SUBGROUPS OF PRESCHOOLERS WITH AUTISM AND INFLUENTIAL FACTORS OF THEIR RESPONSES TO TEACCH, LEAP, AND NON-MODEL-SPECIFIC PRESCHOOL PROGRAMS

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A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the School of Education (Applied Developmental Science and Special Education).

Chapel Hill
2018

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ABSTRACT

Shuting Zheng: Subgroups of Preschoolers with Autism and Influential Factors of Their Responses to TEACCH, LEAP, and NMS Preschool Programs
(Under the Direction of Harriet Able)

Children with autism spectrum disorder (ASD) show a wide range of developmental characteristics and differ from each other in terms of symptom presentation. This heterogeneity leads to difficulties when trying to individualize treatments that work for individual children with ASD. Therefore, identifying and understanding subgroups of children on the spectrum and the potential influential factors that affect intervention outcomes are critical tasks.

This dissertation aims to: (1) determine distinct subgroups of preschoolers with ASD based on pre-intervention developmental and behavioral measures and describe the profiles of the subgroups, (2) examine child or family factors that influence changes in social communication development over time for preschoolers in TEACCH, LEAP, and non-model-specific (NMS) classrooms. To address these aims, secondary data analysis was conducted using data from a larger study to compare the efficacy of three comprehensive treatment programs (i.e., TEACCH, LEAP, and NMS programs) that serve preschool-aged children with ASD.

Cluster analysis identified three distinct subgroups of preschoolers with ASD in the current sample (N = 198) based on the children's comprehensive developmental profiles: Cluster 1 (N = 76; 38.58%) was the moderate functioning group of children with low levels of cognitive and language abilities but few social difficulties and repetitive behaviors; Cluster 2 (N = 69; 35.03%) was the high functioning group of children with high levels of cognitive and language abilities and moderate levels of social difficulties and repetitive behaviors; and Cluster 3 (N = 52; 26.4%) was the low functioning group of children who showed the most delays across all aspects of development in the current sample.

Fuzzy regression discontinuity design was applied to examine the effects of influential factors on intervention outcomes as measured by social impairment change scores. Specifically, this study examined the effects of child cognitive ability, language ability, autism severity level, and parent stress level. Among these four factors, the level of parent stress on the intervention outcomes in the group comparisons (TEACCH vs. NMS and TEACCH vs. LEAP) was the only significant factor, indicating that children of parents with higher stress levels show greater decreases in social difficulties/impairments as measured by Social Responsiveness Scale change scores (i.e., these children showed improvement in social functioning and development). Analyses of regression discontinuity plots also showed the preliminary effects of child factors on intervention outcomes. Limitations of the current study and implications for future research and practice also are discussed.

To my mentors and friends, I couldn't have done this without you.

Thank you for all of your support along the way.

ACKNOWLEDGEMENTS

First, I would like to thank the families, children, teachers, and staff who participated in the original study. I would also like to thank Drs. Sam Odom and Brian Boyd for their generosity to grant me access to the dataset to address research questions of my interests.

Second, I want to thank my advisor, Dr. Harriet Able, and my mentor, Dr. Kara Hume, who have been my advocates and support throughout the program. Also, I have been extremely lucky to have Dr. Brian Boyd to guide me through the process of the dissertation and offer precious advice and suggestions. I also extend my special thanks to the rest of my committee and to Dr. Chris Wiesen at Odum Institute who devoted their time and energy to helping me succeed. In addition, I am grateful for all the friends and professors who generously spent time working with me and shared their wisdom during my time at UNC-Chapel Hill.

Lastly, I would like to thank my family who has always trusted in and supported me. I thank my wonderful and loving husband, Yu, for bearing with me during my emotional break-downs and negativity at times, and for all his late-night phone calls to cheer me up. I truly could not have gone this far without your love and support. I thank my parents for their generous support both financially and emotionally, and my little sister who always believes in me. Thank you for constant prayers and timely video chats when I needed them the most.

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LIST OF ABBREVIATIONS

ABA	Applied Behavior Analysis
ADOS	Autism Diagnostic Observation Schedule
ADI-R	Autism Diagnostic Interview-Revised
AEPS-2	Assessment, Evaluation, and Programming System-2
APA	American Psychiatric Association
APERS	Autism Program Environment Rating Scale
ASAP	Advancing Social-communication And Play
ASD	Autism Spectrum Disorder
BDI 2	Beck Depression Inventory–II
CAP	Comprehensive Autism Program
CARS	Childhood Autism Rating Scale
CLASS	Classroom Assessment Scoring System
CPRT	Classroom Pivotal Response Teaching
CTMs	Comprehensive Treatment Models
DSM-5	Diagnostic And Statistical Manual Of Mental Disorders-Fifth Edition
DTT	Discrete Trial Training
ECE	Early Childhood Education
ECERS-3	Early Childhood Environment Rating Scales-Third Edition
ECSE	Early Childhood Special Education
EHS/HS	Early Head Start and Head Start
EI	Early Intervention
EIBI	Early Intensive Behavioral Intervention

EMAS-T	Ender Multidimensional Anxiety Scale-Trait
ESDM	Early Start Denver Model
ESEA	Elementary and Secondary Education Act
ESSA	Every Student Succeeds Act
FAPE	Free and Appropriate Public Education
FRDD	Fuzzy Regression Discontinuity Design
HMTW	Hanen More Than Words
ICP	Inclusive Classroom Profile
IDEA	Individuals with Disabilities Education and Improvement Act
JA	Joint Attention
IJA	Initiating Joint Attention
RJA	Responding Joint Attention
LEAP	Learning Experiences And Alternative Program For Preschoolers and Their Parents
MSEL	Mullen Scales of Early Learning
NDBIs	Naturalistic Developmental and Behavioral Interventions
NIEER	National Institute for Early Education Research
NPDC	National Professional Development Center on ASD
NMS	Non-Model Specific
PCDI	Princeton Child Development Institute
PECS	Picture Exchange Communication System
PICS	Pictorial Infant Communication Scales
PLS-4	Preschool Language Scale-4
PRT	Pivotal Response Training

