted with caution due the sample sizes being disparate, the results suggest the hypothesis that the metro area would have less service delay should be rejected. Even though the same number of service providers were located in the metro areas as the non-metro (n=27), the burden appears to be greater due to the greater number of children needing services. Previous research on access to services for individuals with ASD does suggest that geographic location can be a barrier to service. Limited access to services, for instance, has been found to be associated with residing in non-metropolitan areas (Thomas, Ellis, McLaurin, Daniels, & Morrissey, 2007). It is evident that access to high-quality timely services like EIBI can be challenging for families. Socio- economic status and culture/ethnicity was not examined by county or delay but may be relevant for investigating who requires more support in navigating access to autism-related services (regardless of geographic location).

The distribution of age of diagnosis by county or region was not evaluated but should also be examined in future research. Previous research suggests that living in an urban area is associated with earlier autism diagnosis (Mandell, Novak, & Zubritsky, 2005). Children diagnosed at a younger age who access services sooner do better overall. If more rural areas of the state are associated with later diagnostic age due to less service providers or clinicians, then policy makers and stakeholders need to be aware of that. Taken together, delays to EIBI varied throughout counties and regions of the state, perhaps driven by access to service providers or waitlists evident in the metro areas. Visual analysis of the delays by county displayed in GIS maps in figures 17-19 may be a useful way to track access. The visualization of information may help stakeholders make

decisions and be aware of where the service providers are and current waitlists. In sum, although some children received EIBI services before a diagnosis of ASD was given, there are waitlists and delays to services statewide which may be detrimental to children's educational experiences and elementary school outcomes.

Limitations

The study was observational in nature and the educational outcomes were limited to those available in administrative databases (i.e., MCA-III scores and placement information). Other indicators for academic achievement were not available, such as the individualized education plans for the students receiving special education services. School-based early intervention services were not accounted for because there was no education data available for school years 2008 and 2009. Given that early childhood special education (ECSE) is the most common service provider for the age group evaluated it could be assumed that most children in the sample were also receiving ECSE due to IDEA (i.e., under federal law, early intervention services end at age 3 and are then determined by the child's school). A subset of the sample did have ECSE data (presented in the results section), however, ECSE services were not accounted for in the GEE models. The sample is exclusively from one state (Minnesota) and therefore the findings are specific to Minnesota. No information on mother's education, income, or socioeconomic status, other than qualification for free or reduced meals, was available. Finally, quality of EIBI service was not assessed or known. There are standards of practice for EIBI service providers, but there may be variability in terms of curriculum or type of EIBI service provided. The current study was not an effectiveness of EIBI study.

Rather I was interested in the effect of delayed EIBI service start on educational outcomes. It is likely that some of the variance could have been attributed to type or quality of EIBI.

Future Research and Conclusions

It is important that children diagnosed with ASD receive services during critical times of early development. IDEA is a federal law mandating services to children with disabilities throughout the United States and governing how states provide services (IDEA, 2014). Minnesota's early intensive developmental and behavioral benefit (DHS, 2016) requires Medicaid/Medical Assistance to cover EIBI, yet stakeholders describe waitlists and delays in accessing needed services. Evidence presented in Chapter 2 on the effectiveness of EIBI indicate gains in communication, adaptive behavior, and IQ for young children with ASD. The effects of waitlists/delay of EIBI services for individuals with ASD have not been studied extensively. This study was developed to investigate if a delay in EIBI services affected later educational outcomes for Medicaid-enrolled children with a diagnosis of ASD. Overall, the results showed that children who experienced a shorter delay to start EIBI and were diagnosed younger had better educational outcomes (i.e., a general education placement, participated in the MCA-achievement test and had higher scores). The average delay to EIBI across the state of Minnesota was nine months indicating that there are families waiting to start intensive services.

One area future research should expand on regarding delays to service is to explore alternative service delivery strategies. A telehealth (internet based video-conferencing) model of service could potentially bridge the gap in service delivery time after a

diagnosis. Implications of this type of research include more efficient allocation of services for families and children with ASD throughout Minnesota. For example, Vismara and colleagues (2016) used a randomized controlled trial to compare parent training using the Early Start Denver Model (i.e., EIBI) delivered via telehealth and community treatment as usual early intervention program. More parent satisfaction and implementation fidelity was observed after 12-weeks for the telehealth ESDM group (Vismara et al., 2016). Further, telehealth can reduce costs for providing services and could potentially eliminate any geographic barriers to autism-related services (e.g., Lindgren et al., 2016). In general, more research is needed to investigate how to deliver EIBI via telehealth to increase access to services for families and test whether that could close the diagnosis to service gap (and reduce wait lists).

Future research should also extend the findings on the cost-effectiveness of timely access to EIBI. Piccininni and colleagues (2017) reported that in Canada the economic effect of eliminating wait times to EIBI was associated with lifetime savings of Can\$267,000 per individual when they compared estimates to current wait times. Although the cost of treatment is expensive, it can ultimately save society money in the long-term. The cost-savings associated with EIBI on special education costs, for instance, are estimated at \$208,500 per child (Chasson, Harris, & Neely, 2007). The cost of EIBI across settings ranges from \$40,000 to \$60,000 per child per year (Amendah et al., 2011). With prevalence estimates at 1 in 68 for ASD diagnoses (CDC, 2016), the burden on service providers is growing and may result in more children and families spending more time on waitlists for intensive services. A cost-benefit analysis of a delay to service

therefore should be calculated for this cohort of 667 children in the future to provide further evidence for why timely early intervention for children with ASD is critical.

ASD is a lifelong neurodevelopmental disorder, but early diagnosis and intervention over time can improve quality of life. Recent research focused on earlier diagnosis by monitoring the early brain development associated with prodromal ASD cases are promising (e.g., Hazlett et al., 2017). These findings on the potential for earlier diagnosis paired with the development of programming aimed at intervention for children at high risk for ASD (e.g., Green et al., 2015) could facilitate optimal outcomes. The primary focus to date has been on early diagnosis and intervention rather than on the educational outcomes of children with ASD. Given incidence trends and growing prevalence, there needs to be more effort to measure and track academic/educational achievement among individuals with ASD to evaluate growth and areas of need in relation to early intervention.

Among the cohort evaluated, over 94% qualified for special education services in elementary school at follow-up with over 70% qualifying under an ASD diagnosis. Average special education service hours ranged from 116 hours to 220 hours across the school years examined and the most common instructional placement setting was general education. A racial disparity was evident in the outcomes examined within Minnesota between Black and White students and of the eligible students, only half participated in the MCA- test. The study results are the only to date to examine these educational outcomes in relation to a delay to EIBI service for children with ASD. Overall, children that experienced a longer delay to EIBI did not do as well in school as children with a

shorter delay.

In summary, the current study aimed to evaluate how delays to EIBI relate to educational outcomes for young children with ASD enrolled in Medicaid. The main effects of delay to EIBI, the average hours of EIBI per week, and the distribution of delay by county and region within Minnesota were investigated in an observational study of retrospective data. It is promising that some children did not experience any delay to service and that others had very positive educational outcomes. The overall goal in providing services in a timely manner to children with ASD is to facilitate long-term positive outcomes. More support and research is warranted, but early intensive intervention is vital for families and children with ASD to improve outcomes and promote better quality of life.

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Table 1

Review of EIBI

Article	n	Model	Hours per week	Months of Tx	Comparison	Meta-analyses	Results
Lovaas, 1987	59	UCLA	40 vs. 10 vs. none	24	Control group and TAU control group	E,H, M, R,RW,V	<ul style="list-style-type: none"> • 47% of the treatment group achieved normal intellectual and educational functioning, with normal-range IQ scores and successful first grade performance. • 40% had mild ID and assigned to special classes for the language delayed. • 10% were profoundly ID and assigned to restricted classes. • Only 2% of the control-group children achieved normal educational and intellectual functioning. • 45% had mild ID and placed in language-delayed classes. • 53% had severe ID and placed in restricted/autistic classes.
Anderson et al., 1987	14	UCLA	15-25	12 to 24	None	R, RW, M, V	<ul style="list-style-type: none"> • Most of the children demonstrated significant gains in language, self-care, social, and academic development.
Harris et al., 1991	9	EIBI	35-45	11.4	Typically developing peers	RW,V	<ul style="list-style-type: none"> • The children with autism made 19-point increase in IQ and an 8-point gain in language quotient. • The IQ measure remained stable for the typically developing peers and language increased.
Birnbrauer & Leach, 1993	14	UCLA	M=18.7	21.6	Control group	E, R, RW, V	<ul style="list-style-type: none"> • Four of the children approached normal levels of functioning • Improvements in the remainder of the children were moderate to minimal.
McEachin et al., 1993	36	UCLA	40 vs 10	24	Control group	H, S	<ul style="list-style-type: none"> • Follow up between 0 and 9 years of Lovaas, 1987 study participants. • The experimental group retained gains in IQ and adaptive behavior compared to the control group.
Koegel et al., 1996	17	PRT	--	--	Alternative tx group	S	<ul style="list-style-type: none"> • The PRT parent training paradigm resulted in the families showing positive interactions.

Smith, et al., 1997	21	UCLA	30 vs. 10	35 vs. 26	Lower dose tx control group	E, H, R, RW, M, V	<ul style="list-style-type: none"> • Children with the highest dose had higher mean IQ and more expressive speech than the comparison group. • Behavior problems decreased in both groups. • The intensively treated children achieved clinically meaningful gains relative to the comparison group.
Jocelyn et al., 1998	35	EIBI	<i>Not reported</i>	12 weeks	TAU control group	S	<ul style="list-style-type: none"> • There were greater gains in language and increased caregivers knowledge about autism and parent satisfaction in the experimental caregiver group.
Sheinkopf & Siegel, 1998	22	UCLA	<i>M=27 vs. 11.1</i>	<i>15.7 vs. 18</i>	TAU control group	H,R,RW, S, V	<ul style="list-style-type: none"> • Children in the treatment group had significantly higher posttreatment IQ scores.
Weiss, 1999	20	EIBI	40	24	None	M, R, V	<ul style="list-style-type: none"> • Initial acquisition of skills was correlated with later learning rates, severity of autism symptomatology and adaptive behavior two years into treatment.
Harris & Handleman, 2000	27	EIBI	35 to 40	93	None	R,V, W	<ul style="list-style-type: none"> • A higher IQ at intake and being of younger age were both predictive of being in a regular education class after discharge, whereas having a lower IQ and being older at intake were closely related to placement in a special education classroom.
Luiselli et al., 2000	16	EIBI	6 to 20	5 to 22	Under 3 yr and over 3 yrs	W	<ul style="list-style-type: none"> • Children who were involved in services before and after 3 years of age all had significant changes on six developmental domains • There were no significant differences between these groups. • Overall improvement was predicted by the duration of time that a child spent in home-based intervention.
Smith, Groen, & Wynn, 2000	28	UCLA	24.5 vs. 15 to 20	33.4 vs. 24	Parent training control group	E, H, R,RW, M,S, V,W	<ul style="list-style-type: none"> • At follow-up, the intensive treatment group outperformed the parent training group on measures of intelligence, visual-spatial skills, language, and academics, though not adaptive functioning or behavior problems.
Boyd & Corley, 2001	22	UCLA	20 to 30	23	None	R, RW, W	<ul style="list-style-type: none"> • There were no instances of 'recovery' to typical functioning but parental satisfaction was high with the treatment.

Mudford et al., 2001	75	EIBI	32	20 to 40 (21)	None	W	<ul style="list-style-type: none"> • Most children started treatment later than in Lovaas (1987; 57%), and 16% did not exceed minimum IQ criterion.
Bibby et al., 2002	66	UCLA	$M=30.3$	32.8	None	R,RW, V, W	<ul style="list-style-type: none"> • After intervention, IQ scores had not changed but adaptive behavior scores increased significantly. No children aged >72 months attained normal functioning, and some did receive mainstream placement.
Eikeseth et al., 2002	25	UCLA	$M=28$ vs. 29.1	12.2 vs. 13.6	Eclectic control group	E, H,R,S, V, W	<ul style="list-style-type: none"> • The behavioral treatment group made significantly larger gains on standardized tests compared to the eclectic treatment group.
Bernard-Opitz, Ing, & Kong, 2004	8	EIBI	6 and 10 at home with parents	10 weeks	Naturalistic language play paradigm, cross over	S	<ul style="list-style-type: none"> • Gains in attending and compliance were higher following the behavioral condition compared to the natural play condition. • Seven participants had reduced autism scores after the intervention.
Beglinger & Smith, 2005	37	EIBI	30-40	0 to 44	subtypes of ASD	C, W	<ul style="list-style-type: none"> • All three social subtypes (active, passive, aloof) were present and correlated with IQ after a period of intervention and change in IQ.
Howard et al., 2005	61	EIBI	25-40 vs. 25-30 vs. 15	13.6 vs. 14.2 vs. 13.3	2 Eclectic control groups	C,E,H, M,R,S, V,W	<ul style="list-style-type: none"> • The IBT group received statistically significant higher mean standard scores than the two eclectic control groups. • The eclectic control groups did not differ in terms of mean scores. • Learning rates were higher for the IBT group than the other groups at follow up.
Matos & Mustaca, 2005	9	UCLA	30	9 to 12	None	R,V	<ul style="list-style-type: none"> • Gains were evident in intellectual functioning, communication, and socialization. • Autism symptoms also were reduced significantly.
Sallows & Graupner, 2005	23	UCLA	$M=37.6$ vs. 31.3	48	Lower dosage tx control group	C, H, M, R,RW,S, V	<ul style="list-style-type: none"> • 48% of all children achieved average scores at follow up, and at age 7, were in regular education classrooms. • Pretreatment imitation, language, and social responsiveness skills predicted later treatment outcomes.

Cohen et al., 2006	42	UCLA	35-40	36	Eclectic control group	C, E, H, M, R, RW, S, V, W	<ul style="list-style-type: none"> The EIBT group had significantly higher IQ and adaptive behavior scores than the eclectic comparison group. There was no difference found between groups for language comprehension and nonverbal skills. Six of the 21 EIBT children were fully included into regular education and 11 others were also, with support. Only 1 child from the eclectic group was placed in regular education.
Eldevik et al., 2006	28	UCLA	12.5 vs. 12	20.3 vs. 21.4	Eclectic control group	E, H, M, R, RW, S, V, W	<ul style="list-style-type: none"> After 2 years of treatment, the behavioral group made larger gains than the eclectic group in intellectual functioning and communication.
Baker-Ericzen et al., 2007	158	PRT	1	12	None	R, V, W	<ul style="list-style-type: none"> All the children showed significant improvements in adaptive functioning. Younger children showed the least impairment at intake and the most improvement at follow up.
Ben-Itzhak & Zachor, 2007	25	EIBI	35	12	None	C, M, R, V, W	<ul style="list-style-type: none"> Significant progress was made after 1 year of intervention. Children with higher initial cognitive levels and fewer social interaction deficits had better acquisition in receptive and expressive language and play skills. More progress in expressive language was associated with social abilities, and progress in play skills was associated with pre-intervention cognitive level.
Eikeseth et al., 2007	25	UCLA	<i>M</i> =28 vs. 29.1	31.4 vs. 33.3	Eclectic control group	R, RW, S, H, V, W	<ul style="list-style-type: none"> At an average age of approximately 8 years, the behavioral treatment group showed more increases in IQ and adaptive functioning than the eclectic group. The behavioral treatment group displayed less aberrant behaviors and social problems at follow-up.
Magiati et al., 2007	44	UCLA	<i>M</i> =32.4 vs. 25.6	25.5 vs. 26	Eclectic control group	R, RW, V, S, M, H, C	<ul style="list-style-type: none"> Both groups showed improvements in age equivalent scores. There were no significant group differences in cognitive ability, language, play or severity of autism at follow-up.
Reed et al., 2007a	27	EIBI	<i>M</i> = 30.4 vs. 12.6	9 to 10	High vs low intensity	R, M, V, W	<ul style="list-style-type: none"> Largest gains were observed for the high intensity group with gains in intellectual and educational functioning.

Reed et al., 2007b	48	EIBI	<i>M</i> =30.4 vs. 12.7 vs. 8.5	10	Special nursery placement or portage	R, V, M	<ul style="list-style-type: none"> Children in the ABA condition made greater intellectual and educational gains than children in the portage program. They also made greater educational gains than students in the nursery program.
Remington et al., 2007	44	EIBI	<i>M</i> =25.6 vs. 15.3	24	TAU control group	R, E, V, M, H, C, W	<ul style="list-style-type: none"> After 2 years, robust differences were observed on measures of intelligence, language, daily living skills, positive social behavior for children in EIBI compared to the TAU group.
Zachor et al., 2007	39	EIBI	35 vs. 40	12	Eclectic control group	W	<ul style="list-style-type: none"> The ABA group showed significantly greater improvements than the Eclectic group at follow-up. Pre-post intervention differences in language and communication domain were significant for the ABA group. Both groups showed significant improvement in reciprocal social interaction.
Anan et al., 2008	72	EIBI	15	2.8	None	R, V	<ul style="list-style-type: none"> Analyses revealed gains on the Mullen Early Learning Composite and the Vineland Adaptive Behavior Composite after 12 weeks of treatment. Additionally, 14% and 11% of the children moved from the 'impaired' to 'non-impaired' range on Mullen and Vineland composite scores.
Ben-Itzhak, et al., 2008	81	EIBI	45	12	TAU control group	R, W, V	<ul style="list-style-type: none"> The groups did not differ in the change in core autism symptoms post-intervention. IQ scores increased significantly more in the autism group than with the DD group. IQ improvements were significantly correlated with reduction in autism symptoms and stereotyped behaviors.
Perry et al., 2008	332	EIBI	20 to 40	4 to 47	None	W, C	<ul style="list-style-type: none"> Results indicated statistically significant and clinically significant improvements in the reduction in autism severity, gains in cognitive and adaptive levels, and rate of development. The majority of children (75%) showed some gains during IBI and 11% achieved average functioning.

Hayward et al., 2009	44	UCLA	36	12	Parent training control group	W	<ul style="list-style-type: none"> Children in both groups improved significantly on IQ, visual-spatial IQ, receptive and expressive language, social skills, motor skills and adaptive behavior. Mean IQ for participants in both groups increased by 16 points between intake and follow-up.
Granpeesheh et al., 2009	245	EIBI	<i>M</i> =76.65 in a month	4	None	W, C	<ul style="list-style-type: none"> The younger participants showed a greater benefit from increased treatment hours and there was a significant increase in new skill acquisition with increased treatment hours.
Dawson et al., 2010	48	Denver	15 to 16	24	Community intervention group	W,C	<ul style="list-style-type: none"> Compared with children who received community-intervention, children who received ESDM showed significant improvements in IQ, adaptive behavior, and autism diagnosis.
Smith et al., 2010	45	PRT	15,10,5-tapered	12,6,3 - tapered	Two cohorts	C	<ul style="list-style-type: none"> Gains were observed on expressive and receptive language measures for children with an IQ of 50 and for children with IQs less than 50. Behavior problems decreased significantly over the 1-year treatment for both groups, but autism symptoms decreased only for those with an IQ of 50 or more.
Fava et al., 2011	22	EIBI	14 vs. 12	6	Eclectic control group	C	<ul style="list-style-type: none"> The intervention group outperformed the eclectic group in measures of autism severity, developmental and language skills. The intervention group reduced challenging behaviors.
Fernell et al., 2011	198	EIBI	15,25-30, or 30-40	24	Non-intensive group	C	<ul style="list-style-type: none"> Vineland composite scores increased and there was no significant difference between the intensive and non-intensive groups.
Perry et al., 2011	332	EIBI	20 to 40	4 to 47 (18)	Younger vs. older in analyses	C	<ul style="list-style-type: none"> Children who achieved average functioning had higher developmental levels at intake, were younger than the rest of the children, and were in treatment longer.
Eikeseth et al., 2012	59	UCLA	15 to 37	24	TAU control group	C	<ul style="list-style-type: none"> Children in the EIBI group showed significant improvements in adaptive behaviors, maladaptive behaviors, and autism symptoms after one year of treatment, and this change continued into year 2 to a lesser degree.

Flanagan et al., 2012	142	EIBI	20-35	24	Waitlist group	C	<ul style="list-style-type: none"> The E?IBI group had better outcomes in all measured areas (milder autism severity, higher adaptive functioning, and higher cognitive skills). Younger initial age predicted better cognitive outcomes in the E?IBI group but not the Waitlist group. Higher initial adaptive skills predicted better outcomes in both groups.
Strauss et al., 2012	44	EIBI	10 at home, 25 center base	6	Eclectic control group	C	<ul style="list-style-type: none"> The EIBI group outperformed the eclectic group in measures of autism severity, developmental and language skills. Parent training and parent-mediated treatment provision led to reduced challenging behaviors and increased treatment fidelity.
Eapen et al., 2013	26	Denver	15-20	10	None	C	<ul style="list-style-type: none"> Improvements were found in children's performance in the visual reception, receptive language and expressive language domains. Parents reported significant increases in their child's receptive communication and motor skills and a significant decrease in autism-specific features.
Stock et al., 2013	14	PRT	15-25 vs 15,10,5 (taper)	12	Low intensity EIBI comparison group	C	<ul style="list-style-type: none"> Statistically significant changes in cognitive scores, receptive and expressive language age equivalents, and problem behavior scores were observed for both groups. No significant results for either adaptive behavior or parenting stress scores.
Virues-Ortega & Rodriguez, 2013	24	EIBI	15-47	24	None	C	<ul style="list-style-type: none"> Total intervention time, pre-intervention functioning, and age contributed to the greatest increases in skills.
Vivanti et al., 2013	21	Denver	15-25	12	None	C	<ul style="list-style-type: none"> Children with more functional use of objects, goal understanding and imitation made the most developmental gains. Cognitive abilities, social attention, intensity of the treatment and chronological age were not associated with treatment gains.
Howard et al., 2014	61	EIBI	25-30 vs. 15-17	14	Eclectic control group	C	<ul style="list-style-type: none"> At 3 years of follow up, children who received EIBI were twice as likely to score in the normal range on measures of cognitive, language, and adaptive functioning than were children who eclectic interventions.

MacDonald et al., 2014	141	EIBI	20-30	7-15	Typically developing preschool group	C	<ul style="list-style-type: none"> Results indicate significant gains with the greatest gains seen in the children who entered treatment prior to 2 years old. Increases were seen on joint attention, play, imitation and language while decreases were seen in stereotypy.
Rivard et al., 2014	93	EIBI	16-20	12	None	C	<ul style="list-style-type: none"> IQ, adaptive behavior, and socio-emotional competencies improved and autism symptoms decreased marginally.
Vivanti et al., 2014	27	Denver	15-25	12	Eclectic treatment group	C	<ul style="list-style-type: none"> Children in both groups made gains in cognitive, adaptive and social skills. The ESDM (spell out once) group had significantly higher gains in receptive language developmental rate.
Estes et al., 2015	39	Denver	20	24	TAU control group	C	<ul style="list-style-type: none"> The ESDM group maintained gains during the 2-year follow-up period in intellectual ability, adaptive behavior, symptom severity, and challenging behavior. The ESDM group had improved core autism symptoms and adaptive behavior as compared with the TAU group. The two groups were not significantly different in intellectual functioning at age 6.
Smith et al., 2015a	118	PRT	15,10,6 (taper)	12	Higher IQ, Moderate low IQ, and Very low IQ	C	<ul style="list-style-type: none"> Gains were observed in language and cognitive outcomes and were significant for all groups. Baseline cognitive scores significantly predicted 1-year outcomes.
Smith et al., 2015b	71	EIBI	15-20	24	None	C	<ul style="list-style-type: none"> Younger age and higher IQ at intake predicted outcomes at 12 and 24 months. Adjusting for age, IQ, baseline predictor scores, EIBI hours, treatment site, and sensorimotor rituals, social engagement predicted later IQ and adaptive behavior.

Notes: Meta- analyses/literature reviews: R= Reichow, 2012; Eldevik et al., 2009; Reichow & Wolery, 2009; S= Spreckley & Boyd, 2009; H=Howlin, Magiati, & Charman, 2009; Virués-Ortega, 2010; Makrygianni & Reed, 2010; Warren et al., 2011, Caron, Berube, & Paquet, 2017; M= mean; Tx=treatment; IQ= Intellectual Quotient; EIBI= Early intensive behavioral intervention; Denver= Early Start Denver Model; PRT= Pivotal Response Training; UCLA= University of California at Los Angeles model; TAU= treatment as usual; ABA= Applied Behavior Analysis

Table 2

Variables utilized from each dataset

Dataset	Variable	Type	Coding
MMIS	Delay to service in months	Continuous	Subtract date of ASD Dx from IST start date
MMIS	Age at diagnosis	Continuous	Age in years of first claim (checked 12 mo prior)
MMIS	Intellectual disability status	Categorical	Billing codes for mild, moderate, severe, profound, and unspecified recoded into binary variable
MMIS	Disability category	Categorical	Billing code ICD-9-CM 299 recoded as binary for autistic disorder
MMIS	Date of birth	Categorical	Used for matching and linking datasets
MMIS	Race	Categorical	Not recoded
MMIS	Gender	Categorical	Not recoded
MMIS	County of residence	Categorical	Used first entered
MMIS	Procedure codes	Categorical	Unduplicated and used to classify billing claims or dates of service (IST, PT, OT, SP)
MMIS	Individualized Skills Training (IST)	Categorical	CTSS billing codes included H2014 UA and H2014 UA HR
MMIS	Occupational therapy	Categorical	CTSS billing codes included 97110 GO and 97530 GO
MMIS	Physical therapy	Categorical	CTSS billing code 97110 GP and 97530 GP
MMIS	Speech therapy	Categorical	CTSS billing code 92507 GN
MMIS	Start and end service dates	Continuous	Sum of the number service days for each type of service
MMIS	Total hours of service	Continuous	Sum of each unit of service for each type of service (e.g., 1 unit of IST= 15 min)
MARSS	Grade level	Ordinal	Not recoded
MARSS	Special ed status	Categorical	Not recoded
MARSS	Instructional setting	Categorical	Not recoded
MARSS	Primary disability	Categorical	Not recoded
MARSS	Sped service hours	Continuous	Unduplicated and sum all together
MARSS	Free or reduced lunch	Categorical	Recoded into binary for each
MCA	Reading scale score	Continuous	Not recoded
MCA	Math scale score	Continuous	Not recoded
MCA	Science scale score	Continuous	Not recoded
MCA	Reading proficiency	Categorical	Not recoded

MCA	Math proficiency	Categorical	Not recoded
MCA	Science proficiency	Categorical	Not recoded

Note: IST= individualized skills training; CTSS= Children's therapeutic services and supports; ASD= autism spectrum disorder; MARSS= Minnesota automated reporting student system; MMIS= Medicaid Management Information System; MCA=Minnesota Comprehensive Assessment

Table 3

Percentage of the Sample (n=667) with Group Characteristic

Characteristics	% of sample
Gender^{a,b}	
Female	17.8%
Male	82.2%
Race/ethnicity^{a,b}	
American Indian	2.4%
Asian	5.1%
Hispanic	6.1%
Black	14.7%
White	71.7%
Age of ASD diagnosis^a	
2- years old	3.4%
3- years old	29.7%
4 -years old	35.4%
5 -years old	26.5%
6-years old	4.9%
Free/Reduced Price Lunch receipt	64.5%
Homeless^b	1.4%
Limited English Proficiency^b	5.9%
Comorbid Disability^a	
Language disorder	39.0%
Developmental delay	15.4%
Mild intellectual disability (IQ 50-70)	7.5%
Moderate intellectual disability (IQ 35-49)	5.8%
Severe intellectual disability (IQ 20-34)	3.4%
Profound intellectual disability (IQ <20)	0.7%
Unspecified Intellectual disability	20.4%
Average hours of EIBI per week^a	19.04 (12.00)*
Average delay to EIBI in months^a	8.99 (10.63)*
Received Speech and Language Therapy^a	51.9%
Received Occupational Therapy^a	42.9%
Received Physical Therapy^a	12.4%

Note. * indicates estimate is represented by a mean (sd). ^a indicates the variable is from the MMIS dataset and ^b indicates the variable is from the MARSS dataset.

Table 4

MMIS dataset 2008-2010 Independent Variables

Demographics	Average delay to EIBI in months	Average age of ASD diagnosis	Average hours per week of EIBI	SLT Receipt	OT Receipt	PT Receipt
Gender						
Female (n=119)	8.29 (10.48)	3.87 yrs (0.94)	19.41 (12.42)	49%	47%	13%
Male (n=548)	9.14 (10.65)	3.99 yrs (0.89)	18.96 (11.92)	53%	55%	12%
Racial group						
American Indian(n= 16)	5.13 (5.85)	4.46 yrs (0.81)	10.44 (6.42)	50%	25%	13%
Asian (n=34)	8.15 (8.96)	4.07 yrs (0.84)	23.12 (11.05)	44%	50%	15%
Hispanic (n= 41)	7.59 (8.76)	4.00 yrs (0.85)	15.76 (12.40)	59%	44%	10%
Black (n=98)	10.96 (11.84)	3.82 yrs (0.87)	17.81 (12.39)	65%	50%	9%
White (n=478)	8.90 (10.67)	3.97 yrs (0.91)	19.57 (11.92)	49%	41%	13%
Residence						
Metro (n=460)	9.89 (11.24)	3.97 yrs (0.90)	19.36 (12.45)	59%	48%	13%
Non-metro (n=207)	7.00 (8.78)	3.97 yrs (0.90)	18.33 (10.94)	37%	31%	11%
Comorbid Disability						
Language Disorder (n=260)	10.17 (11.17)	3.90 yrs (0.90)	17.34 (11.85)	84%	63%	16%
Developmental delay (n=103)	9.09 (10.84)	3.92 yrs (0.93)	17.77 (11.33)	74%	59%	23%
Mild ID (n=50)	11.92 (12.00)	4.33 yrs (0.80)	17.86 (10.47)	66%	52%	16%
Moderate ID (n=39)	12.92 (12.62)	4.08 yrs (0.76)	18.88 (12.73)	54%	51%	8%
Severe ID (n=23)	16.22 (12.82)	3.85 yrs (0.77)	19.98 (12.81)	65%	57%	30%
Profound ID (n=5)	11.20 (10.85)	4.33 yrs (0.44)	14.93 (8.07)	60%	80%	20%
Unspecified ID (n=136)	11.75 (11.82)	3.78 yrs (0.82)	19.49 (12.00)	65%	54%	21%

Table 5

EIBI service information

EIBI Service Provision	Total Sample (n=667)	Residence	
		Metro (n=460)	Non-Metro (n=207)
Place of Service			
Home	402 (60%)	273 (59%)	129 (62%)
Office	228 (34%)	174 (38%)	54 (26%)
School	18 (3%)	2 (.4%)	16 (8%)
Community Mental Health Center	17 (3%)	10 (2%)	7 (3%)
Mobile Unit	2 (.3%)	1 (.2%)	1 (.2%)
EIBI Service Professional			
Psychologist	430 (65%)	308 (67%)	122 (59%)
Social Worker	134 (20%)	80 (17%)	54 (26%)
Marriage and Family Therapist	88 (13%)	66 (14%)	22 (11%)
Mental Health Provider	9 (1%)	2 (.4%)	7 (3%)
Licensed Clinical Counselor	3 (.4%)	2 (.4%)	1 (.5%)
Undefined	3 (.4%)	2 (.4%)	1 (.5%)
Number of EIBI Service Provision Companies⁺			
	59	27	29 ⁺
Average age in years to start EIBI services			
	4.70 yrs	4.79 yrs	4.50 yrs

Note: ⁺ indicates that 3 of the companies' information was no longer available.

Table 6

Comorbid early childhood special education services through Minnesota Public Schools for SY2010

Demographics	Primary Diagnosis DD	Primary Diagnosis ASD	Average special education service hours	Eligible for Free/reduced meal
Total Sample (n=274)	109 (39.8%)	129 (47.1%)	321.81 (385.52)	97 (35.4%)
Gender				
Female (n=54)	23 (42.6%)	12 (22.2%)	364.49 (665.31)	18 (33.3%)
Male (n=220)	86 (39.1%)	104 (47.3%)	311.33 (278.55)	79 (35.9%)
Racial group				
American Indian(n=5)	2 (40.0%)	0	167.86 (126.98)	2 (40.0%)
Asian (n=13)	5 (38.5%)	7 (53.8%)	370.54 (196.45)	2 (15.4%)
Hispanic (n=18)	7 (38.9%)	8 (44.4%)	277.84 (192.56)	7 (38.9%)
Black (n=49)	20 (40.8%)	27 (55.1%)	390.93 (293.31)	31 (63.4%)
White (n=189)	75 (39.7%)	87 (46.0%)	308.80 (430.47)	51 (27.0%)
Residence				
Metro (n=188)	71 (37.8%)	96 (51.1%)	348.46 (442.83)	60 (31.9%)
Non-metro (n=86)	38 (44.2%)	33 (38.4%)	263.56 (202.29)	37 (43.0%)
Comorbid Disability				
Language Disorder (n=113)	46 (40.7%)	59 (52.2%)	350.15 (517.12)	38 (33.6%)
Mild ID (n=12)	6 (50.0%)	5 (41.7%)	261.05 (216.95)	5 (41.7%)
Moderate ID (n=10)	5 (50.0%)	3 (30.0%)	418.32 (389.43)	3 (30.0%)
Severe ID (n=3)	1 (3.0%)	2 (66.7%)	563.80 (211.34)	1 (3.0%)
Unspecified ID (n=58)	0	4 (6.9%)	413.80 (315.25)	22 (37.9%)

Note: DD=Developmental Delay; Means and standard deviations are reported for special education hours.

Table 7

Comorbid early childhood special education services through Minnesota Public Schools for SY2011

Demographics	Primary Diagnosis DD	Primary Diagnosis ASD	Average special education service hours	Eligible for free/reduced meal
Total Sample (n=148)	47 (31.8%)	83 (56.1%)	344.54 (306.16)	51 (34.5%)
Gender				
Female (n=31)	8 (25.8%)	18 (58.1%)	334.30 (213.70)	10 (32.3%)
Male (n=117)	39 (33.3%)	65 (55.6%)	347.25 (327.02)	41(35.0%)
Racial group				
American Indian(n= 4)	4 (100%)	0	339.68 (353.73)	4 (100%)
Asian (n=6)	2 (33.3%)	4 (66.7%)	269.18 (139.21)	0
Hispanic (n=10)	2 (20.0%)	5 (50.0%)	260.72 (235.63)	5 (50.0%)
Black (n=25)	6 (24.0%)	15 (60.0%)	522.07 (478.73)	17 (68.0%)
White (n=103)	33 (32.0%)	59 (57.3%)	314.17 (248.91)	25 (24.3%)
Residence				
Metro (n=92)	21 (22.8%)	61 (66.3%)	366.84 (348.55)	34 (37.0%)
Non-metro (n=56)	26 (46.4%)	22 (39.3%)	307.91 (217.55)	17 (30.4%)
Comorbid Disability				
Language Disorder (n=62)	18 (29.0%)	39 (62.9%)	369.58 (351.89)	25 (40.3%)
Mild ID (n=4)	3 (75.0%)	1 (25.0%)	511.65 (324.29)	2 (50.0%)
Moderate ID (n=6)	1 (16.7%)	3 (50.0%)	476.52 (641.28)	2 (33.3%)
Severe ID (n=4)	1 (25.0%)	3 (75.0%)	419.35 (527.31)	0
Unspecified ID (n=30)	9 (30.0%)	15 (50.0%)	458.78 (402.65)	13 (43.3%)

Note: DD= Developmental Delay; Means and standard deviations are reported for special education hours.

Table 8

Comorbid early childhood special education services through Minnesota Public Schools for SY2012

Demographics	Primary Diagnosis DD	Primary Diagnosis ASD	Average special education service hours	Eligible for free/reduced meal
Total Sample (n=62)	21 (33.9%)	31 (50.0%)	409.15 (308.55)	19 (30.6%)
Gender				
Female (n=15)	4 (26.7%)	6 (40.0%)	301.63 (248.18)	2 (13.3%)
Male (n=47)	17 (36.2%)	25 (53.2%)	443.47 (320.20)	17 (36.2%)
Racial group				
American Indian(n= 1)	1 (100%)	0	1408.00	1 (100%)
Asian (n=1)	1 (100%)	0	124.00	1 (100%)
Hispanic (n= 5)	2 (40.0%)	2 (40.0%)	584.68 (371.53)	1 (20.0%)
Black (n=9)	2 (22.2%)	6 (66.7%)	509.68 (392.11)	6 (66.7%)
White (n=46)	15 (32.6%)	23 (50.0%)	354.89 (238.78)	10 (21.7%)
Residence				
Metro (n=36)	7 (19.4%)	22 (61.1%)	408.03 (318.72)	10 (27.8%)
Non-metro (n=26)	14 (53.8%)	9 (34.6%)	410.71 (300.13)	9 (34.6%)
Comorbid Disability				
Language Disorder (n=26)	7 (26.9%)	16 (61.5%)	424.56 (329.46)	9 (34.6%)
Mild ID (n=3)	2 (66.7%)	1 (33.3%)	807.40 (600.39)	2 (66.7%)
Moderate ID (n=1)	0	0	217.50	0
Severe ID (n=1)	1 (100%)	0	854.80	1 (100%)
Unspecified ID (n=15)	4 (26.7%)	10 (66.7%)	543.63 (380.87)	6 (40.0%)

Note: DD= Developmental Delay; Means and standard deviations are reported for special education hours.

Table 9

Comorbid early childhood special education services through Minnesota Public Schools for SY2013

Demographics	Primary Diagnosis DD	Primary Diagnosis ASD	Average special education service hours	Eligible for free/reduced meal
Total Sample (n=9)	3 (33.3%)	6 (66.7%)	273.29 (241.20)	3 (33.3%)
Gender				
Female (n=2)	0	2 (100%)	420.60 (534.71)	0
Male (n=7)	3 (42.9%)	4 (57.1%)	231.20 (143.58)	3 (42.9%)
Racial group				
Black (n=2)	0	2 (100%)	163.60 (171.26)	1 (50.0%)
White (n=7)	3 (42.9%)	4 (57.1%)	304.63 (259.85)	2 (27.8%)
Residence				
Metro (n=5)	1 (20.0%)	4 (80.0%)	192.84 (115.13)	2 (40.0%)
Non-metro (n=4)	2 (50.0%)	2 (50.0%)	373.85 (336.45)	1 (25.0%)
Comorbid Disability				
Language Disorder (n=3)	1 (33.3%)	2 (66.7%)	184.90 (159.46)	3 (100%)
Unspecified ID (n=2)	1 (50.0%)	1 (50.0%)	189.60 (134.49)	1 (50.0%)

Note: DD= Developmental Delay; Means and standard deviations are reported for special education hours.