DATA	Project Developmentally Appropriate Treatment For Autism
PSI	Parenting Stress Index
QRIS	Quality Rating and Improvement Systems
RBSR	Repetitive Behavior Scales-Revised
RDD	Regression Discontinuity Design
RPMT	Responsive Education and Pre-linguistic Milieu Teaching
RRBIs	Repetitive and Restricted Behaviors and Interests
SCERTS	Social Communication, Emotional Regulation, and Transaction Support
SCQ	Social Communication Questionnaire
SEQ 2	Sensory Experience Questionnaire 2.0
SES	Socioeconomic Status
SGD	Speech Generating Devices
SMART	Sequential Multiple Assignment Randomized Trial
SRD	Sharp Regression Discontinuity
SRS	Social Responsiveness Scale
STAR	Strategies for Teaching Based on Autism Research
VABS	Vineland Adaptive Behavior Scales, Survey Edition
2SLS	Two-Stage Least Squares

Chapter 1 Introduction

The number of children who have an autism diagnosis under Part B of the Individuals with Disabilities Education and Improvement Act (IDEA) and who are enrolled in preschool programs has grown rapidly, likely due to progress in early identification and detection of autism. In the 2016-2017 school year alone, over 76,000 children, aged 3 to 5 years, were served under the autism eligibility category of Part B (U.S. Department of Education, 2017). Children with autism spectrum disorder (ASD) often experience social communication delays and display repetitive and restricted patterns of behaviors and interests (Diagnostic and Statistical Manual of Mental Disorders Fifth Edition [DSM 5], American Psychiatric Association, 2013), and those symptoms can negatively affect their educational performance. The purpose of public preschool programs is to lessen the effects of the disability and provide specialized services and support within schools to meet the needs of young children with ASD.

Social communication deficits can manifest in young children with ASD as early as 12 months of age (Landa, Holman, & Garrett-Mayer, 2007). Their difficulty in learning social signs and communication skills early in development results in their missing out on important social interaction opportunities with their caregivers and others, thus exacerbating their delay (Crais & Watson, 2014; Dawson, 2008; Eapen, Čenčec, & Walter, 2013; Sullivan, Stone, & Dawson, 2014). Therefore, early intervention (EI) and early childhood special education (ECSE) services must provide interventions to support children’s social learning and development (Koegel, Koegel, & McNerney, 2001; Schreibman et al., 2015; Sullivan, Stone, & Dawson, 2014).

Preschool is often a child's first school experience where he/she learns to interact with peers and adults other than family members. However, preschoolers on the spectrum have difficulties in joint attention and engagement with peers and adults, functional play, social interaction, and communication (Gulsrud, Hellemann, Shire, & Kasari, 2016). Therefore, they may not fully realize the benefits of social experiences with their typically developing peers, even when placed in the same classroom setting. In fact, researchers have found that young children with ASD might be at increased risk of peer rejection and experience social anxiety when included in preschool programs without the support they need (Chamberlain, Kasari, & Rotheram-Fuller, 2007; Lee, Joseph, Strain & Dunlap, 2017). Therefore, effective intervention strategies and evidence-based treatments that target social communication deficits and other autism-specific characteristics need to be in place in ECSE programs for these children to engage successfully in class participation and peer interactions. Moreover, researchers have indicated that social and functional skills are better generalized and maintained when they are learned in meaningful, inclusive contexts with peers (Barton, Lawrence, & Deurloo, 2012).

Evidence-based Interventions for Preschoolers with ASD

Interventions for children with ASD should be evidence-based and individualized using a combination of developmental and behavioral strategies that are implemented in natural settings (National Research Council, 2001; Odom, Hume, Boyd, & Stabel, 2012; Schreibman et al., 2015). Currently, two categories of intervention strategies with research evidence are available: focused interventions and comprehensive treatment models (CTMs). Focused interventions for young children with ASD typically are implemented over short periods of time and often target a singular developmental or behavioral outcome, such as joint attention (Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Kaale, Smith, & Sponheim, 2012), imitation (Ingersoll, 2008; Toth et al., 2006), or play (Siller, Hutman & Sigman, 2013). Several focused interventions have shown efficacy in promoting specific areas of early development in children with ASD. The National Professional Development Center (NPDC) on Autism Spectrum Disorder identified 27 established focused intervention strategies, among which 25 strategies have been empirically validated for preschoolers with ASD (Wong at al., 2015).

CTMs, on the other hand, provide program-wide interventions that target multiple developmental domains in one treatment model and often include various evidence-based, focused interventions (Odom, Boyd, Hall, & Hume, 2010; Boyd et al., 2014). Odom and colleagues (2010) reviewed and evaluated 30 CTMs and found that the CTMs were operationalized well, but most of them had limited empirical evidence of efficacy. Many of these CTMs focused on preschoolers as their primary target population. Among the available CTMs, Learning Experiences: Alternative Programs for Preschoolers and Parents (LEAP) and TEACCH are two long-standing intervention programs for individuals with ASD (Boyd et al., 2014), with LEAP designed specifically for preschoolers.

Within the context of research and practice, CTMs often are compared to treatment-as-usual or more non-model-specific (NMS) classroom practices. One of the differences between the two approaches is that CTMs often have a centralized conceptual/theoretical foundation that integrates various intervention components whereas NMS programs involve the use of eclectic instructional methods without necessarily employing a guiding theory (Odom, Hume, Boyd & Stabel, 2012). This eclectic or NMS approach to early education and practice is not uncommon, as practitioners are likely to use different strategies, often based on their professional knowledge, to meet the needs of the individual children and families they serve (Boyd, Kucharczyk, & Wong, 2016). High-quality eclectic models that are implemented by well-trained professionals can potentially benefit children with ASD and their families (Odom et al., 2012). Thus, understanding and giving consideration to these more eclectic approaches to classroom practice and the role they play in supporting child and family outcomes may be worthwhile.