Table 10

Educational Outcomes by School Year (SY)

Educational variables	SY 2010 (n=326)	SY 2011 (n=451)	SY 2012 (n=543)	SY 2013 (n=609)	SY 2014 (n=607)
Grade level					
Kindergarten	57.0%	31.7%	18.0%	10.8%	2.5%
1	35.3%	37.7%	26.2%	17.2%	10.7%
2	7.7%	25.7%	31.3%	24.0%	16.1%
3		4.9%	20.3%	28.1%	22.7%
4			4.2%	15.8%	26.2%
5				4.1%	17.6%
6					4.1%
Qualified for Special Ed	97.2%	94.9%	95.0%	94.4%	94.0%
Primary diagnosis of ASD	71.4%	71.0%	70.5%	70.6%	69.9%
Special education service hours average	220.02 (314.61)	177.12 (345.29)	183.26 (325.82)	115.80 (272.46)	117.98 (290.84)
Instructional setting					
General education	44.5%	44.1%	40.9%	41.3%	40.7%
Resource room	15.6%	14.9%	15.8%	15.9%	17.1%
Self- contained	35.3%	36.1%	37.4%	37.4%	36.4%
Restricted school	4.6%	4.9%	5.9%	5.4%	5.8%
Participation in MCAs					
Reading ⁺		45.5%	52.6%	57.9%	56.9%
Math ⁺		45.5%	54.1%	58.6%	56.4%
Science ⁺⁺				36.0%	53.3%

Note. The estimates for average special education service hours is represented by a mean (sd). + indicates that the sample only includes 3rd graders and above . ++ indicates that only 5th graders participated.

Table 11

Educational outcomes SY2010

Demographics	Qualified for Special education	Primary diagnosis of ASD	Special education service hours
Gender			
Female (n=52)	49 (94.2%)	28 (53.8%)	257.57 (398.20)
Male (n=274)	268 (97.8%)	205 (74.8%)	212.89 (296.46)
Racial group			
American Indian(n= 11)	10 (90.9%)	4 (36.4%)	189.86 (217.59)
Asian (n=20)	20 (100%)	18 (90.0%)	271.59 (351.33)
Hispanic (n= 21)	20 (95.2%)	14 (66.7%)	290.18 (342.22)
Black (n=43)	42 (97.7%)	26 (60.5%)	281.10 (352.72)
White (n=231)	225 (97.4%)	171 (74.0%)	199.24 (304.72)
Residence			
Metro (n=227)	221 (97.4%)	168 (74.0%)	217.83 (312.58)
Non-metro (n=99)	96 (97.0%)	65 (65.7%)	225.04 (320.74)
Comorbid Disability			
Language Disorder (n=120)	119 (99.2%)	85 (70.8%)	269.33 (345.82)
Developmental delay (n=45)	44 (97.8%)	32 (71.1%)	194.82 (293.67)
Mild ID (n=36)	35 (97.2%)	25 (69.4%)	213.54 (323.25)
Moderate ID (n=24)	24 (100%)	20 (83.3%)	300.48 (278.27)
Severe ID (n=17)	17 (100%)	8 (47.1%)	362.48(387.92)
Profound ID (n=4)	4 (100%)	3 (75%)	469.05 (631.04)
Unspecified ID (n=64)	62 (96.9%)	43 (67.2%)	237.90 (314.61)

Table 12

Educational outcomes SY2011

Demographics	Qualified for Special education	Primary diagnosis of ASD	Special education service hours	MCA participation (22 eligible)
Gender				
Female (n=73)	68 (93.2%)	40 (54.8%)	194.23 (437.78)	2 /4 (50.0%)
Male (n=378)	360 (95.2%)	280 (74.1%)	173.82 (316.08)	8/18 (44.4%)
Racial group				
American Indian(n=12)	11 (91.7%)	5 (41.7%)	80.41 (174.42)	0/0
Asian (n=21)	21 (100%)	18 (85.7%)	263.31 (464.51)	1/1 (100%)
Hispanic (n= 30)	28 (93.3%)	21 (70.0%)	117.27 (237.91)	0/0
Black (n=60)	58 (96.7%)	40 (66.7%)	276.84 (418.81)	1/3 (33.3%)
White (n=328)	310 (94.5%)	236 (72.0%)	162.38 (331.66)	8/18 (44.4%)
Residence				
Metro (n=313)	297 (94.9%)	228 (72.8%)	192.35 (369.30)	8/17 (47.1%)
Non-metro (n=138)	131 (94.9%)	92 (66.7%)	142.60 (281.59)	2/5 (40.0%)
Comorbid Disability				
Language Disorder (n=171)	164 (95.9%)	122 (71.3%)	256.85 (406.62)	1/6 (16.7%)
Developmental delay (n=67)	64 (95.5%)	44 (65.7%)	217.32 (389.63)	1/3 (33.3%)
Mild ID (n=42)	42 (100%)	30 (71.4%)	211.87 (425.00)	1/5 (20.0%)
Moderate ID (n=28)	27 (96.4%)	22 (78.6%)	181.40 (317.24)	1/1 (100%)
Severe ID (n=15)	15 (100%)	8 (53.3%)	330.19 (504.25)	0/0
Profound ID (n=4)	4 (100%)	3 (75%)	459.28 (870.59)	0/0
Unspecified ID (n=87)	84 (96.6%)	59 (67.8%)	265.67 (459.93)	1/3 (33.3%)

Table 13

Educational outcomes SY2012

Demographics	Qualified for Special education	Primary diagnosis of ASD	Special education service hours	MCA participation (133 eligible)
Gender				
Female (n=93)	87 (93.5%)	52 (55.9%)	236.79 (366.52)	11/25 (44.0%)
Male (n=450)	429 (95.3%)	331 (73.6%)	172.20 (316.08)	61/108 (56.5%)
Racial group				
American Indian(n= 15)	14 (93.3%)	6 (40.0%)	202.35 (359.56)	1/3 (33.3%)
Asian (n=26)	26 (100%)	22 (84.6%)	177.14 (124.52)	3/6 (50.0%)
Hispanic (n= 34)	32 (94.1%)	24 (70.6%)	124.52 (233.47)	6/8 (75.0%)
Black (n=77)	76 (98.7%)	50 (64.9%)	254.03 (356.84)	5/17 (29.4%)
White (n=391)	368 (94.1%)	281 (71.9%)	174.10 (322.75)	57/99 (57.6%)
Residence				
Metro (n=374)	359 (96.0%)	272 (72.7%)	212.84 (350.78)	51/93 (54.8%)
Non-metro (n=169)	157 (92.9%)	111 (65.7%)	117.79 (251.09)	20/40 (50.0%)
Comorbid Disability				
Language Disorder (n=207)	202 (97.6%)	146 (70.5%)	246.42 (368.10)	16/42 (38.1%)
Developmental delay (n=80)	78 (97.5%)	50 (62.5%)	218.53 (367.00)	8/21 (39.1%)
Mild ID (n=42)	42 (100%)	31 (73.8%)	197.41 (376.00)	7/19 (36.8%)
Moderate ID (n=34)	34 (100%)	26 (76.5%)	230.69 (345.82)	4/10 (40.0%)
Severe ID (n=19)	19 (100%)	11 (57.9%)	196.68 (355.74)	0/5
Profound ID (n=5)	5 (100%)	3 (60.0%)	327.90 (612.97)	0/4
Unspecified ID (n=106)	103 (97.2%)	72 (67.9%)	265.68 (398.80)	10/29 (34.5%)

Table 14

Educational outcomes SY2013

Demographics	Qualified for Special education	Primary diagnosis of ASD	Special education service hours	MCA participation (292 eligible)
Gender				
Female (n=111)	103 (92.8%)	63 (56.8%)	162.97 (327.78)	26/51 (51.0%)
Male (n=498)	472 (94.8%)	367 (73.7%)	105.29 (257.74)	145/241 (60.2%)
Racial group				
American Indian(n= 16)	15 (93.8%)	7 (43.8%)	80.16 (225.45)	6/10 (60%)
Asian (n=29)	29 (100%)	24 (82.8%)	83.25 (279.69)	7/12 (58.3%)
Hispanic (n= 39)	37 (94.9%)	24 (61.5%)	97.72 (228.19)	12/19 (63.2%)
Black (n=90)	88 (97.8%)	60 (66.7%)	148.93 (285.87)	14/37 (37.8%)
White (n=435)	406 (93.3%)	315 (72.4%)	114.05 (274.77)	132/214 (61.7%)
Residence				
Metro (n=417)	399 (95.7%)	309 (74.1%)	125.02 (293.78)	123/206 (59.7%)
Non-metro (n=192)	176 (91.7%)	121 (63.0%)	95.77 (218.50)	48/86 (55.8%)
Comorbid Disability				
Language Disorder (n=236)	228 (96.6%)	168 (71.2%)	141.67 (307.82)	46/103 (44.7%)
Developmental delay (n=94)	90 (95.7%)	61 (64.9%)	169.58 (338.54)	18/41 (43.9%)
Mild ID (n=48)	47 (97.8%)	35 (72.9%)	115.36 (290.34)	16/35 (45.7%)
Moderate ID (n=37)	37 (100%)	25 (70.3%)	65.10 (159.53)	8/21 (38.1%)
Severe ID (n=20)	20 (100%)	11 (55.0%)	157.97 (338.52)	1/15 (6.7%)
Profound ID (n=5)	5 (100%)	3 (60.0%)	310.68 (651.39)	0/5
Unspecified ID (n=123)	119 (96.7%)	85 (69.1%)	193.50 (386.05)	21/55 (38.2%)

Table 15

Educational outcomes SY2014

Demographics	Qualified for Special education	Primary diagnosis of ASD	Special education service hours	MCA participation (429 eligible)
Gender				
Female (n=107)	99 (92.5%)	59 (55.1%)	132.05 (299.42)	35/67 (52.2%)
Male (n=500)	472 (94.4%)	365 (73.0%)	114.97 (289.19)	195/362 (53.9%)
Racial group				
American Indian(n= 16)	16 (100%)	6 (37.5%)	66.39 (248.20)	7/12 (58.3%)
Asian (n=28)	28 (100%)	23 (82.1%)	123.74 (285.56)	6/21 (28.6%)
Hispanic (n= 35)	32 (91.4%)	18 (51.4%)	46.34 (155.82)	14/26 (53.8%)
Black (n=87)	86 (98.9%)	59 (67.8%)	179.89 (380.17)	25/61 (41.0%)
White (n=441)	409 (92.7%)	318 (72.1%)	112.96 (279.25)	178/309 (57.6%)
Residence				
Metro (n=416)	399 (95.9%)	307 (73.8%)	147.71 (327.48)	160/303 (52.8%)
Non-metro (n=191)	172 (90.1%)	117 (61.3%)	53.23 (171.49)	70/126 (55.6%)
Comorbid Disability				
Language Disorder (n=231)	221 (95.7%)	161 (69.7%)	139.92 (332.59)	63/157 (40.1%)
Developmental delay (n=93)	90 (96.8%)	58 (62.4%)	106.35 (276.05)	24/64 (37.5%)
Mild ID (n=49)	48 (98.0%)	35 (71.4%)	158.52 (370.75)	17/43 (39.5%)
Moderate ID (n=37)	37 (100%)	24 (64.9%)	143.99 (388.55)	9/30 (30.0%)
Severe ID (n=20)	20 (100%)	11 (55.0%)	95.78 (177.75)	2/17 (11.8%)
Profound ID (n=5)	5 (100%)	3 (60.0%)	240.30 (490.84)	0/5 (0.0%)
Unspecified ID (n=125)	123 (98.4%)	86 (68.8%)	190.28 (396.41)	30/88 (34.1%)

Table 16

Instructional Placements SY2010

Demographics	General Education	Resource Room	Self-Contained Classroom	Separate school
Gender				
Female (n=52)	20 (38.5%)	8 (15.4%)	22 (42.3%)	2 (3.8%)
Male (n=274)	125 (45.6%)	43 (15.7%)	93 (33.9%)	13 (4.7%)
Racial group				
American Indian(n= 11)	4 (36.4%)	3 (27.3%)	3 (27.3%)	1 (9.1%)
Asian (n=20)	9 (45.0%)	1 (5.0%)	9 (45.0%)	1 (5.0%)
Hispanic (n= 21)	12 (42.9%)	2 (9.5%)	7 (33.3%)	0
Black (n=43)	12 (27.9%)	5 (11.6%)	23 (53.5%)	3 (7.0%)
White (n=231)	108 (46.8%)	40 (17.3%)	73 (31.6%)	10 (4.3%)
Residence				
Metro (n=227)	95 (41.9%)	35 (15.4%)	88 (38.8%)	9 (4.0%)
Non-metro (n=99)	50 (50.5%)	16 (16.2%)	27 (27.3%)	6 (6.1%)
Comorbid Disability				
Language Disorder (n=120)	42 (35.0%)	21 (17.5%)	51 (42.5%)	6 (5.0%)
Developmental delay (n=45)	12 (26.7%)	10 (22.2%)	20 (44.4%)	3 (6.7%)
Mild ID (n=36)	10 (27.8%)	8 (22.2%)	15 (41.7%)	3 (8.3%)
Moderate ID (n=24)	7 (29.2%)	3 (12.5%)	14 (58.3%)	0
Severe ID (n=17)	0	3 (17.6%)	13 (76.5%)	1 (5.9%)
Profound ID (n=4)	0	0	3 (75.0%)	1 (25.0%)
Unspecified ID (n=64)	19 (29.7%)	13 (20.3%)	28 (43.8%)	4 (6.3%)

Table 17

Instructional Placements SY2011

Demographics	General Education	Resource Room	Self-Contained Room	Separate school
Gender				
Female (n=73)	32 (43.8%)	10 (13.7%)	26 (35.6%)	5 (6.8%)
Male (n=378)	167 (44.2%)	57 (15.1%)	137 (36.2%)	17 (4.5%)
Racial group				
American Indian(n= 12)	5 (41.7%)	1 (8.3%)	4 (33.3%)	2 (16.7%)
Asian (n=21)	7 (33.3%)	4 (19.0%)	9 (42.9%)	1 (4.8%)
Hispanic (n= 30)	15 (50.0%)	5 (16.7%)	10 (33.3%)	0
Black (n=60)	19 (31.7%)	5 (8.3%)	33 (55.0%)	3 (5.0%)
White (n=328)	153 (46.6%)	52 (15.9%)	107 (32.6%)	16 (4.9%)
Residence				
Metro (n=313)	132 (42.2%)	41 (13.1%)	124 (39.6%)	16 (5.1%)
Non-metro (n=138)	67 (48.6%)	26 (18.8%)	39 (28.3%)	6 (4.3%)
Comorbid Disability				
Language Disorder (n=171)	56 (32.7%)	25 (14.6%)	78 (45.6%)	12 (7.0%)
Developmental delay (n=67)	25 (37.3%)	10 (14.8%)	29 (43.3%)	3 (4.5%)
Mild ID (n=42)	15 (35.7%)	7 (16.7%)	16 (38.1%)	4 (9.5%)
Moderate ID (n=28)	3 (10.7%)	4 (14.3%)	19 (67.9%)	2 (7.1%)
Severe ID (n=15)	0	4 (26.7%)	9 (60.0%)	2 (13.3%)
Profound ID (n=4)	0	0	3 (75.0%)	1 (25.0%)
Unspecified ID (n=87)	24 (27.6%)	12 (13.8%)	47 (54.0%)	4 (4.6%)

Table 18

Instructional Placements SY2012

Demographics	General Education	Resource Room	Self-Contained Room	Separate school
Gender				
Female (n=93)	35 (37.6%)	13 (14.0%)	40 (43.0%)	5 (5.4%)
Male (n=450)	187 (41.6%)	73 (16.2%)	163 (36.2%)	27 (6.0%)
Racial group				
American Indian(n= 15)	6 (40.0%)	1 (6.7%)	7 (46.7%)	1 (6.7%)
Asian (n=26)	10 (38.5%)	4 (15.4%)	11 (42.3%)	1 (3.8%)
Hispanic (n= 34)	12 (35.3%)	6 (17.6%)	16 (47.1%)	0
Black (n=77)	17 (22.1%)	12 (15.6%)	43 (55.8%)	5 (6.5%)
White (n=391)	177 (45.3%)	63 (16.1%)	126 (32.2%)	25 (6.4%)
Residence				
Metro (n=374)	144 (38.5%)	53 (14.2%)	157 (42.0%)	20 (5.3%)
Non-metro (n=169)	78 (46.2%)	33 (19.5%)	46 (27.2%)	12 (7.1%)
Comorbid Disability				
Language Disorder (n=207)	66 (31.9%)	29 (14.0%)	96 (46.4%)	16 (7.7%)
Developmental delay (n=80)	21 (26.3%)	14 (17.5%)	42 (52.5%)	3 (3.8%)
Mild ID (n=42)	12 (28.6%)	8 (19.0%)	18 (42.9%)	4 (9.5%)
Moderate ID (n=34)	4 (11.8%)	6 (17.6%)	21 (61.8%)	3 (8.8%)
Severe ID (n=19)	1 (5.3%)	4 (21.1%)	11 (57.9%)	3 (15.8%)
Profound ID (n=5)	0	0	4 (80.0%)	1 (20.0%)
Unspecified ID (n=106)	20 (18.9%)	18 (17.0%)	58 (54.7%)	10 (9.4%)

Table 19

Instructional Placements SY2013

Demographics	General Education	Resource Room	Self-Contained Room	Separate school
Gender				
Female (n=111)	45 (40.5%)	12 (10.8%)	48 (43.2%)	6 (5.4%)
Male (n=498)	206 (41.4%)	85 (17.1%)	180 (36.1%)	27 (5.4%)
Racial group				
American Indian(n= 16)	7 (43.8%)	3 (18.8%)	5 (31.3%)	1 (6.3%)
Asian (n=29)	11 (37.9%)	4 (13.8%)	13 (44.8%)	1 (3.4%)
Hispanic (n= 39)	18 (46.2%)	7 (17.9%)	14 (35.9%)	0
Black (n=90)	20 (22.2%)	12 (13.3%)	51 (56.7%)	7 (7.8%)
White (n=435)	195 (44.8%)	71 (16.3%)	145 (33.3%)	24 (5.5%)
Residence				
Metro (n=417)	163 (39.1%)	57 (13.7%)	175 (42.0%)	22 (5.3%)
Non-metro (n=192)	88 (45.8%)	40 (20.8%)	53 (27.6%)	11 (5.7%)
Comorbid Disability				
Language Disorder (n=236)	84 (35.6%)	34 (14.4%)	106 (44.9%)	12 (5.1%)
Developmental delay (n=94)	30 (31.9%)	13 (13.8%)	47 (50.0%)	4 (4.3%)
Mild ID (n=48)	14 (29.2%)	11 (22.9%)	20 (41.7%)	3 (6.3%)
Moderate ID (n=37)	3 (8.1%)	11 (29.7%)	23 (62.2%)	0
Severe ID (n=20)	1 (5.0%)	2 (10.0%)	17 (85.0%)	0
Profound ID (n=5)	0	0	4 (80.0%)	1 (20.0%)
Unspecified ID (n=123)	25 (20.3%)	21 (17.1%)	69 (56.1%)	8 (6.5%)

Table 20

Instructional Placements SY2014

Demographics	General Education	Resource Room	Self-Contained Room	Separate school
Gender				
Female (n=107)	46 (43.0%)	11 (10.3%)	45 (42.1%)	5 (4.7%)
Male (n=500)	201 (40.2%)	93 (18.6%)	176 (35.2%)	30 (6.0%)
Racial group				
American Indian(n= 16)	7 (43.8%)	3 (18.8%)	5 (31.3%)	1 (6.3%)
Asian (n=28)	10 (35.7%)	4 (14.3%)	13 (46.4%)	1 (3.6%)
Hispanic (n= 35)	16 (45.7%)	6 (17.1%)	13 (37.1%)	0
Black (n=87)	18 (20.7%)	13 (14.9%)	45 (51.7%)	11 (12.6%)
White (n=441)	196 (44.4%)	78 (17.7%)	145 (32.9%)	22 (5.0%)
Residence				
Metro (n=416)	157 (37.7%)	63 (15.1%)	168 (40.4%)	28 (6.7%)
Non-metro (n=191)	90 (47.1%)	41 (21.5%)	53 (27.7%)	7 (3.7%)
Comorbid Disability				
Language Disorder (n=231)	78 (33.8%)	41 (17.7%)	97 (42.0%)	15 (6.5%)
Developmental delay (n=93)	29 (31.2%)	13 (14.0%)	46 (49.5%)	5 (5.4%)
Mild ID (n=49)	12 (24.5%)	13 (26.5%)	22 (44.9%)	2 (4.1%)
Moderate ID (n=37)	5 (13.5%)	10 (27.0%)	20 (54.1%)	2 (5.4%)
Severe ID (n=20)	1 (5.0%)	2 (10.0%)	15 (75.0%)	2 (10.0%)
Profound ID (n=5)	0	0	4 (80.0%)	1 (20.0%)
Unspecified ID (n=125)	26 (20.8%)	17 (13.6%)	72 (57.6%)	10 (8.0%)

Table 21

Frequency of children whose MCA- Math scores met or exceeded proficiency by school year

	SY2011 (n=10)	SY2012 (n=72)	SY2013 (n=171)	SY2014 (n=228)
Demographics				
Total Sample	3 (30%)	34 (47%)	75 (44%)	92 (40%)
Gender				
Female	1 (10%)	4 (6%)	10 (6%)	10 (4%)
Male	2 (20%)	30 (42%)	65 (38%)	82 (36%)
Racial group				
American Indian	0	0	2 (1%)	3 (1%)
Asian	0	1 (1%)	5 (3%)	5 (2.2%)
Hispanic	0	4 (6%)	5 (3%)	3 (1%)
Black	0	0	2 (1%)	4 (2%)
White	3 (30%)	29 (40%)	61 (36%)	77 (34%)
Residence				
Metro	3 (30%)	22 (31%)	52 (30%)	65 (29%)
Non-metro	0	12 (17%)	23 (14%)	27 (12%)
Comorbid Disability				
Language Disorder	0	7 (10%)	16 (9%)	24 (11%)
Developmental delay	0	4 (6%)	7 (4%)	7 (3%)
Mild ID	0	3 (4%)	4 (2%)	3 (1%)
Moderate ID	1 (10%)	1 (1%)	2 (1%)	2 (9%)
Severe ID	0	0	0	0
Profound ID	0	0	0	0
Unspecified ID	0	6 (8%)	11 (6%)	9 (4%)

Table 22

Frequency of children whose MCA- Reading scores met or exceeded proficiency by school year

Demographics	SY2011 (n=10)	SY2012 (n=70)	SY2013 (n=169)	SY2014 (n=230)
Total Sample	3 (30%)	36 (50%)	45 (27%)	71(31%)
Gender				
Female	1 (10%)	6 (8%)	7 (4%)	10 (4%)
Male	2 (20%)	30 (42%)	38 (23%)	61 (27%)
Racial group				
American Indian	0	1(1%)	1(1%)	2 (1%)
Asian	0	1(1%)	3 (2%)	2 (1%)
Hispanic	0	3 (4%)	4 (2.4%)	3 (1.3%)
Black	0	0	0	3 (1.3%)
White	3 (30%)	31(43%)	37 (22%)	61 (27%)
Residence				
Metro	3 (30%)	25 (35%)	31 (18%)	47 (20%)
Non-metro	0	11 (15%)	14 (8%)	24 (10%)
Comorbid Disability				
Language Disorder	0	8 (11%)	7 (4%)	14 (6%)
Developmental delay	0	4 (6%)	6 (4%)	6 (3%)
Mild ID	0	2 (3%)	3 (2%)	2 (1%)
Moderate ID	1 (10%)	2 (3%)	1 (1%)	2 (1%)
Severe ID	0	0	0	0
Profound ID	0	0	0	0
Unspecified ID	0	5 (7%)	3 (2%)	6 (3%)

Table 23

Frequency of 5th graders whose MCA- Science scores met or exceeded proficiency by school year

Demographics	SY2013 (n=9)	SY2014 (n=57)
Total Sample	1 (11%)	20 (35%)
Gender		
Female	0	1 (2%)
Male	1 (11%)	19 (33%)
Racial group		
American Indian	0	0
Asian	0	1 (2%)
Hispanic	0	1 (2%)
Black	0	0
White	1 (11%)	18 (32%)
Residence		
Metro	1 (11%)	10 (18%)
Non-metro	0	10 (18%)
Comorbid Disability		
Language Disorder	0	2 (4%)
Developmental delay	0	3 (5%)
Mild ID	0	1 (2%)
Moderate ID	0	1 (2%)
Severe ID	0	0
Profound ID	0	0
Unspecified ID	0	2 (4%)

Table 24

Attrition

Demographics	MMIS/EIBI (Time 1)	SY2014 (5-6 yrs of Follow up)	Attrition/ Missing
Gender			
Female	119	107	12
Male	548	500	48
<i>Total</i>	-	-	<i>60(9.00%)</i>
Racial group			
American Indian	16	16	0
Asian	34	28	6
Hispanic	41	35	6
Black	98	87	11
White	478	441	37
<i>Total</i>	-	-	<i>60(9.00%)</i>
Residence			
Metro	460	416	44
Non-metro	207	191	16
<i>Total</i>	-	-	<i>60(9.00%)</i>
Comorbid Disability			
Language Disorder	260	231	29
Developmental delay	103	93	10
Mild ID	50	49	1
Moderate ID	39	37	2
Severe ID	23	20	3
Profound ID	5	5	0
Unspecified ID	136	125	11
<i>Total</i>	-	-	<i>56 (8.40%)</i>

Table 25

Spearman's Rank Correlational matrix for General Education Instructional Placement by School Year

	SY2010	SY2011	SY2012	SY2013	SY2014
SY2010	1.00	.69***	.58***	.54***	.50***
SY2011	.69***	1.00	.73***	.68***	.58***
SY2012	.58***	.73***	1.00	.84***	.68***
SY2013	.54***	.68***	.84***	1.00	.77***
SY2014	.50***	.58***	.68***	.77***	1.00

Note: *** $p < .001$

Table 26

Spearman's Rank Correlational matrix for a primary diagnosis of ASD by School Year

	SY2010	SY2011	SY2012	SY2013	SY2014
SY2010	1.00	.86***	.82***	.78***	.69***
SY2011	.86***	1.00	.88***	.81***	.72***
SY2012	.82***	.88***	1.00	.89***	.81***
SY2013	.78***	.81***	.89***	1.00	.92***
SY2014	.69***	.72***	.81***	.92***	1.00

Note: *** $p < .001$

Table 27

*Spearman Rank Correlational matrix for Special Education Service Hours by School**Year*

	SY2010	SY2011	SY2012	SY2013	SY2014
SY2010	1.00	.34***	.10**	.16**	.03
SY2011	.34***	1.00	.44***	.43***	.30***
SY2012	.10	.44***	1.00	.47***	.48***
SY2013	.16**	.43***	.47***	1.00	.58***
SY2014	.03	.30***	.48***	.58***	1.00

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 28

*Spearman Rank Correlational matrix for MCA- Mathematics Scaled Scores by School**Year*

	SY2011	SY2012	SY2013	SY2014
SY2011	1.00	.82**	.71	.97***
SY2012	.82**	1.00	.77***	.75***
SY2013	.71	.77***	1.00	.86***
SY2014	.97***	.75***	.86***	1.00

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 29

Spearman Rank Correlational matrix for MCA- Reading Scaled Scores by School Year

	SY2011	SY2012	SY2013	SY2014
SY2011	1.00	.70*	.86**	.86**
SY2012	.70*	1.00	.79***	.78***
SY2013	.86**	.79***	1.00	.80***
SY2014	.86**	.78***	.80***	1.00

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 30

Generalized Estimating Equation Regression Model for General Education Placement

Predictors	B	SE	Adjusted OR (95% CI)	χ^2	p
Delay to EIBI in Months	-0.04	0.01	0.97 (0.95,0.98)	18.77	<.001***
Diagnosis Age in Years	-0.35	0.08	0.71 (0.60,0.83)	19.04	<.001***
Male	0.10	0.19	1.10 (0.75,1.61)	0.25	.62
Intellectual Disability	-1.16	0.17	0.31 (0.23,0.44)	46.21	<.001***
Race- White (ref)				15.59 ⁺	.004**
Asian	-0.29	0.36	0.75 (0.37,1.52)	0.63	.43
Hispanic	0.19	0.31	1.21 (0.66,2.20)	0.38	.54
Black	-0.80	0.21	0.45 (0.30,0.69)	13.76	<.001***
American Indian	-0.33	0.52	0.72 (0.26,1.98)	0.42	.52
Non-metro residence	-0.02	0.16	0.98 (0.72,1.34)	0.01	.91
Speech services	-0.36	0.17	0.70 (0.50,0.97)	4.68	.03*
OT services	0.04	0.16	1.04 (0.75,1.43)	0.05	.82
PT services	0.01	0.23	1.01 (0.64,1.58)	0.001	.98
Free/reduced lunch recipient	0.13	0.15	1.14 (0.85,1.54)	0.79	.37
School Year- 2010 (ref)				19.71 ⁺	.001***
2011	-0.17	0.10	0.84 (0.69,1.02)	2.98	.09
2012	-0.41	0.12	0.67 (0.53,0.84)	12.41	<.001***
2013	-0.50	0.12	0.61 (0.48,0.76)	17.80	<.001***
2014	-0.54	0.12	0.59 (0.46,0.75)	18.82	<.001***

Note: * $p < .05$, ** $p < .01$, *** $p < .001$, ⁺ indicates Type- III Wald chi-square test; n=667

Table 31

Generalized Estimating Equation Regression Model for Educational ASD Diagnoses

Predictors	<i>B</i>	<i>SE</i>	<i>Adjusted OR (95% CI)</i>	χ^2	<i>p</i>
Delay to EIBI in Months	0.02	0.009	1.02 (1.01,1.04)	6.48	.01**
Diagnosis Age in Years	-0.34	0.10	0.72 (0.59, 0.86)	12.40	<.001***
Male	0.81	0.21	2.25 (1.50,3.38)	15.29	<.001***
Intellectual Disability	-0.01	0.19	0.99 (0.68,1.43)	0.004	.95
Race-White (ref)				9.74 ⁺	.05*
Asian	0.83	0.48	2.30 (0.89,5.92)	2.97	.09
Hispanic	-0.38	0.32	0.68 (0.36,1.28)	1.43	.23
Black	-0.37	0.24	0.69 (0.43, 1.11)	2.38	.12
American Indian	-0.90	0.49	0.41 (0.16,1.05)	3.43	.06
Non-metro residence	-0.39	0.19	0.68 (0.47,0.98)	4.40	.04*
Speech services	0.10	0.20	1.11 (0.76,1.63)	0.28	.60
Occupational therapy services	0.10	0.20	1.10 (0.75, 1.61)	0.24	.63
Physical therapy services	-0.79	0.25	0.46 (0.28,0.75)	9.65	.002**
Free/reduced lunch recipient	-0.87	0.19	0.42 (0.29,0.61)	20.18	<.001***
School Year- 2010 (ref)				3.79 ⁺	.44
2011	0.01	0.07	1.01 (0.88,1.17)	0.04	.85
2012	0.10	0.08	1.11 (0.94,1.31)	1.51	.22
2013	0.12	0.10	1.13 (0.94,1.37)	1.65	.20
2014	0.09	0.10	1.09 (0.89,1.34)	0.68	.41

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test; n=667

Table 32

Generalized Estimating Equation Regression Model for MCA- Reading Participation

Predictors	<i>B</i>	<i>SE</i>	<i>Adjusted OR (95% CI)</i>	χ^2	<i>p</i>
Delay to EIBI in Months	-0.02	0.01	0.98 (0.96,0.99)	4.65	.03*
Diagnosis Age in Years	-0.17	0.12	0.84 (0.66,1.07)	2.03	.15
Male	0.24	0.28	1.27 (0.73,2.20)	0.70	.40
Intellectual Disability	-1.13	0.22	0.33 (0.21,0.50)	25.23	<.001***
Race- White (ref)				10.36 ⁺	.04*
Asian	-1.07	0.50	0.34 (0.13,0.92)	4.56	.03*
Hispanic	-0.02	0.39	0.98 (0.46,2.13)	0.002	.97
Black	-0.74	0.30	0.48 (0.27,0.86)	6.07	.01**
American Indian	0.004	0.56	1.00 (0.34,3.01)	0.001	.99
Non-metro residence	-0.42	0.23	0.66 (0.42,1.03)	3.42	.07
Speech services	-0.60	0.23	0.55 (0.35,0.87)	6.70	.01**
OT services	-0.07	0.23	0.93 (0.60,1.45)	0.10	.76
PT services	0.29	0.32	1.33 (0.72,2.47)	0.82	.37
Free/reduced lunch recipient	0.18	0.22	1.20 (0.79,1.83)	0.73	.39
School Year- 2011 (ref)				12.74 ⁺	.01**
2012	-0.22	0.26	0.80 (0.48,1.32)	0.77	.38
2013	-0.36	0.29	0.70 (0.40,1.22)	1.61	.20
2014	-0.60	0.29	0.55 (0.31,0.97)	4.26	.04*

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test; n=444

Table 33

Generalized Estimating Equation Regression Model for MCA- Math Participation

Predictors	<i>B</i>	<i>SE</i>	<i>Adjusted OR (95% CI)</i>	χ^2	<i>p</i>
Delay to EIBI in Months	-0.03	0.01	0.98 (0.96,0.99)	7.13	.01*
Diagnosis Age in Years	-0.17	0.12	0.84 (0.67,1.07)	1.99	.16
Male	0.21	0.28	1.23 (0.72,2.11)	0.58	.46
Intellectual Disability	-1.14	0.22	0.33 (0.21,0.50)	26.25	<.001***
Race White (ref)				11.01 ⁺	.03*
Asian	-1.15	0.50	0.32 (0.12,0.84)	5.32	.02 *
Hispanic	0.03	0.40	1.03 (0.47,2.28)	0.01	.94
Black	-0.71	0.30	0.49 (0.28,0.87)	5.92	.02**
American Indian	-0.06	0.56	0.94 (0.32,2.81)	0.01	.91
Non-metro residence	-0.39	0.23	0.68 (0.43,1.06)	2.96	.09
Speech services	-0.64	0.24	0.53 (0.33,0.83)	7.52	.01**
OT services	-0.01	0.23	0.99 (0.63,1.56)	0.002	.98
PT services	0.33	0.33	1.40 (0.74,2.65)	1.05	.31
Free/reduced lunch recipient	0.13	0.22	1.14 (0.75,1.74)	0.36	.55
School Year 2011 (ref)				16.65 ⁺	.001***
2012	-0.08	0.21	0.92 (0.61,1.40)	0.14	.71
2013	-0.22	0.24	0.80 (0.51,1.27)	0.89	.35
2014	-0.52	0.25	0.59 (0.37,0.96)	4.47	.03*

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test; n=444

Table 34

Generalized Estimating Equation Regression Model for MCA-Reading Scale Scores

Predictors	<i>B</i>	<i>SE</i>	95% <i>CI</i>	χ^2	<i>p</i>
Delay to EIBI in Months	-0.002	0.003	(-0.008, 0.004)	0.44	.51
Diagnosis Age in Years	-0.02	0.04	(-0.10, 0.05)	0.32	.57
Male	-0.07	0.09	(-0.24, 0.10)	0.68	.41
Intellectual Disability	-0.20	0.09	(-0.38, -0.03)	5.16	.02**
Race White (ref)				11.02 ⁺	.03*
Asian	-0.06	0.15	(-0.36, 0.24)	0.15	.70
Hispanic	-0.08	0.13	(-0.34, 0.19)	0.34	.56
Black	-0.42	0.12	(-0.67, -0.18)	11.67	.001***
American Indian	-0.04	0.15	(-0.34, 0.26)	0.07	.79
Non-metro residence	-0.01	0.07	(-0.15, 0.13)	0.01	.91
Speech services	-0.11	0.07	(-0.25, 0.04)	2.21	.14
OT services	0.18	0.07	(0.04, 0.32)	6.64	.01**
PT services	0.07	0.10	(-0.12, 0.26)	0.47	.50
Free/reduced lunch recipient	-0.05	0.07	(0.20, 0.10)	0.42	.52
School Year 2011 (ref)				70.36 ⁺	<.001***
2012	-0.10	0.08	(-0.25, 0.04)	1.92	.17
2013	-0.38	0.08	(-0.53, -0.23)	24.81	<.001***
2014	-0.31	0.08	(-0.46, -0.15)	15.26	<.001***

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test; n=256

Table 35

Generalized Estimating Equation Regression Model for MCA-Math Scale Scores

Predictors	<i>B</i>	<i>SE</i>	<i>95% CI</i>	χ^2	<i>p</i>
Delay to EIBI in Months	-0.006	0.003	(-0.01, -0.001)	4.89	.03*
Diagnosis Age in Years	-0.08	0.03	(-0.14, -0.02)	6.55	.01**
Male	0.08	0.08	(-0.08, 0.24)	0.92	.34
Intellectual Disability	-0.16	0.07	(-0.30, -0.02)	5.27	.02*
Race- White (ref)				17.57 ⁺	.002**
Asian	0.12	0.14	(-0.16, 0.39)	0.69	.41
Hispanic	-0.05	0.13	(-0.30, 0.19)	0.19	.67
Black	-0.45	0.11	(-0.67, -0.23)	15.54	<.001***
American Indian	-0.02	0.16	(-0.34, 0.30)	0.02	.89
Non-metro residence	-0.03	0.06	(-0.15, 0.10)	0.18	.67
Speech services	-0.09	0.07	(-0.22, 0.04)	1.94	.16
OT services	0.08	0.06	(-0.05, 0.20)	1.45	.23
PT services	0.05	0.08	(-0.10, 0.20)	0.47	.49
Free/reduced lunch recipient	-0.06	0.07	(-0.19, 0.07)	0.78	.38
School Year- 2011 (ref)				22.94 ⁺	<.001***
2012	-0.13	0.11	(-0.34, 0.08)	1.55	.21
2013	-0.23	0.11	(-0.45, -0.02)	4.59	.03*
2014	-0.29	0.11	(-0.50, -0.08)	7.15	.01**

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test ; n=257

Table 36

Generalized Estimating Equation Regression Model for Special Education Service Hours