Progress continues to be made in designing and identifying effective interventions to promote better developmental outcomes for children with ASD. The seminal paper on Naturalistic Developmental and Behavioral Interventions represents a collective effort to articulate shared characteristics of various evidence-based intervention approaches (Schreibman et al., 2015). However, even with this effort, no single intervention has been established with consensus as the standard of care for all children with ASD (Stahmer, Schreibman, & Cunningham, 2011). The Lovaas-based, applied behavior analysis (ABA) intervention has the longest history and the most research evidence; however, efficacy studies have shown varied child outcomes (Ben-Itzchak, Watson, & Zachor, 2014; Hedvall et al., 2015; Reichow, Barton, Boyd, & Hume, 2012). One potential reason for this mix of intervention outcomes is the heterogeneity of ASD. There is hardly a “one-size-fits-all” intervention that works for every child with ASD and their family.

The Heterogeneity of Autism

Due to the heterogeneous nature of ASD, children with ASD tend to show vast individual differences regarding the degree of their delays and needs (Zwaigenbaum et al., 2015a). In the DSM-5 diagnostic criteria, ASD is described as a condition that is associated with different levels of severity and comorbid conditions (DSM 5, 2013). Some of the individual differences in ASD appear to be related to the numerous genes and gene mutations that have been identified (Ronald et al., 2006; Jeste & Geschwind, 2014).

Beyond the genetic basis of ASD, researchers have explored autism behavioral phenotypes and subtypes to better understand and parse the heterogeneity. For example, Tager-Flusberg and Joseph (2003) identified two subtypes of ASD based on individuals' cognitive and language profiles and identified these behavioral profiles to be associated with physical markers of neural development (i.e., head circumference). Fountain, Winter, and Bearman (2012) identified six different developmental trajectories of social development, communication, and repetitive behaviors for children with ASD aged 2 to 14 years. Another longitudinal exploration found three classes of severity for social communication and repetitive behaviors at the time of diagnosis; yet, by age six, children with ASD had merged into two classes of autism severity (Georgiades et al., 2014). These findings demonstrate that developmental differences emerge between children on the spectrum as well as within children over time. Given that autism is a developmental disorder and children with this disorder (and children in general) change over time, those with different developmental profiles may show different responses to different interventions (Sherer & Schreibman, 2005).

Influential Factors for Responses to Intervention

Researchers have tried to understand how interventions work by identifying influential factors that impact children's development and intervention outcomes. The term 'influential factors' is used to refer to pretreatment characteristics of children and families that differentially affect intervention outcomes. Currently, no definitive set of pretreatment child (or family) variables is available that consistently predicts intervention outcomes, but a group of influential child factors shows emerging evidence. Early cognitive and social communication ability are two influential factors with a strong empirical basis. Early social communication behaviors, such as joint attention(JA), imitation, and object play, are developmental predictors of later communication and intellectual functioning in elementary-aged children (aged 5 to 7) with ASD (Poon, Watson, Baranek, & Poe, 2012; Stahmer, Schreibman, & Cunningham, 2011; Toth et al., 2006). As an example, children's social skills at age two can predict both their receptive and expressive language abilities at age five (Thurm, Lord, Lee, & Newschaffer, 2007). Moreover, Sallows and Graupner (2005) applied regression modeling and documented that pretreatment imitation, language, and social responsiveness could predict children’s outcomes after four years of intensive behavioral treatment. Thus, early social communication skills have an impact on both general development and responses to intervention. However, many previous studies have examined discrete social skills (e.g., joint attention skills, symbolic play, and joint engagement states) as influential factors and intervention outcomes (Kasari et al., 2010; Kasari, Gulsurd, Paprella, Hellemann, & Berry, 2015; Schertz, Odom, Baggett, & Sideris, 2013) instead of social development as a whole. Yet, to understand social development, the simultaneous effects of multiple child and family factors must be considered, as the combination of these characteristics likely affects how children with ASD socially interact with their world.

Problem Statement

EI and ECSE research and practice provide a broad range of intervention strategies and programs for young children with ASD and their families. However, as our understanding of the active ingredients of intervention and influential factors with regard to individual children’s responses to intervention is still limited, parents and professionals are left with little guidance and direction for choosing and tailoring intervention strategies to meet the needs of individual children with ASD and their families (Stahmer, Schreibman, & Cunningham, 2011). Thus, more work is needed to address the perennial question of ‘what intervention works for whom?’ (Vivanti, 2017). Current intervention efficacy studies have drawn conclusions about effectiveness based primarily on group outcomes rather than intervention effects for children with different developmental profiles. Some studies have examined moderators to identify influential factors of children's intervention responses, but moderator analysis tends to focus on separate pretreatment child characteristics (e.g., cognitive ability), and a single characteristic is not representative of an individual child. Therefore, such analysis approaches are not always sufficient for determining the nature of relationships between child and family characteristics and intervention outcomes. Research is needed that examines the profiles of children rather than individual characteristics in order to advance knowledge of which interventions work best for different types of children with ASD.

To address this deficit in the literature, more refined analyses of comparative efficacy studies are needed to examine how subgroups of children with different developmental profiles respond to various intervention models. This effort will help us to understand the combination of child (and/or family) factors that are related to intervention change(s), thus making it possible to move towards more individualized interventions for children with ASD. Such analyses often require large sample sizes; therefore, secondary data analysis is used to identify developmental subgroups of children with ASD and their responses to interventions. This dissertation project used data from the TEACCH and LEAP comparative efficacy study (PIs: Drs. Samuel Odom and Brian Boyd; Boyd et al., 2014).