Predictors	<i>B</i>	<i>SE</i>	<i>95% CI</i>	χ^2	<i>p</i>
Delay to EIBI in Months	-0.01	0.01	(-0.02, 0.003)	6.28	.01**
Diagnosis Age in Years	-0.10	0.06	(-0.22, 0.02)	2.49	.11
Male	-0.33	0.13	(-0.58, -0.07)	6.19	.01**
Intellectual Disability	0.18	0.10	(-0.03, -0.37)	3.21	.09
Race- White (ref)				8.79 ⁺	.07
Asian	-0.15	0.21	(-0.56, 0.26)	0.51	.48
Hispanic	-0.23	0.17	(-0.56, 0.09)	1.98	.16
Black	0.26	0.12	(0.02, 0.49)	4.47	.03*
American Indian	0.13	0.39	(-0.64, 0.89)	0.11	.75
Non-metro residence	-0.30	0.10	(-0.50, -0.10)	8.36	.004**
Speech services	-0.13	0.13	(-0.39, 0.12)	1.02	.31
OT services	-0.13	0.13	(-0.38, 0.13)	0.97	.32
PT services	0.16	0.14	(-0.12, 0.44)	1.28	.26
Free/reduced lunch recipient	0.13	0.10	(-0.07, 0.32)	1.66	.20
School Year-2010 (ref)				33.39 ⁺	<.001***
2011	-0.17	0.10	(-0.37, 0.03)	2.83	.09
2012	-0.10	0.10	(-0.30, 0.10)	0.92	.34
2013	-0.56	0.11	(-0.78, -0.34)	25.15	<.001***
2014	-0.40	0.12	(-0.64, -0.17)	11.39	.001***

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test ; n=605

Table 37

Generalized Estimating Equation for General Education Placement with EIBI Dosage

Predictors	<i>B</i>	<i>SE</i>	<i>Adjusted OR (95% CI)</i>	χ^2	<i>p</i>
Average EIBI hours per week	-0.01	0.007	0.99 (0.98,1.01)	0.96	.33
Delay to EIBI in Months	-0.04	0.008	0.97 (0.95,0.98)	19.42	<.001***
Diagnosis Age in Years	-0.36	0.08	0.70 (0.59,0.82)	19.78	<.001***
Male	0.09	0.19	1.10 (0.75,1.60)	0.24	.63
Intellectual Disability	-1.16	0.17	0.32 (0.23,0.44)	45.72	<.001***
Race- White (ref)				15.58 ⁺	.004**
Asian	-0.28	0.36	0.76 (0.38,1.52)	0.62	.43
Hispanic	0.18	0.31	1.20 (0.66,2.19)	0.34	.56
Black	-0.79	0.21	0.45 (0.30,0.69)	13.77	<.001***
American Indian	-0.36	0.52	0.69 (0.25,1.92)	0.49	.49
Non-metro residence	-0.02	0.16	0.98 (0.72,1.34)	0.02	.90
Speech services	-0.38	0.17	0.68 (0.49,0.95)	5.21	.02*
OT services	0.04	0.16	1.04 (0.76,1.44)	0.07	.79
PT services	0.01	0.23	1.00 (0.64,1.57)	0.001	.98
Free/reduced lunch recipient	0.07	0.16	1.07 (0.78,1.47)	0.18	.67
School Year- 2010 (ref)				23.32 ⁺	<.001***
2011	-0.17	0.10	0.84 (0.69,1.02)	3.02	.08
2012	-0.41	0.12	0.67 (0.53,0.83)	12.53	<.001***
2013	-0.51	0.12	0.60 (0.48,0.76)	17.97	<.001***
2014	-0.54	0.12	0.58 (0.46,0.74)	19.03	<.001***

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test ; n=667

Table 38

Generalized Estimating Equation for ASD Educational Diagnoses with EIBI Dosage

Predictors	<i>B</i>	<i>SE</i>	<i>Adjusted OR (95% CI)</i>	χ^2	<i>p</i>
Average EIBI hours per week	0.04	0.01	1.04 (1.02,1.06)	17.01	<.001***
Delay to EIBI in Months	0.03	0.01	1.03 (1.01,1.04)	7.76	.005**
Diagnosis Age in Years	-0.28	0.10	0.76 (0.63,0.92)	7.95	.005**
Male	0.83	0.21	2.30 (1.52,3.47)	15.67	<.001***
Intellectual Disability	-.05	0.19	0.95 (0.66,1.39)	0.06	.80
Race-White (ref)				8.92 ⁺	.06
Asian	0.77	0.46	2.17 (0.88,5.36)	2.79	.09
Hispanic	-0.33	0.31	0.72 (0.40, 1.31)	1.14	.29
Black	-0.41	0.24	0.66 (0.41, 1.06)	2.92	.09
American Indian	-0.76	0.49	0.47 (0.18, 1.21)	2.44	.12
Non-metro residence	-0.39	0.19	0.68 (0.47,0.97)	4.52	.03*
Speech services	0.23	0.19	1.25 (0.86,1.83)	1.35	.25
OT services	0.05	0.19	1.05 (0.72, 1.53)	0.07	.79
PT services	-0.80	0.26	0.45 (0.27,0.74)	9.82	.002**
Free/reduced lunch recipient	-0.54	0.21	0.59 (0.39,0.88)	6.53	.01**
School Year- 2010 (ref)				3.67 ⁺	.45
2011	0.02	0.07	1.02 (0.88,1.17)	0.04	.84
2012	0.11	0.09	1.11 (0.94,1.31)	1.47	.22
2013	0.13	0.10	1.13 (0.94,1.37)	1.64	.20
2014	0.09	0.11	1.09 (0.89,1.35)	0.69	.41

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test ; n=667

Table 39

Generalized Estimating Equation for MCA- Reading participation with EIBI Dosage

Predictors	<i>B</i>	<i>SE</i>	<i>Adjusted OR (95% CI)</i>	χ^2	<i>p</i>
Average EIBI hours per week	-0.04	0.01	0.97 (0.95,0.98)	13.75	<.001***
Delay to EIBI in Months	-0.03	0.01	0.97 (0.96,0.99)	7.52	.01**
Diagnosis Age in Years	-0.28	0.13	0.76 (0.59,0.97)	4.83	.03*
Male	0.25	0.27	1.29 (0.76,2.18)	0.88	.35
Intellectual Disability	-1.09	0.23	0.33 (0.21,0.52)	22.99	<.001***
Race- White (ref)				10.68 ⁺	.03*
Asian	-1.08	0.49	0.33 (0.13,0.89)	4.82	.03*
Hispanic	-0.01	0.42	0.99 (0.43,2.26)	0.001	.98
Black	-0.75	0.30	0.48 (0.27,0.85)	6.31	.01**
American Indian	-0.16	0.59	0.85 (0.27,2.68)	0.08	.78
Non-metro residence	-0.46	0.23	0.63 (.41,0.99)	4.07	.04*
Speech services	-0.71	0.23	0.49 (0.31,0.77)	9.52	.002**
OT services	-0.04	0.23	0.96 (0.62,1.50)	0.03	.86
PT services	0.25	0.33	1.29 (0.68,2.43)	0.62	.43
Free/reduced lunch recipient	-0.10	0.23	0.90 (0.58,1.42)	0.20	.66
School Year- 2011 (ref)				11.86 ⁺	.01**
2012	-0.23	0.27	0.80 (0.47,1.35)	0.71	.40
2013	-0.37	0.30	0.69 (0.39,1.24)	1.56	.21
2014	-0.61	0.30	0.54 (0.30,0.98)	4.14	.04*

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test ; n=444

Table 40

Generalized Estimating Equation for MCA -Math participation with EIBI Dosage

Predictors	<i>B</i>	<i>SE</i>	<i>Adjusted OR (95% CI)</i>	χ^2	<i>p</i>
Average EIBI hours per week	-0.03	0.01	0.97 (0.95,0.99)	12.43	.001***
Delay to EIBI in Months	-0.03	0.01	0.97 (0.95,0.99)	10.50	.001***
Diagnosis Age in Years	-0.27	0.13	0.76 (0.60,0.98)	4.63	.03*
Male	0.22	0.26	1.25 (0.75,2.09)	0.73	.39
Intellectual Disability	-1.11	0.23	0.33 (0.21,0.51)	24.14	<.001***
Race White (ref)				11.16 ⁺	.03*
Asian	-1.14	0.49	0.32 (0.12,0.83)	5.44	.02
Hispanic	0.04	0.43	1.04 (0.45,2.40)	0.01	.93
Black	-0.71	0.29	0.49 (0.28,0.87)	6.05	.01**
American Indian	0.21	0.58	0.81 (0.26,2.51)	0.14	.71
Non-metro residence	-0.42	0.23	0.66 (0.42,1.03)	3.41	.07
Speech services	-0.75	0.23	0.48 (0.30,0.75)	10.26	.001***
OT services	0.02	0.23	1.02 (0.65,1.61)	0.005	.93
PT services	0.31	0.33	1.36 (0.71,2.60)	1.30	.36
Free/reduced lunch recipient	-0.15	0.23	0.86 (0.55,1.36)	0.40	.53
School Year 2011 (ref)				17.20 ⁺	.001***
2012	-0.09	0.22	0.92 (0.60,1.42)	0.14	.71
2013	-0.23	0.25	0.79 (0.49,1.28)	0.91	.34
2014	-0.54	0.26	0.58 (0.35,0.96)	4.44	.04*

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test ; n=444

Table 41

Generalized Estimating Equation for MCA-Reading Scale Scores with EIBI Dosage

Predictors	<i>B</i>	<i>SE</i>	<i>95% CI</i>	χ^2	<i>p</i>
Average EIBI hours per week	-0.004	0.003	(-0.01, 0.002)	1.61	.21
Delay to EIBI in Months	-0.003	0.003	(-0.009, 0.003)	0.98	.32
Diagnosis Age in Years	-0.03	0.04	(-0.11, 0.04)	0.66	.42
Male	-0.06	0.08	(-0.22, 0.11)	0.49	.49
Intellectual Disability	-0.20	0.09	(-0.38, -0.03)	5.20	.02**
Race White (ref)				13.58 ⁺	.01*
Asian	-0.07	0.15	(-0.36, 0.23)	0.20	.65
Hispanic	-0.08	0.14	(-0.34, 0.19)	0.30	.58
Black	-0.45	0.12	(-0.69, -0.21)	13.53	.001**
American Indian	-0.06	0.15	(-0.35, 0.24)	0.15	.70
Non-metro residence	-0.02	0.07	(-0.17, 0.12)	0.10	.75
Speech services	-0.12	0.07	(-0.26, 0.03)	2.59	.11
OT services	0.18	0.07	(0.04, 0.32)	6.69	.01**
PT services	0.05	0.10	(-0.13, 0.24)	0.33	.57
Free/reduced lunch recipient	-0.08	0.08	(-0.24, 0.08)	1.04	.31
School Year 2011 (ref)				71.38 ⁺	<.001***
2012	-0.11	0.07	(-0.25, 0.04)	2.08	.15
2013	-0.38	0.08	(-0.53, -0.24)	25.98	<.001***
2014	-0.31	0.08	(-0.46, -0.16)	16.17	<.001***

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test; $n=256$

Table 42

Generalized Estimating Equation for MCA-Math Scale Scores with EIBI Dosage

Predictors	<i>B</i>	<i>SE</i>	<i>95% CI</i>	χ^2	<i>p</i>
Average EIBI hours per week	-0.004	0.003	(-0.01, 0.002)	1.63	.20
Delay to EIBI in Months	-0.007	0.003	(-0.01, -0.002)	7.26	.01**
Diagnosis Age in Years	-0.09	0.03	(-0.15, -0.03)	7.66	.01**
Male	0.09	0.08	(-0.07, 0.25)	1.26	.26
Intellectual Disability	-0.17	0.07	(-0.30, -0.03)	5.52	.02*
Race- White (ref)				20.04 ⁺	<.001***
Asian	0.11	0.14	(-0.17, 0.38)	0.59	.44
Hispanic	-0.05	0.13	(-0.30, 0.20)	0.13	.71
Black	-0.47	0.11	(-0.68, -0.25)	18.13	<.001***
American Indian	-0.04	0.16	(-0.35, 0.28)	0.05	.83
Non-metro residence	-0.04	0.06	(-0.16, 0.09)	0.33	.57
Speech services	-0.10	0.07	(-0.23, 0.03)	2.32	.13
OT services	0.07	0.06	(-0.05, 0.19)	1.38	.24
PT services	0.05	0.08	(-0.10, 0.19)	0.37	.55
Free/reduced lunch recipient	-0.10	0.07	(-0.24, 0.05)	1.72	.19
School Year- 2011 (ref)				23.78 ⁺	<.001***
2012	-0.13	0.10	(-0.33, 0.07)	1.54	.22
2013	-0.23	0.11	(-0.44, -0.03)	4.84	.03*
2014	-0.29	0.11	(-0.49, -0.08)	7.51	.01**

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test; n=257

Table 43

Generalized Estimating Equation for Special Education Service Hours with EIBI Dosage

Predictors	<i>B</i>	<i>SE</i>	<i>95% CI</i>	χ^2	<i>p</i>
Average EIBI hours per week	-0.01	0.004	(-0.02,-0.003)	7.09	.01**
Delay to EIBI in Months	-0.01	0.01	(-0.02,-0.004)	7.91	.01**
Diagnosis Age in Years	-0.12	0.06	(-0.24, -0.01)	4.20	.04*
Male	-0.34	0.13	(-0.60, -0.08)	6.72	.01**
Intellectual Disability	0.19	0.10	(-0.01, -0.39)	3.62	.06
Race- White (ref)				9.58 ⁺	.05*
Asian	-0.14	0.21	(-0.54, 0.27)	0.43	.51
Hispanic	-0.25	0.16	(-0.56, 0.07)	2.36	.16
Black	0.26	0.12	(0.03, 0.50)	4.71	.03*
American Indian	0.08	0.38	(-0.66, 0.82)	0.04	.84
Non-metro residence	-0.30	0.10	(-0.50, -0.10)	8.36	.004**
Speech services	-0.17	0.13	(-0.42, 0.09)	1.68	.20
OT services	-0.11	0.13	(-0.35, 0.13)	0.80	.37
PT services	0.15	0.14	(-0.12, 0.43)	1.23	.27
Free/reduced lunch recipient	0.04	0.11	(-0.17, 0.25)	0.14	.71
School Year-2010 (ref)				33.87 ⁺	<.001***
2011	-0.16	0.10	(-0.36, 0.04)	2.53	.11
2012	-0.10	0.10	(-0.30, 0.11)	0.89	.35
2013	-0.56	0.11	(-0.78, -0.34)	25.28	<.001***
2014	-0.40	0.12	(-0.63, -0.17)	11.16	.001***

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; ⁺ indicates Type- III Wald chi-square test; n=605

Table 44

Means, Standard Deviations, and t-test results for Delay to EIBI by Residence

Residence	Average Delay to EIBI in months		<i>df</i>	<i>t</i>	<i>p</i>	<i>Hedges' g</i>
	<i>M</i>	<i>SD</i>				
Metro (n=460)	9.89	11.25	499.41	-3.59	.001	0.27
Non-Metro (n=207)	7.00	8.80				

Table 45

Means and Standard Deviations for the Delay to EIBI by Region

Region	<u>Delay to EIBI in months</u>	
	<i>M</i>	<i>SD</i>
Central (n=29)	5.17	8.43
Metro (n=460)	9.89	11.25
Northeast (n=33)	10.67	12.97
Northwest (n=16)	4.50	8.49
Southeast (n=83)	6.70	7.43
Southwest (n=5)	4.40	4.39
West Central (n=41)	7.22	7.42

Figures

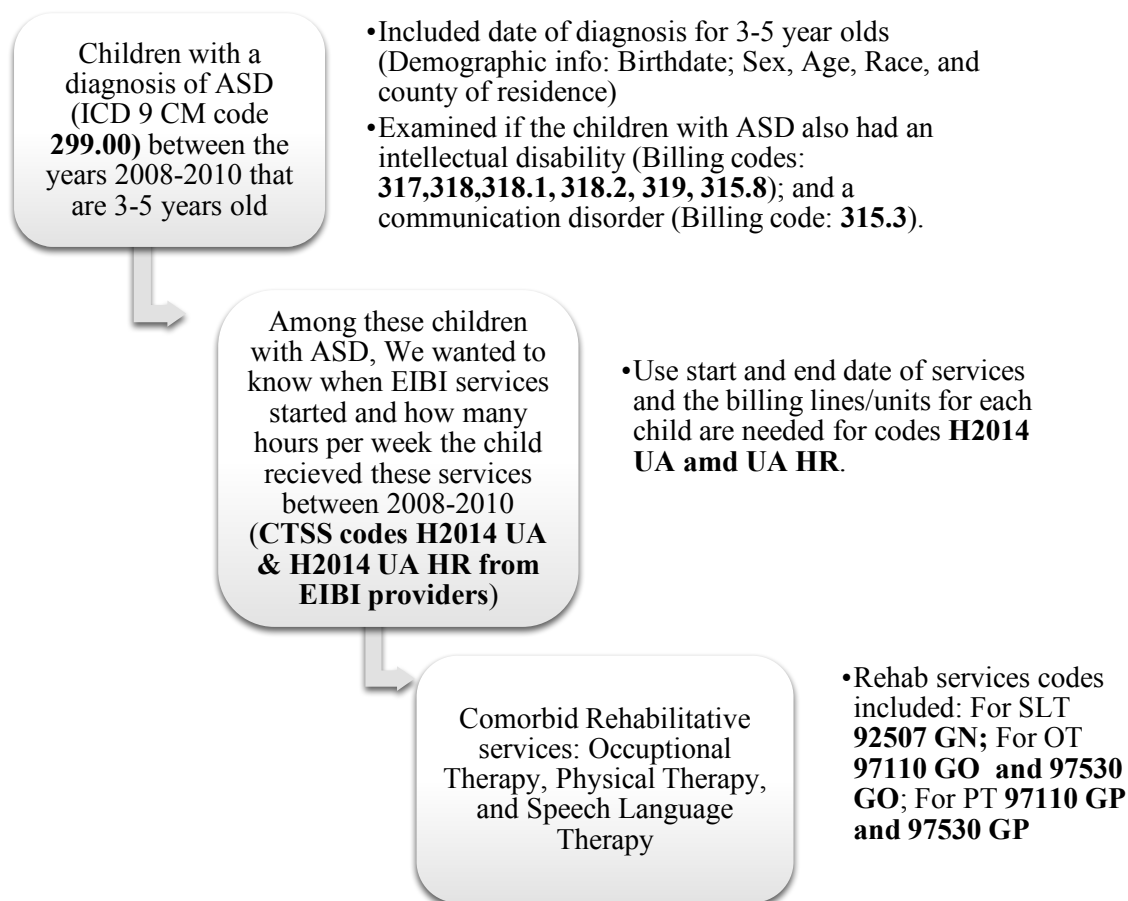


Figure 1. Primary variables of interest used as independent variables from the MMIS dataset.

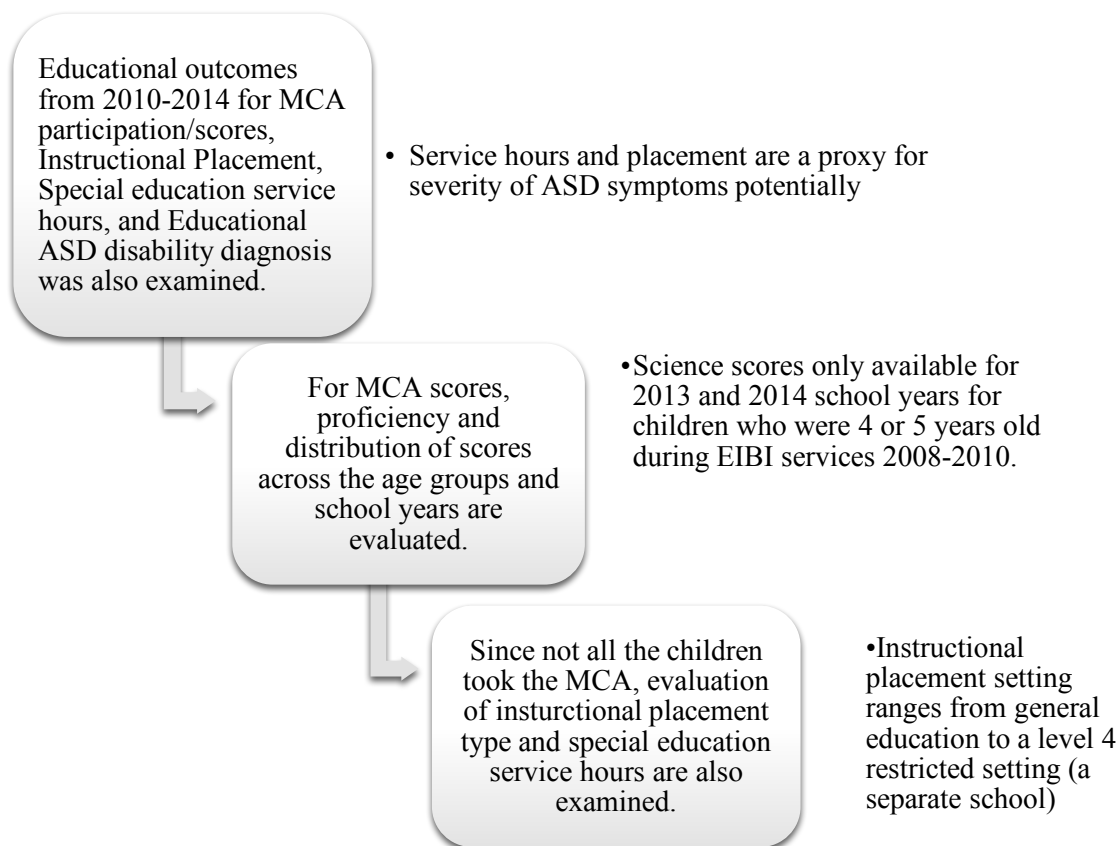


Figure 2. Primary outcome variables of interest used from the MARSS dataset.

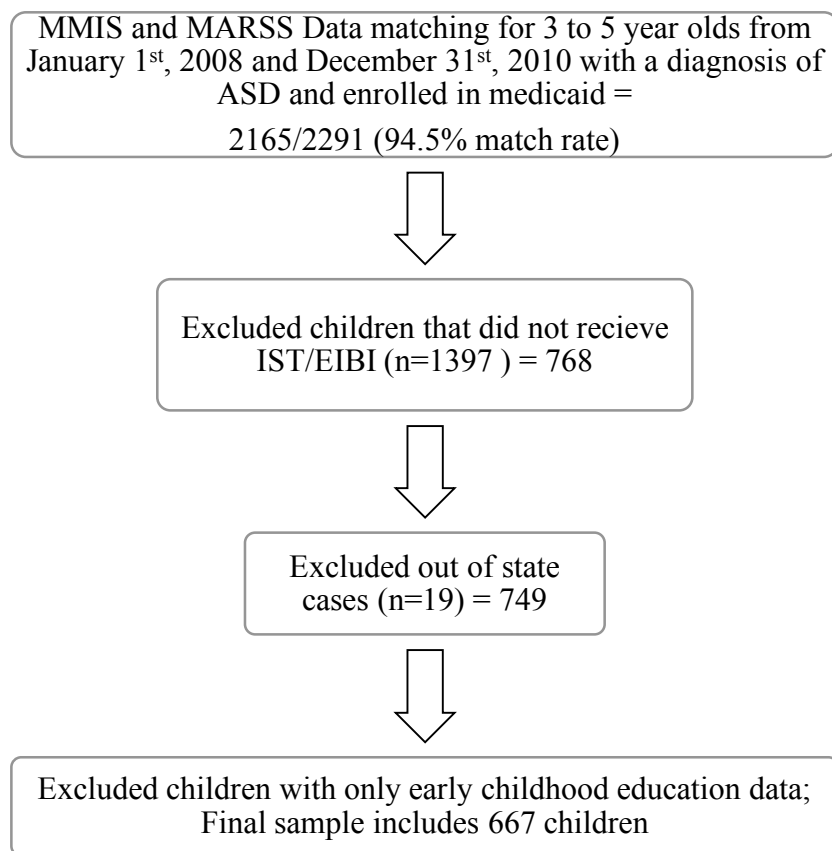


Figure 3. Sample inclusion and exclusion.

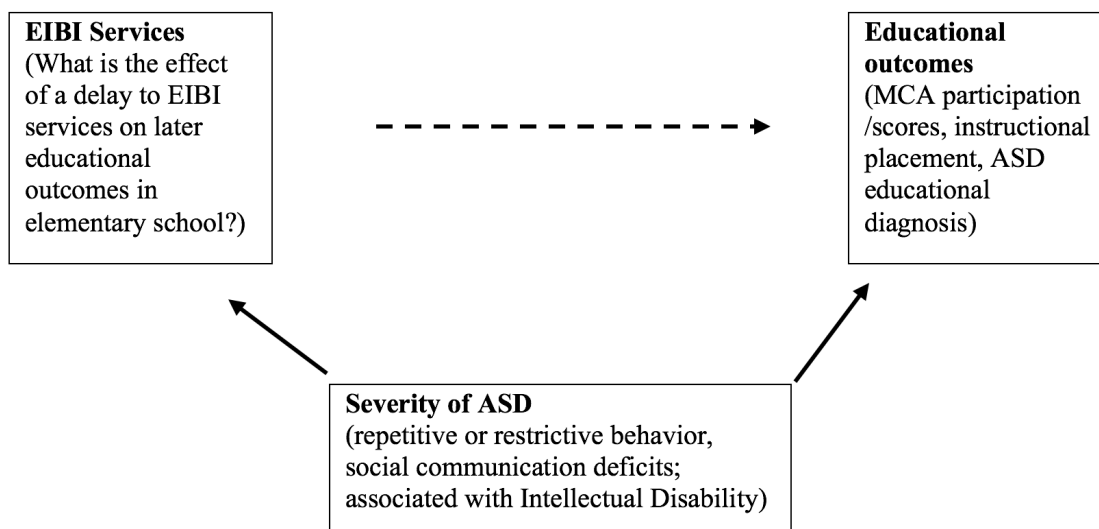


Figure 4. Directed acyclic graph (DAG) showing the relationship between EIBI service receipt, severity of ASD, and educational outcomes.

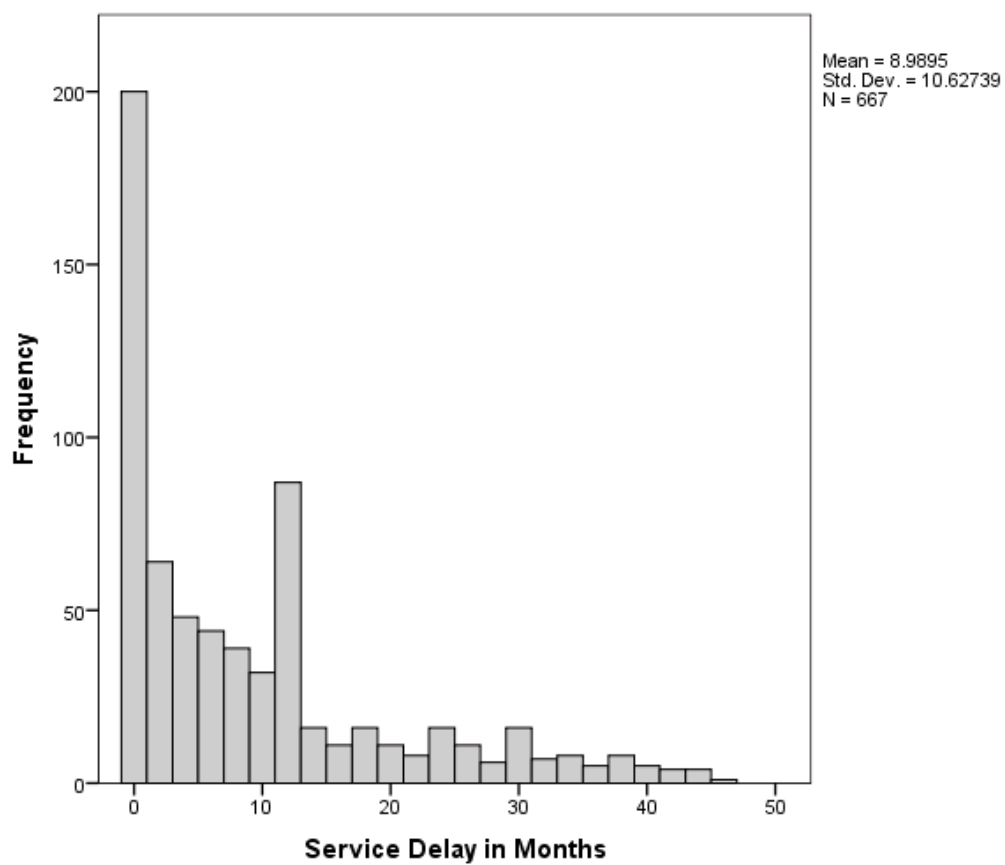


Figure 5. Histogram of the distribution of EIBI service delay in months.

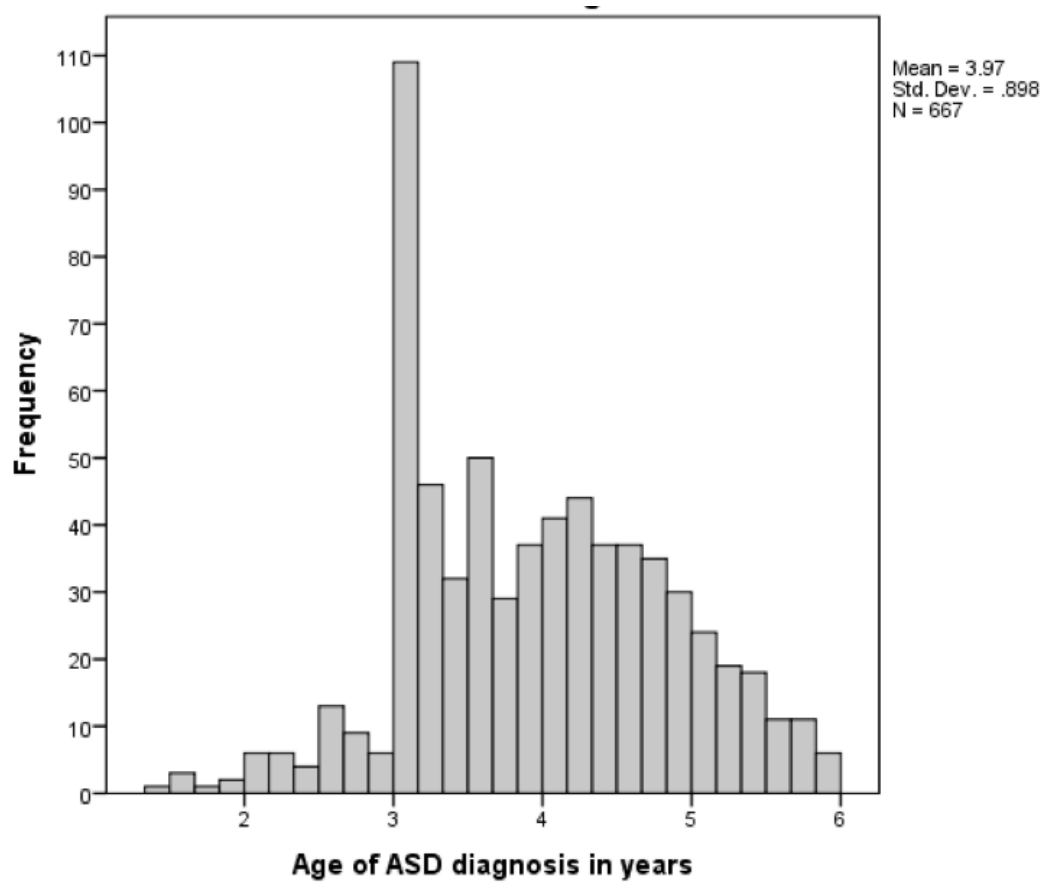


Figure 6. Histogram of the distribution of age for ASD diagnosis (in years).

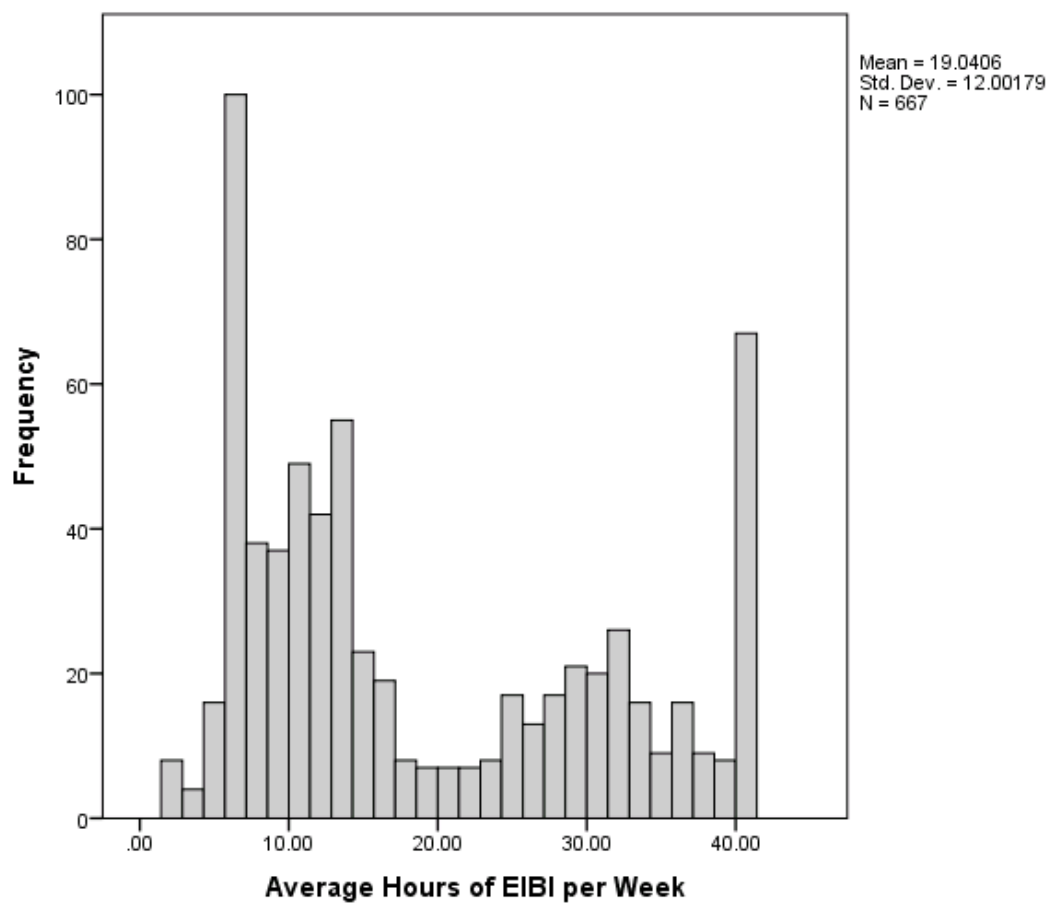


Figure 7. Histogram of the dosage or average hours of EIBI per week.

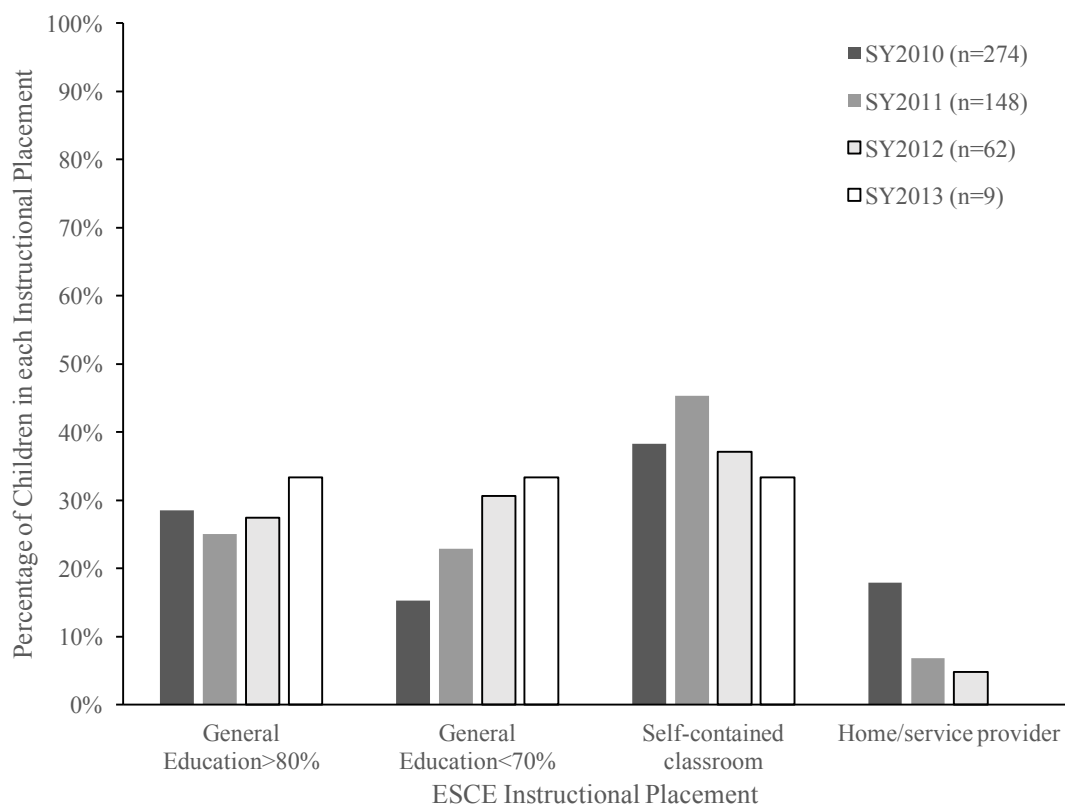


Figure 8. Early childhood special education instructional setting placements for school years 2010-2013 for a subset of the cohort.

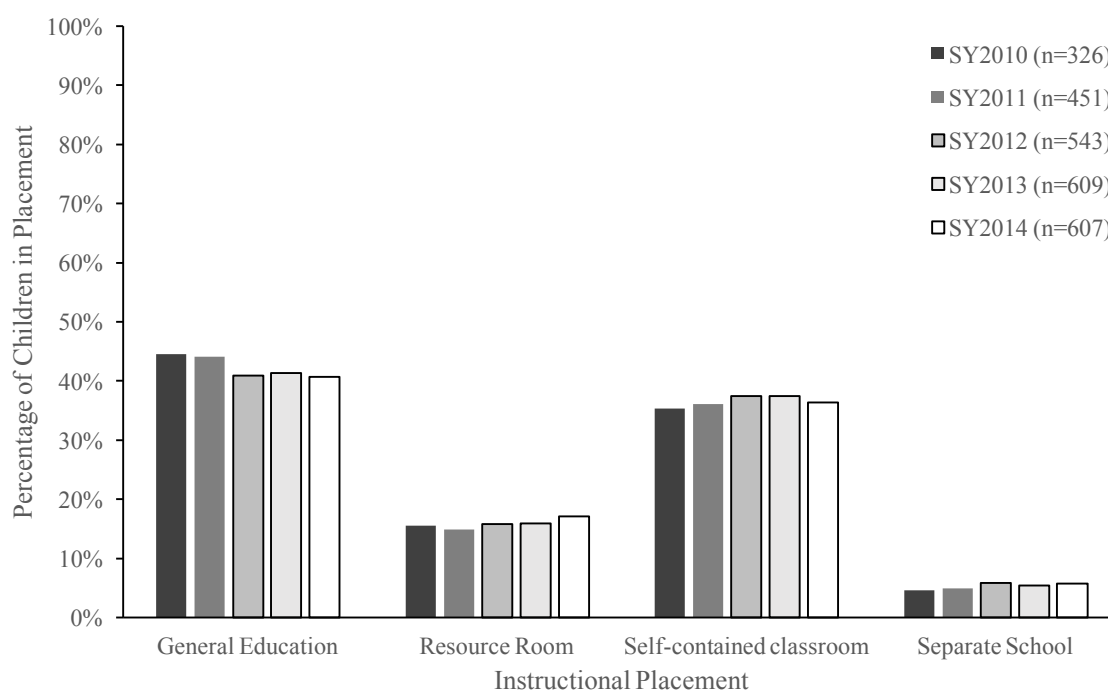


Figure 9. Instructional setting placements by school year.