Description of Comparative Efficacy Study

To understand and compare the relative efficacy of these two treatment programs, Boyd et al. (2014) completed the TEACCH and LEAP comparative efficacy study, which was the first large-scale comparative efficacy study in the field of ASD. This quasi-experimental study, funded by the Institute of Education Sciences, compared the effects of TEACCH, LEAP, and high-quality NMS preschool programs on outcomes for preschool-aged children with ASD. The findings of the study indicated that preschoolers in TEACCH and LEAP programs did not show significantly different outcomes when compared to each other or to children in NMS classrooms. Importantly, within-group moderator analyses identified that (1) pretest cognitive Mullen Scales of Early Learning (MSEL) and Preschool Language Scale-4 (PLS-4) scores had an impact on the rate of improvement in cognitive ability (MSEL) and autism severity for children in the TEACCH group and (2) gender showed moderating effects on communication skills for children in the LEAP group (Boyd et al., 2014). These results demonstrate that children with different pretreatment characteristics have different responses to different intervention models, even when no significant differences of intervention outcomes are present at the group level. As stated, research is still needed to go beyond these approaches to consider the impact of multiple child and family characteristics on different treatment outcomes. Secondary data analysis is an exploratory but important next step in understanding the developmental profiles of responses to interventions in subgroups of children.

Research Questions

This dissertation study used data from the Boyd et al. (2014) TEACCH-LEAP comparative efficacy study to address the general question of 'what intervention works for whom'. Specifically, the following research questions are addressed via secondary data analysis:

1. Are there subgroups of preschoolers with ASD distinct based on pre-intervention developmental and behavioral measures? If so, what are the subgroups and their characteristics?

2. Do child or family factors influence changes in social communication development over time for preschoolers in TEACCH, LEAP, and NMS classrooms? Specifically:

(a) Would children who have different developmental characteristics and are grouped into different clusters (e.g., with different cognitive and language abilities and autism severity levels) respond differently to the three interventions?

(b) Would children of caregivers with different mental health status and socioeconomic status (SES) benefit differently from the three interventions?

Significance of the Current Study

This project addresses the pressing issue of treatment individualization for young children with ASD by examining the heterogeneity of ASD symptoms and exploring whether different preschool intervention programs work differently for children with distinct child and caregiver characteristics. The findings of the cluster analysis will add to the current literature in understanding early developmental profiles and provide insights into the different presentations of autism-related symptoms in subgroups of preschoolers with ASD. The application of fuzzy regression discontinuity design (FRDD) analysis (Campbell, 1969; Trochim, 1984) explores a new method of evaluating ASD intervention programs. The findings will inform researchers and service providers about the intervention effects of the three preschool programs for ASD based on the relationships between child and caregiver factors and social communication development. Further, the findings potentially can provide guidance in service delivery to determine the best service placement for children with ASD based on child characteristics.

Chapter 2 Literature Review

The purpose of this chapter is to review the previous literature to provide both a background and a foundation for the proposed study. Therefore, in this chapter, I first introduce the theoretical framework, then review the social development of children with ASD in comparison to typical development. Second, I discuss the important effect of high-quality preschool programs on the social development of young children and lay out research evidence for existing CTMs for preschoolers with ASD. Third, I raise the issue of heterogeneity of ASD and list influential factors on intervention responses and developmental outcomes. Finally, this chapter concludes with the justification for the proposed secondary data analysis and its implications for treatment individualization.

Theoretical Framework for the Current Study

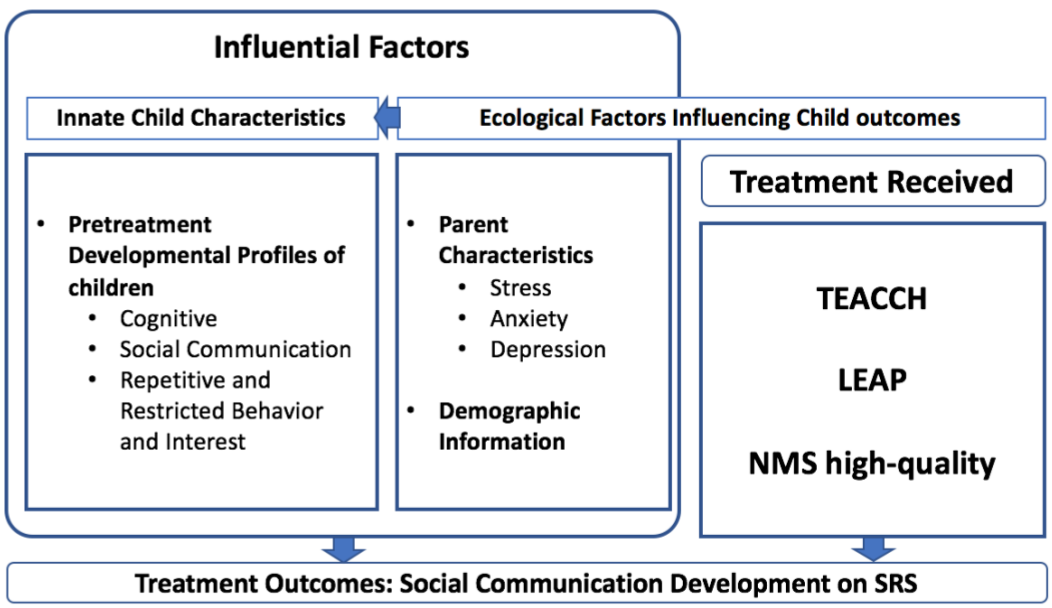
Two prominent theoretical and conceptual frameworks best provide support for exploration of the social development of children with ASD and influential factors of their intervention response: constructivist theory (Piaget, 1970; Vygotsky, 1962; in Odom & Wolery, 2003) and bioecological theory (Bronfenbrenner, 1998).

Piaget and Vygotsky's constructivist theory emphasized the importance of children's actions and interactions with the rest of the world and their constructive roles in shaping individual child development (Piaget, 1970; Vygotsky, 1962). Odom and Wolery (2003) acknowledged that the constructivist theory guided the application of developmentally appropriate practices in early childhood education. The ECSE programs, such as TEACCH and

LEAP in the current study, are designed to meet the developmental needs of children with ASD. Moreover, the bioecological theory suggests that children's behaviors and development are situated in and influenced by the interactions between the evolving child characteristics and the ecological environment at all levels (Bronfenbrenner, 1998). Based on this framework, the present study examines the effects of different child and parent characteristics on intervention responses in the ECSE programs under study and how children with ASD develop as a result of the ecological environment (Figure 2.1).

Figure 2.1

Theoretical Framework for the Proposed Study



Social Development of Preschoolers with ASD

Young children start exploring, learning about, and bonding with the rest of the world from their birth. As toddlers, they strive to gain more independence and autonomy as cognitive and social skills continue to emerge (Santrock, 2010). During the preschool years, children's brains rapidly develop as they continue to interact with and learn from others. Specifically, they make great progress in social-emotional development and show growth in understanding other's perspectives (i.e., theory of mind), self-regulating of emotions and behaviors, acquiring language and early literacy skills, and initiating and establishing social relationships (Gallagher, Dadisman, Farmer, Huss & Hustchins, 2007; Santrock, 2010). Early childhood is the critical period for the development and acquisition of social interaction behaviors and skills, and "form the underpinnings of later social competence and enable children to participate more actively and successfully in a variety of learning contexts" (Wetherby, 2014, p. 28). Research evidence has identified the predictive effect of early social development on individual's future social and emotional competence, and even post-secondary outcomes (e.g., employment and independence) (Joseph, Strain, Olszewski, & Goldstein, 2016; Reszka, 2010). Therefore, researchers have emphasized the importance of intentionally teaching social competence in early intervention (EI) and early childhood special education (ECSE) programs when these skills do not develop as expected.

Atypical social development and social communication deficits are considered core symptoms of ASD. In fact, these issues are often considered early warning signs or "red flags" that the child may be at-risk of developing ASD (Boyd, Odom, Humphreys & Sam, 2010). In the DSM 5 (APA, 2013), social communication and interaction deficits are defined by three dimensions: a) deficits in social-emotional reciprocity (e.g., failure of normal back-and-forth conversation, failure to initiate or respond to social interactions); b) deficits in nonverbal communicative behaviors used for social interaction (e.g., deficits in understanding and use of gestures); and c) deficits in developing, maintaining, and understanding relationships (e.g., difficulties in sharing imaginative play or in making friends). However, early social development in ASD has been theorized in a variety of ways in research and often with different but likely related constructs. In this review, the following aspects of social development are discussed: social motivation, social cognition and communication, and social skills and challenging behaviors.

Social motivation. The social motivation theory hypothesizes that children with ASD are born with a decreased motivation for social reward, and thus social interactions with others are not as naturally reinforcing for them, which leads to fewer opportunities to learn language and communication skills (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). For instance, young children with ASD show decreased gaze shifts and social interest in following other's directions and have deficits in both initiation of joint attention (IJA) and response to joint attention (RJA) (Leekam & Ramsden, 2006; Wetherby, 2014). Both IJA and RJA behaviors are thought to reflect an underlying capacity for social motivation, with decreased social motivation, preschoolers show fewer play and joint attention behaviors in the classroom (Mundy & Newell, 2007). Moreover, research findings showed that preschool teachers, who did not have sufficient training to promote social development in children with ASD, spent relatively less time engaging in joint attention exchanges with them than with their typically developing peers (Wong & Kasari, 2012). Without intentional intervention cultivating social motivation, it would be difficult for young children with ASD to learn social communication skills on their own.

Social cognition and communication. Deficits and delays in social cognition and communication are pervasive in individuals with ASD, regardless of their cognitive abilities (Reichow & Volkmar, 2010). While children with ASD with co-occurring intellectual disabilities or language impairments often have more difficulty understanding social cues and communicating their needs in social contexts, "higher functioning" children with ASD are by no means immune to these issues. Compared to their typically developing peers, children with ASD, in general, have delays in certain areas of social cognition, such as emotion recognition and expression, and theory of mind (i.e., understanding that others have thoughts or beliefs different from one's own) (Baron-Cohen, Tager-Flusberg, & Lombardo, 2013; Volkmar, Lord, Bailey, Schultz, & Klin, 2004). Children with ASD also have a difficult time understanding semantic or symbolic aspects of language, which can manifest in their lack of use of gestures or other non-verbal forms of communication (Wetherby, 2014). Along with these receptive language differences, poor expressive language also can interfere with their social exchanges and reciprocity with peers and adults, particularly in communicating their own needs and feelings accurately and effectively (Griffith, Arnold, Voegler-Lee, & Kupersmidt, 2016). Without the use of conventional social understandings and expressions, they are more likely to be excluded from daily interactions and natural learning opportunities both at home and at school (Crais & Watson, 2014; Reichow & Volkmar, 2010). Further, these social frustrations and rejections may then contribute to an elevated social anxiety and stress level in children with ASD; thus, resulting in decreased social motivation (White, Schry, & Kreiser, 2014), making this a negative feedback loop.