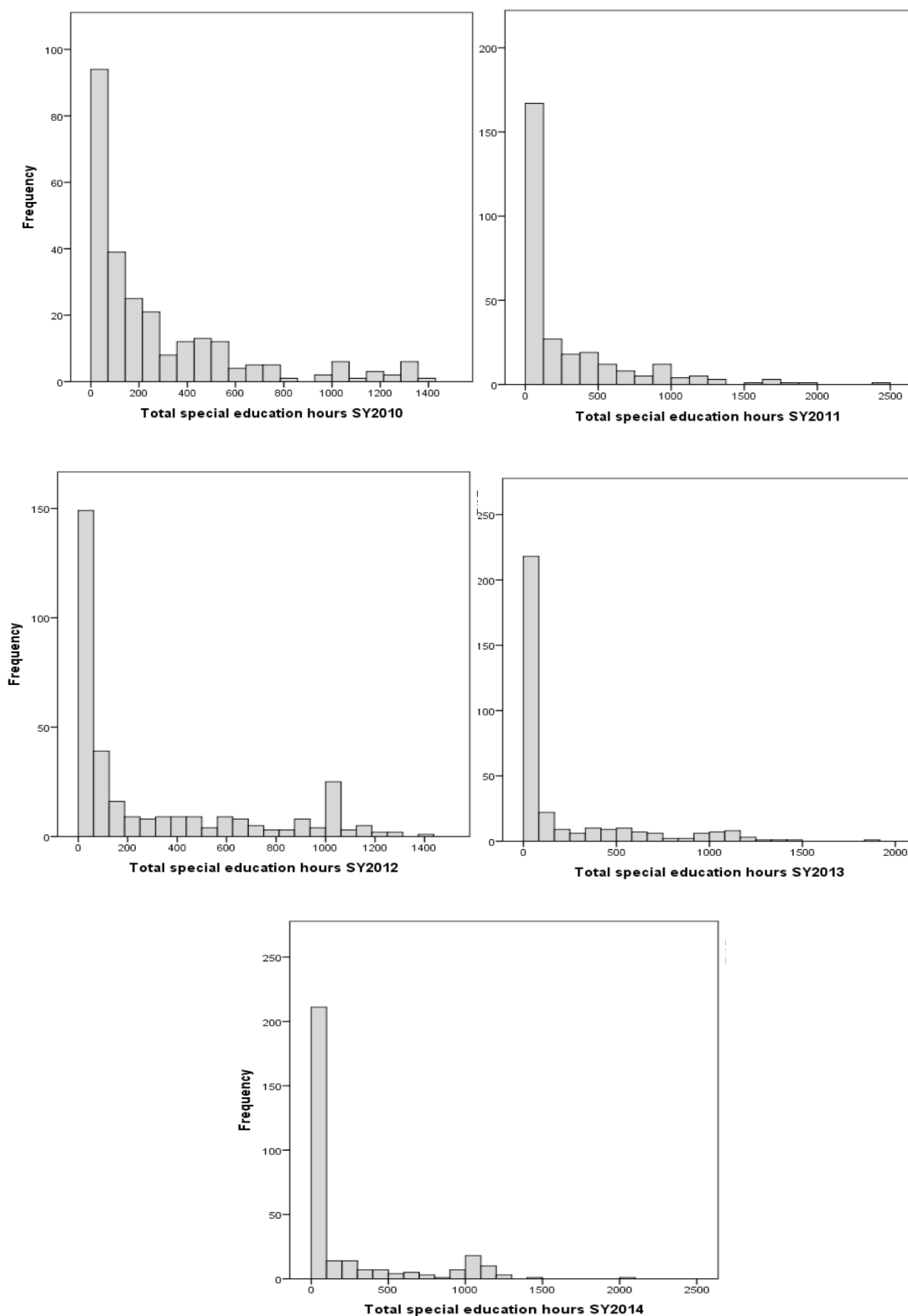


Figure 10. Histogram of the distribution of total special education service hours.

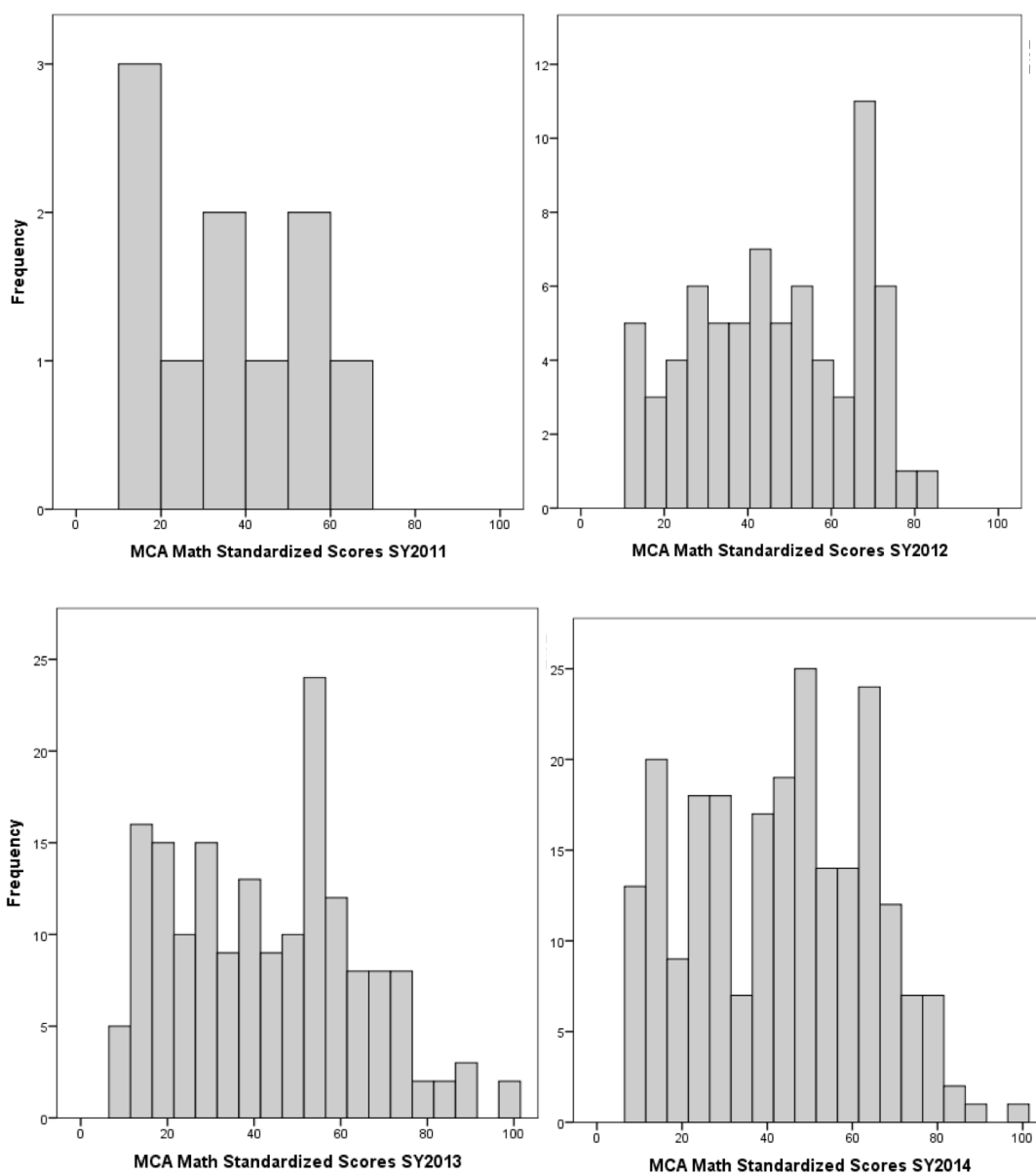


Figure 11. Histograms of the distribution of MCA scores for mathematics by school year (for 3rd graders and above).

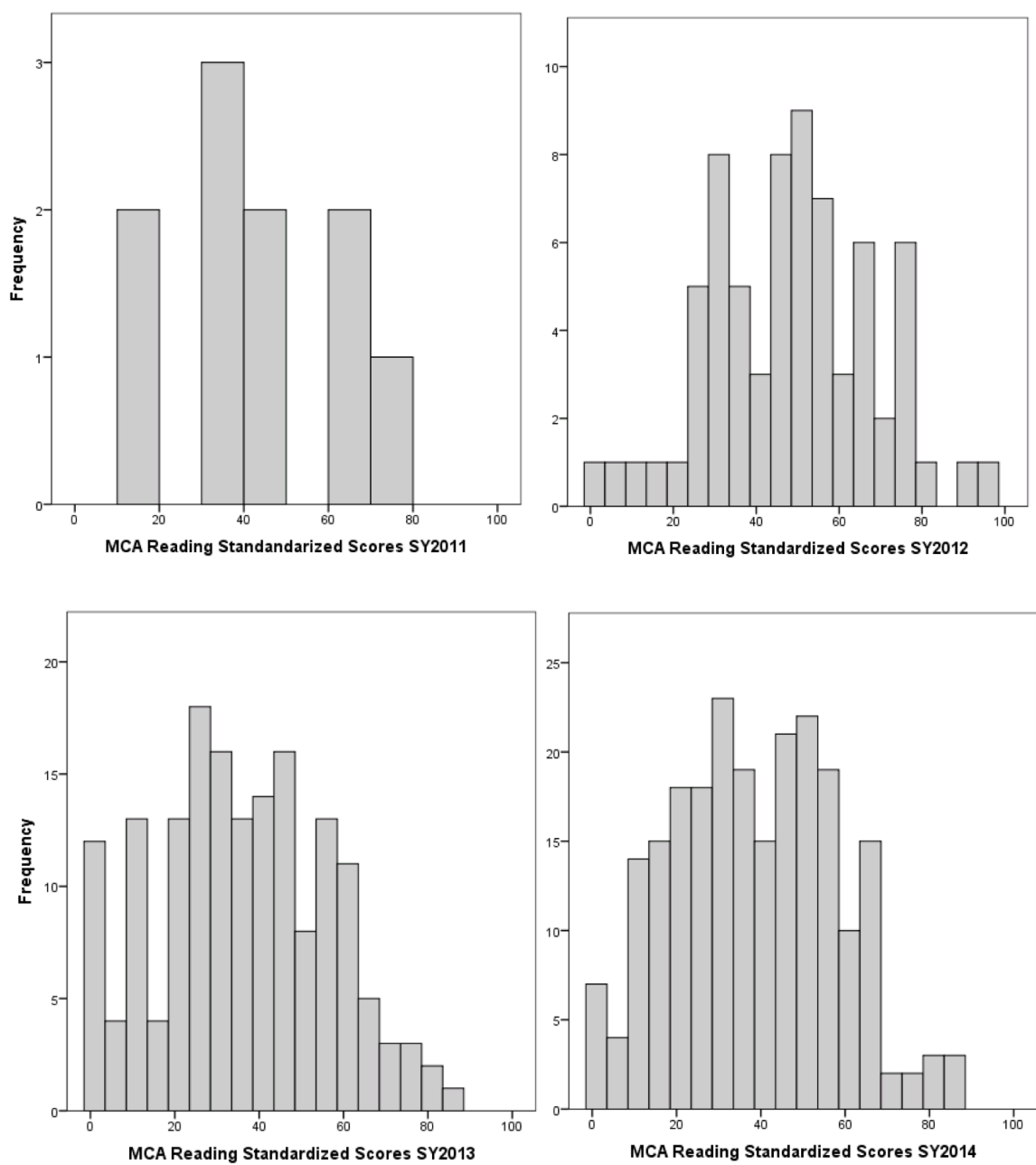


Figure 12. Histograms of the distribution of the MCA scores for reading by school year (for 3rd graders and above).

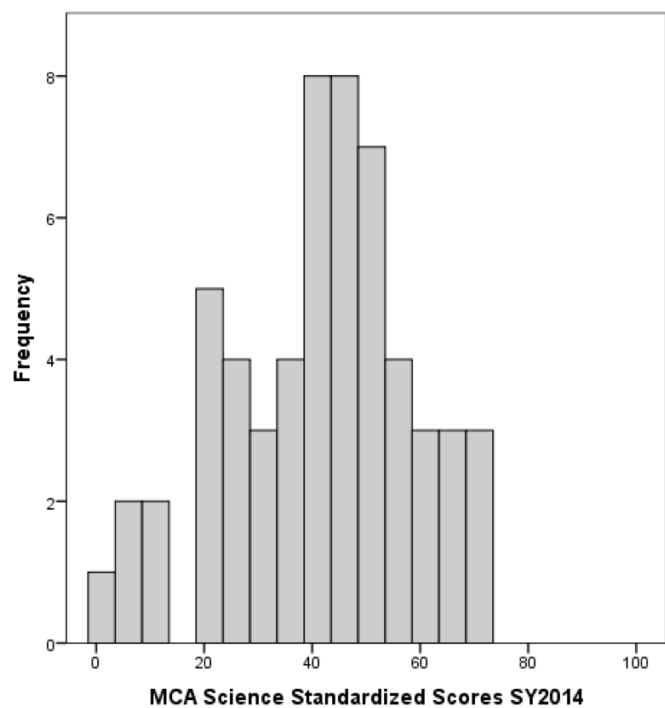
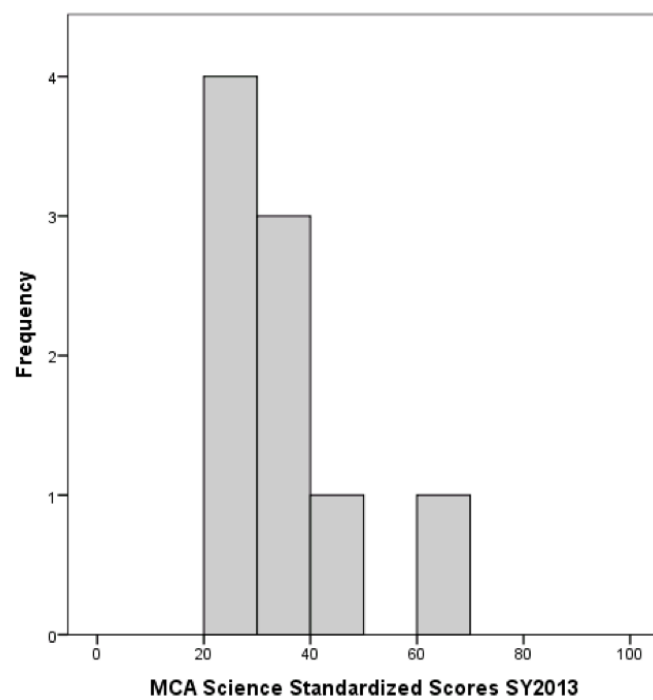


Figure 13. Histograms of the distribution of MCA scores for science (only taken by 5th graders).

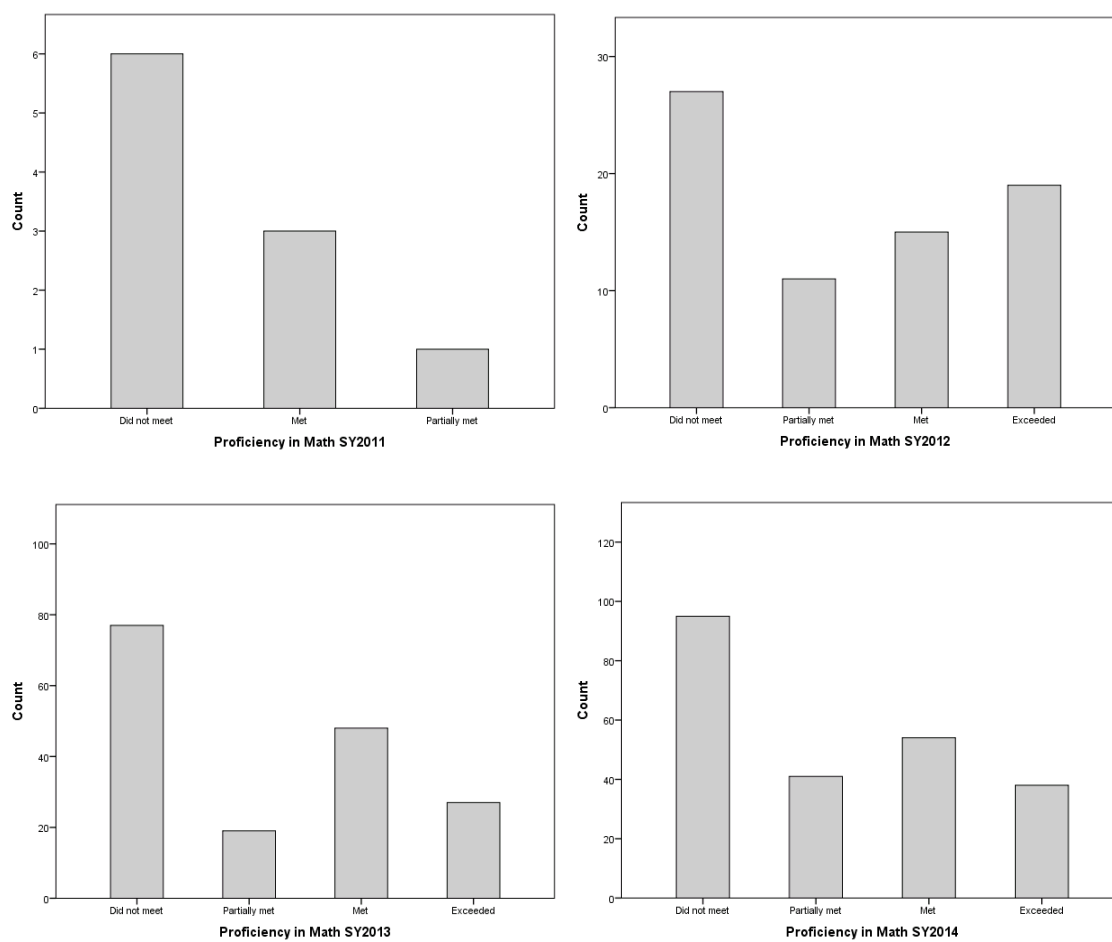


Figure 14. Proficiency in Math on the MCA by School Year.