Social skills and challenging behaviors. Given the aforementioned social deficits, it is not surprising that children with ASD have difficulty developing the social skills and competence needed to successfully participate in activities without any intentional intervention (Joseph et al., 2016). Some critical social skills needed to succeed in preschool include the ability to follow directions and rules, to ask for and receive help, and to get along well with other children in daily activities and play (Griffith, Arnold, Voegler-Lee, & Kupersmidt, 2016). However, some children with ASD experience pervasive delays in acquiring these skills and are at risk for falling behind further. In a study to identify social networks in preschool classrooms, children with ASD were reported to have fewer reciprocal friendships (meaning both children identify each other as their best friend) than typically developing peers in the same class (Chang, Shih, & Kasari, 2016). For young children, friendships have a positive impact on their prosocial behaviors, while peer rejections and conflicts might result in challenging behaviors. As a direct consequence, behavioral challenges and social communication deficits set obstacles for preschoolers as they disrupt social exchanges and prevent children with ASD from joining in higher level social play with their peers.

In all, children with ASD have pervasive deficits in social development, from reduced social motivation to impaired social cognition and skills, which are needed to participate in interactions with others successfully. There have been programmatic and research efforts to promote the social development of children with special needs during the preschool years, including children with ASD, because early social skill development is a predictor of later academic, social and emotional functioning (Griffith, Arnold, Voegler-Lee, & Kupersmidt, 2016).

The Importance of a High-quality Preschool Experience

As preschoolers are ready to participate in classroom-based education, these active and eager learners (especially those with developmental delays) demand specific learning goals, welcoming environments and purposeful instruction to facilitate their development and help them get ready for Kindergarten (Gormley, Gayer, & Phillips, 2008). Both the state and federal government have made efforts and investment in promoting high-quality early childhood education for all children (National Institute for Early Education Research [NIEER], 2016). Under IDEA Part B section 619, public preschool programs are mandated to provide preschoolers with special needs with sufficient support to fully participate in the learning activities in classrooms with all levels of assistance and structure (IDEA, 2004). Children with ASD are served in a variety of settings in preschool programs, e.g., resource rooms, inclusive settings and with push-in and pull out services. They often require an interdisciplinary school team to meet their pervasive developmental needs (Cox, 2012), and would undoubtedly benefit from high-quality preschool programs.

In high-quality preschool programs, children experience a variety of learning opportunities, engage with caring educators and have access to appropriate peer models. They learn social rules to play and negotiate with peers and follow directions from teachers in a predictable environment with established routines. Besides their social emotional and physical development, teachers in state-funded preschool programs are also required to teach children pre-academic skills with developmentally appropriate practices and can prime children's understanding in such areas as early literacy and math (Weiland & Yoshikawa, 2013). High-quality early childhood education not only gives children strong starts in life and potentially nurture a lifelong love of learning, but also sets the ground for later success (Lasser & Fite, 2011).

Previous longitudinal studies have shown that the early childhood education experience has an impact on individual's later academic performance, postsecondary outcomes and quality of life (Barnett, 2008; Yoshiyawa et al., 2013). For example, the prestigious Abecedarian Project followed individuals who participated in high-quality early education into their adulthood and found that these individuals tended to have higher education levels and employment rate, and even better physical health (Campbell et al., 2014) than those who did not have access to high-quality early education. An economic analysis also showed that the investment in early childhood education is a great benefit to society, in general, because of the decreased need for social welfare and services (Heckman, 2012). High-quality preschool programs benefit all children: the long-term outcomes of Head Start programs have shown that economically-disadvantaged children are the ones who have the most positive gains (Deming, 2009); and also, children attending high quality programs are less likely to be subsequently placed in special education (U.S. Department of Education, 2015). Further, children with disabilities, when receiving a high-quality early childhood education, are more likely to establish positive social relationships with both peers and teachers (Tsao, Odom, Buysse, Skinner, West, & Vitztum-Komanecki, 2008).

The Definition of High-quality Preschool Classrooms

Early childhood education researchers have proposed different definitions and constructs of classroom quality and identified quality indicators to improve child outcomes (Pelatti, Dynia, Logan, Justice, & Kederavek, 2016). There are two quality constructs: process quality and structural quality. Process quality often refers to children's actual experiences in the classroom, including teacher-child interactions, emotional and instructional support, and classroom organization (Espinosa, 2002; Pelatti et al., 2016). Process quality indicators have more direct links to child outcomes. Among them, one of the best indicators of quality is teacher-child interactions, which is measured by teachers' responsiveness to children's needs, support of positive behaviors, and stimulation of cognitive and language development through interactions and instructions (Pianta, Downer, & Hamre, 2016). The more frequent and meaningful the interactions are, the better the children perform in their language and social-emotional development (Hamre, Hatfield, Pianta, & Jamil, 2014). In comparison, structural quality indicators include elements such as length and structure of a school day, the number of school days, adult-child ratio, and teacher qualification (Espinosa, 2002). Further investigations exploring the association between process and structural quality identified these two aspects of classroom quality to have complex interactions with each other. For example, the National Institute for Early Education Research (NIEER, 2016) set the high-quality benchmark for the lead teacher degree in ECE to be at least a Bachelor's degree. While higher degrees and qualifications potentially mean more professional training and skills, studies have not found that higher education is associated with better classroom quality or student outcomes, rather teachers need ongoing professional development and coaching to help improve the quality of their classroom practices (Early et al., 2007).

With the funding to further advance the quality of early childhood education (ECE) programs, states across the U.S. use Quality Rating and Improvement Systems (QRIS) to monitor and improve classroom practices; however, these quality standards often vary from state to state. Some common categories of QRIS standards include staff qualifications and professional development, curriculum and learning activities, administration and business practices, family engagement, staff-child ratios, child assessment, and health and safety (QRIS Guide, National Center on Child Care Quality Improvement, April 2015). Several research-validated observational measures are used to help quantify ECE classroom quality. The Early Childhood Environment Rating Scales (ECERS-3, Harms, Clifford, & Cryer, 2015) and Classroom Assessment Scoring System (CLASS, Pianta, La Paro, & Hamre, 2008) are two of the most commonly used and empirically validated classroom quality measures for early childhood settings. These two measures cover a range of quality components to provide a holistic picture of ECE settings.