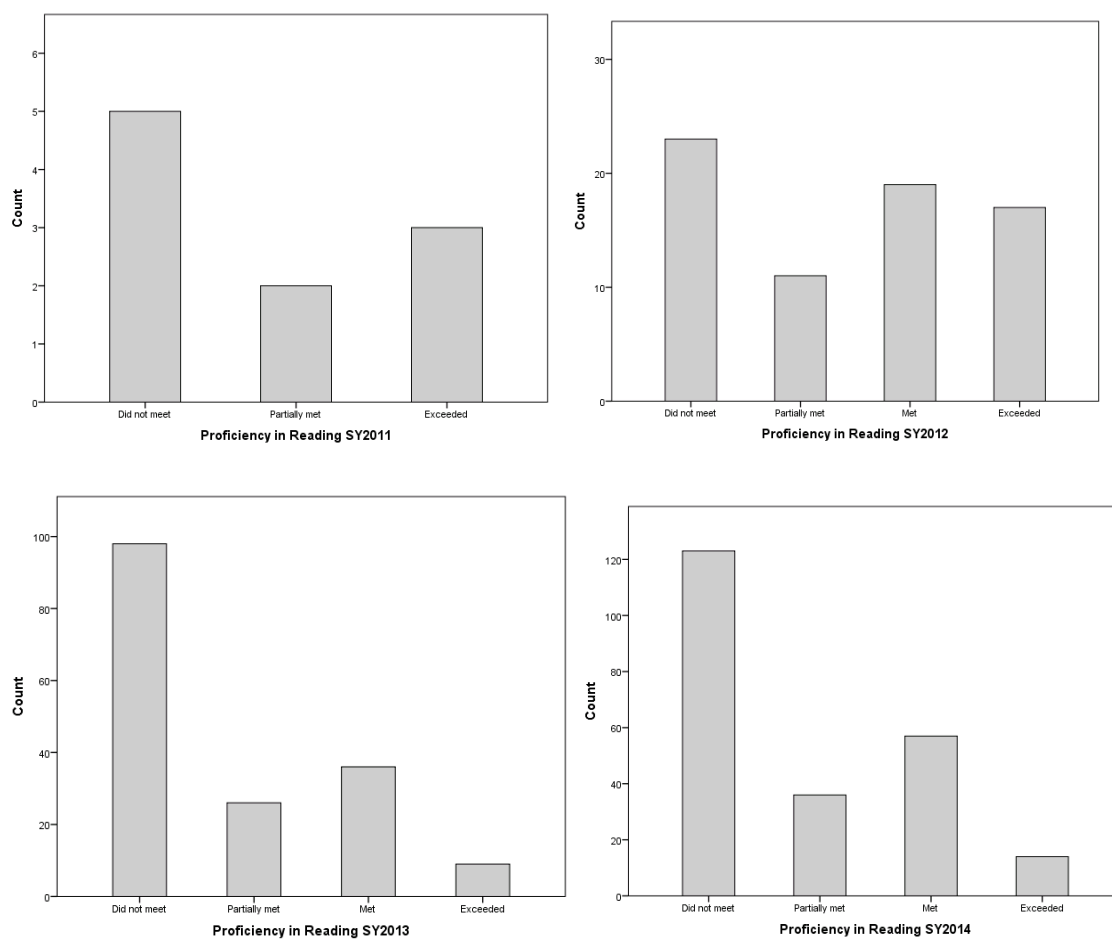


Figure 15. Proficiency in Reading on the MCA by School Year.

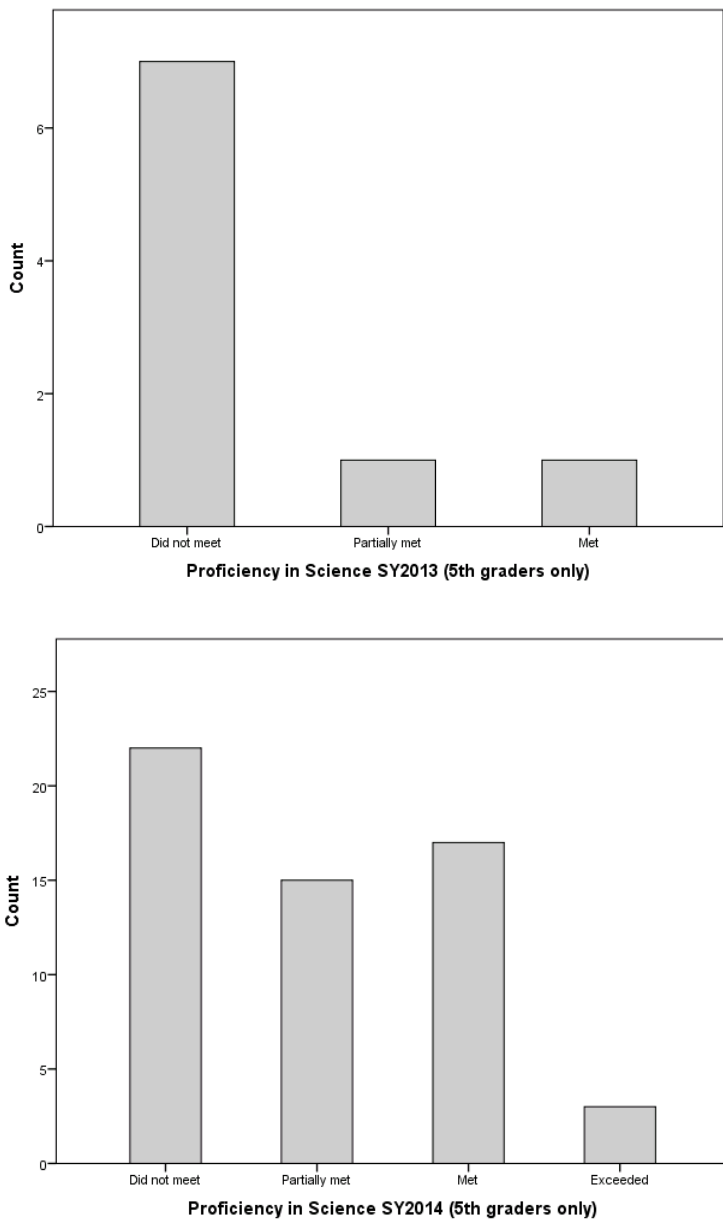


Figure 16. Proficiency in Science on the MCA by School Year.

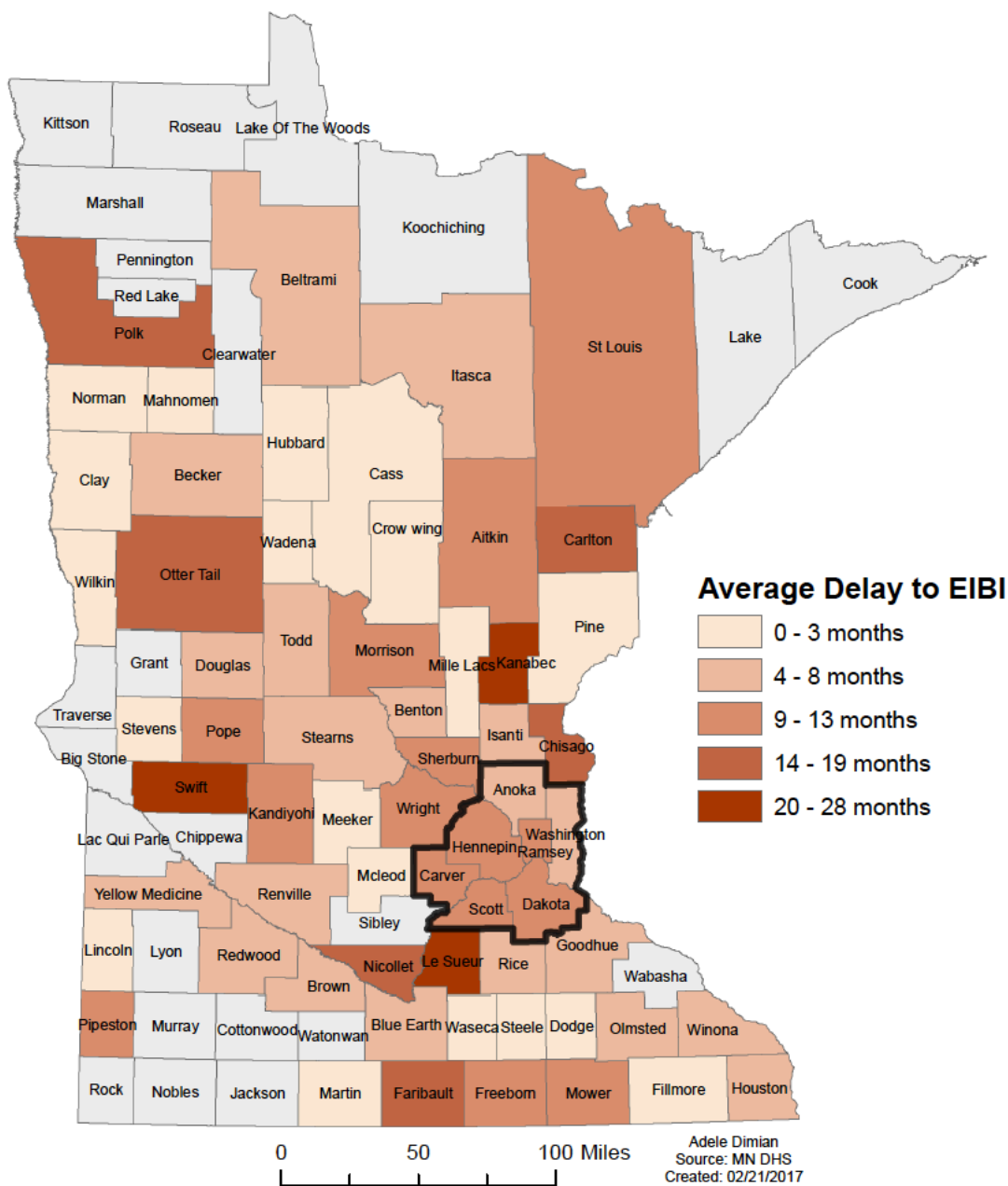


Figure 17. GIS map of the average delay to EIBI in months by county. The black outline delineates the metro area. Grey colored counties are counties where no children from the cohort lived.

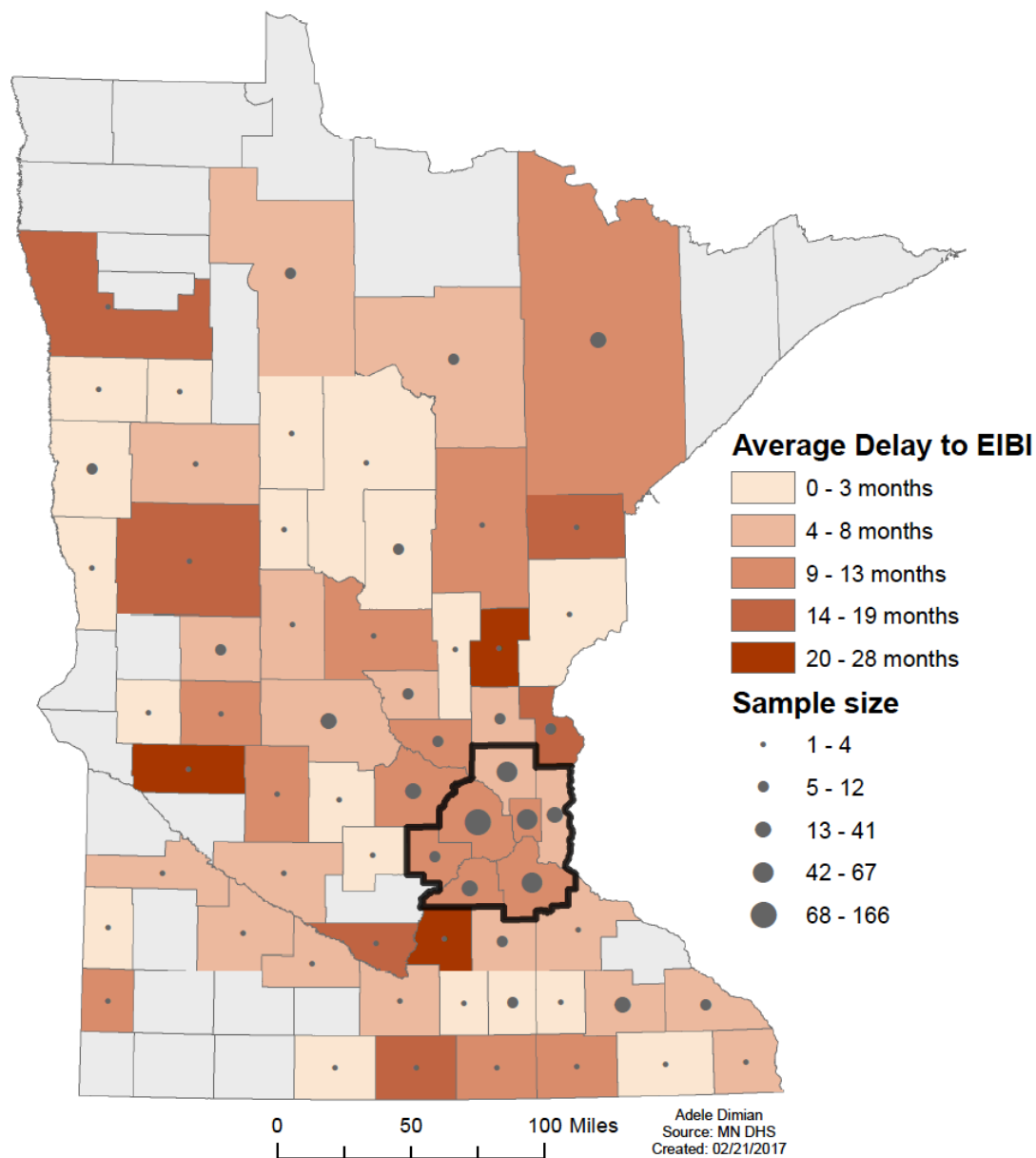


Figure 18. GIS map of the average delay to EIBI in months by county with sample size (n=667). The black outline delineates the metro area and grey colored counties are counties where no children from the cohort lived.

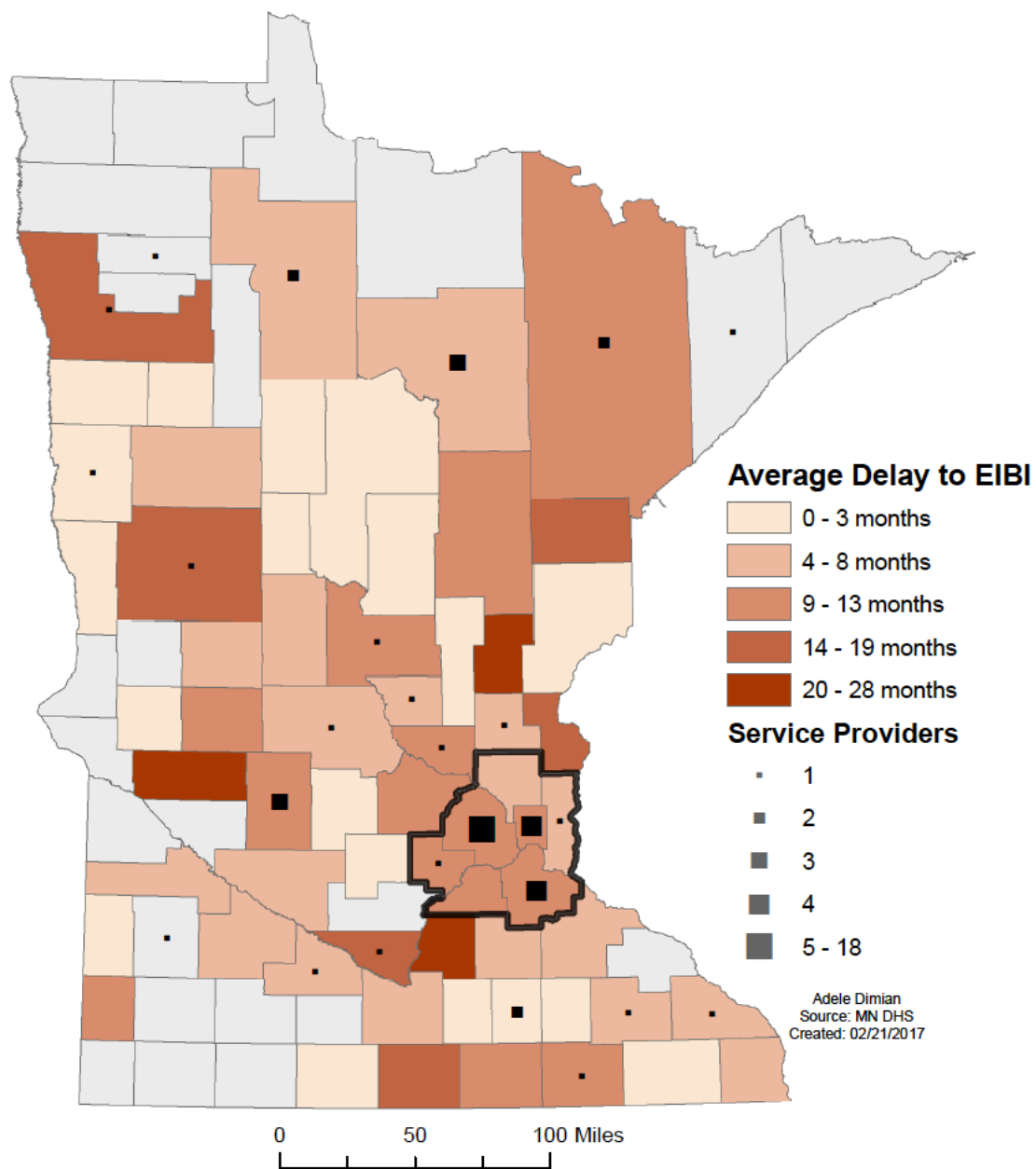


Figure 19. GIS map of the average delay to EIBI in months by county and the number of service providers located in each county. The black outline delineates the metro area. Grey colored counties are counties where no children from the cohort lived.

Appendix A

Data analysis

1. Descriptives by demographic groups
 - a. Gender
 - b. Presence or absence of ID (billing code MMIS-categorical)
 - c. Primary disability categories= ASD (categorical, 0,1)
 - d. Meal program eligibility (0,1)
 - e. Race (categorical)
 - f. Residence (metro or non-metro)
2. Predictors/ Independent Variables
 - a. Delay in months between diagnosis of ASD and EIBI start (RQ 1)
 - b. MMIS average EIBI average hours per week (RQ 2)
 - c. County region received services in
 - d. Comorbid intellectual disability status
 - e. Gender
 - f. Race
 - g. Comorbid services
 - h. Free/reduced lunch receipt
3. Educational outcomes/ Dependent Variables
 - a. 2010-2014 special education service hours
 - b. 2010-2014 instructional placement (special education, general education, resource room, separate school)
 - c. 2010-2014 primary dx category (ASD)
 - d. 2011-2014 3rd grade+ MCA reading and math (proficiency category, scale score, and if took it)
 - e. 2013-2014 5th grade MCA science (proficiency category, scale score, and if took it)
4. Statistical analyses
 - a. Primary-RQ 1: What is the main effect of delay to EIBI on later educational outcomes?
 - i. **IV**- Time in months from dx date to start of EIBI date start
DV- General Ed Placement (yes, no)
Covariates/factors-gender, race, intellectual disability status, age of diagnosis, free/reduced lunch receipt, residence, comorbid service receipt, school year
GEE- Correlation matrix= unstructured, model= binary logistic, distribution= binomial, link function= logit
 - ii. Use same IV and covariate/factors with DV being sped service hours allocated each school year
GEE- Correlation matrix= AR(1), model= gamma with log link, distribution= gamma, link function=log