Admittedly, while we have developed a good understanding of classroom quality indicators and their influences on student outcomes for typically developing children, we still have much to learn about classroom quality indicators for children with disabilities that are associated with improved outcomes. The Inclusive Classroom Profile (ICP; Saukakou, 2012) was developed in response to filling this gap for young children (age from 2 to 5) with disabilities served in inclusive ECE classrooms (Saukakou, 2012). The ICP focuses on adaptations that have been made to provide individualized support for children with disabilities and to ensure full participation in the classroom. Although the ICP has been validated in both the U.K. and U.S. and compared with other standardized measures (e.g., ECERS; Soukakou, Winton, West, Sideris, & Rucker, 2015), there is no empirical study exploring the relationship between the ICP measure of inclusion quality and outcomes for children with disabilities served in high quality, inclusive class.

Quality indicators for preschool ASD programs. The definition and measurement of a high-quality classroom for children with ASD are not as well established as the quality of general ECE classrooms. However, there has been an ongoing effort in the field to quantify and operationalize classroom/program quality for students with ASD (Pearl et al., 2017). The development and validation of the Autism Program Environment Rating Scale (APERS; NPDC, 2011) is an example of such an effort. The APERS was developed as a tool to measure classroom quality as well as facilitate the implementation of evidence-based practices to improve classroom accessibility and participation for children with ASD. The APERS-preschool/elementary school (APERS-PE) version has 64 items covering 11 domains, including class environment, class structure, positive classroom climate, assessment, curriculum and instruction, communication, social competence, personal independence, functional behavior, family involvement, and teaming. Using APERS-PE as a pre- and post-assessment measure, teachers and implementation coaches were able to identify areas of need and significantly improve classroom quality after one year of participation in NPDC implementation and training (Odom, Cox, Brock & NPDC, 2013).

The researchers found that measurement of classroom quality both provided an evaluation of current practices, and informed future adjustments as well as improvement of service delivery. Therefore, continuous research efforts should be devoted to examining quality indicators of classrooms and helping inform preschool programs in order to serve children with ASD more effectively.

Current preschool services for children with ASD. Children with ASD have varied needs and abilities and thus require different levels of classroom support. However, educational placement is often affected by state and local policies as well as the availability of financial and personnel resources (Kurth, 2015) and not just children's individual needs. Still, it has been found that students with better social skills, fewer problem behaviors, and a higher IQ are more likely to be placed in less restrictive settings (Harris & Handleman, 2000; White, Scahill, Klin, Koenig, & Volkmar, 2007). At issue is that many preschool teachers may lack the adequate knowledge or skills to effectively cultivate the social development of children with ASD, as they face limited resources and professional development opportunities (Lawton & Kasari, 2013).

Wong and Turner-Brown (2013) reviewed current preschool curricula and proposed that to meet the needs of children with ASD, preschool curricula should target early core characteristics of ASD (e.g., engagement, joint attention, symbolic play), set functional goals, and use intervention strategies that are developmentally appropriate and socially and culturally relevant. Research evidence is needed to determine the scope and sequence of skills to teach in preschool curricula targeting children with ASD. Current comprehensive treatment models for preschoolers with ASD provide practitioners guidelines to support the implementation of high-quality preschool services.

Comprehensive Treatment Models for Preschoolers with ASD

Program-wide implementation of CTMs is an effective way to ensure high-quality preschool environments and interventions for young children with ASD. CTMs are often manualized intervention programs with a range of evidence-based practices built around a core theoretical framework, and address multiple developmental aspects of children with ASD. Implementing CTMs and studying their efficacy in schools are critical in improving the quality of classroom-based learning experiences for children with ASD, and thus, closing the research-to-practice gap.

Odom and colleagues (2010) evaluated 30 CTMs on five aspects (operationalization, fidelity, replication, outcome data and quality) and found that there is limited evidence for most CTMs, with few replications across different research groups. The overall ratings of the CTMs revealed that only five CTMs (LEAP, UCLA Lovaas Institute, May Institute Model, Princeton Child Development Institute [PCDI], Strategies for Teaching based on Autism Research [STAR]) had sufficient evidence, and that all five intervention models used behaviorism as their core theoretical framework. However, it is important to note that the evidence included in the review for Lovaas, May, PCDI, and STAR is not just from studies involving children under five years of age. Further other programs, such as the Denver Model, Walden Early Childhood Program, and the Social Communication, Emotional Regulation, and Transaction Support (SCERTS) program have been adopted for preschoolers with ASD, but have less supporting research evidence.

There have been several efficacy studies of CTMs in preschool classrooms since the 2010 review. To capture more research evidence, efficacy studies of preschool-based CTMs that have been published since the 2010 review are included below, with brief descriptions detailing study designs and findings. Moreover, for the purpose of this dissertation research, more details on intervention strategies, program philosophy and research evidence of TEACCH and LEAP programs are provided below as they are the programs of interest in this study.

Comprehensive Autism Program (CAP) is a program integrating different evidence-based intervention strategies and models (Pivotal Response Training [PRT], Discrete Trial Training [DTT], the STAR program and structured teaching strategies), supplemented with a coaching and training model for teachers in CAP classrooms (Young, Falco, & Hanita, 2016). In the 2016 RCT study, 78 schools (35 CAP and 30 business-as-usual) with 255 students (160 CAP and 95 business-as-usual) were recruited. With the professional development provided, teachers in the CAP classrooms were able to implement evidence-based practices with high fidelity. The well-implemented CAP intervention helped preschoolers with ASD significantly improve in receptive language and teacher-rated social skills, and this intervention effect was moderated by children's autism severity scores.

Project DATA (Developmentally Appropriate Treatment for Autism) is an inclusive, early childhood special education program with five major components: integrated inclusive early childhood experience; extended intensive instruction; technical and social support for families; collaboration and coordination across service providers; and a quality-of-life influenced curriculum (Schwartz, Thomas, McBride, & Sandall, 2013). The researchers compared pre- and post-intervention performances on outcome measures of 69 preschool children with ASD who received Project DATA intervention. The results showed that preschoolers performed significantly better after receiving Project DATA intervention, across measures of autism severity, vocabulary/receptive language, and social skills. Children also showed developmental gains across subscales on a curriculum-based measure, i.e., Assessment, Evaluation, and Programming System (AEPS-2, Bricker et al., 2002).

Classroom Pivotal Response Teaching (CPRT) is a classroom-based intervention program adapted from the original clinic-based version of PRT. A single case design study was conducted to test the effect of teachers' implementation fidelity, strategy use and satisfaction of CPRT and the engagement level of students after the intervention (Stahmer, Suhrheinrich, & Rieth, 2016). This pilot study grouped 20 teachers from preschool to 3rd-grade special education classrooms into five training groups. The visualization of student and teacher outcomes during ten weeks of CPRT implementation showed that: a) teachers improved their implementation fidelity of CPRT after 12-hours of group training and ongoing individualized coaching, and b) students showed progress in levels of engagement after receiving the CPRT intervention.

The STAR Program (Strategies for Teaching based on Autism Research) relies on three teaching techniques in the family of ABA: DTT, PRT, and teaching during functional routines (Arick, Loos, Falco, & Krug, 2004; Mandell, Stahmer, Shin, Xie, Reisinger, & Marcus, 2013). In a comparative efficacy study (Mandell et al., 2013), researchers randomly assigned classrooms into either STAR (teachers N = 18; students N = 60) or the Structured Teaching intervention (teachers N = 17; students N = 59). In general, the findings highlighted the importance of implementation fidelity on student outcomes. For example, students in STAR classrooms showed more improvement in cognitive abilities when the strategies were implemented with either low or high fidelity; whereas, more gains were observed for students in the Structured Teaching classrooms when the interventions were implemented with moderate levels of fidelity. The study also showed that the STAR and Structured Teaching approaches have some similarities, especially in "classroom organizational and scheduling/transition strategies," which may explain why children in both programs made progress.

LEAP is an inclusive preschool intervention program designed to provide learning opportunities and facilitate social skill development in children with ASD. Dr. Phillip Strain established LEAP in 1981. LEAP classrooms usually include 3 to 4 children with ASD, 8 to 10 typically developing peers (TD), and three adult professionals (with the ratio of ASD: TD: Adults to be about 1:2:1); and children with ASD and their TD peers participated together in all the activities (Strain & Bovey, 2008). To better support social communication development and peer relationships, typically developing peers receive instructions on how to interact with their classmates with ASD through social skill curriculum. Teachers teach the five social skills (i.e., getting a friend's attention, sharing, requesting sharing, play organizing and giving compliments) one at a time and provide supports until children can use the skills independently during play with peers with ASD (Green, 2013).

Besides the primary strategies involved in peer-mediated intervention, the LEAP program also incorporates other evidence-based practices, such as incidental teaching, time delay and pivotal response training (PRT), to facilitate learning and address individual needs of children. The LEAP program also engages families by providing parent training, support groups and service planning and invites families to participate in different aspects of the preschool program. Strain and Bovey (2008) provided more detailed information on the LEAP model in their book Chapter.

Research Evidence. Strain and Bovey (2011) randomly assigned 28 inclusive preschool classrooms with 177 children with ASD to receive two years of LEAP training and coaching and 28 inclusive classrooms with 117 children to a LEAP manual-only group. The research team trained and coached preschool teachers in the treatment group to implement LEAP with high fidelity across the two years, and collected child and teacher data throughout the study. The findings indicated that: a) preschool teachers were able to deliver the LEAP intervention with 80% fidelity or higher with intensive training and ongoing professional development; b) preschoolers with ASD in the treatment group showed significantly larger improvement in measures of cognitive ability (Mullen), language (PLS-4), social and behavioral competence (SSRS) and autism symptoms (CARS), with effect sizes ranging from moderate (0.59) to large (1.22). The 4-year follow-up study (Strain, 2017) showed that cognitive and social developmental gains of children in the LEAP group were maintained, and also all children in this group remained in inclusive settings from kindergarten to 3rd grade. Therefore, comprehensive inclusive programs with evidence-based intervention strategies could give children with ASD a head start and have lasting effects on their later development. However, when compared to other high-quality preschool programs (i.e., TEACCH autism program and NMS eclectic program), LEAP did not prove to be more beneficial in improving child outcomes (Boyd et al., 2014).

The TEACCH Autism Program is a treatment and service program for individuals of all age groups and with all levels of ability. Dr. Eric Schopler formally established TEACCH in 1972. The program is built around the "culture of autism" and acknowledges that individuals with ASD have different patterns of thinking, communicating, behaving and interacting with the world (Mesibov & Shea, 2010). With this theory, the TEACCH structured teaching approach addresses core ASD characteristics by adapting the physical environment to individualize intervention based on children's strengths. Specifically, the TEACCH program utilizes strategies, such as setting up routines and structure, integrating visual supports, organizing work systems, incorporating flexibility and generalization into routines, promoting meaningful social communication and engaging families. The intervention goal of TEACCH is to teach individuals new skills and build their independence to live a meaningful life (Mesibov & Shea, 2011). Please refer to the book Mesibov, Shea & Scholper (2005) for more information.

Research Evidence. However, there is still limited research evidence examining the efficacy of the comprehensive TEACCH program. Boyd et al. (2014) and D'Ella et al. (2014) are two studies that have been conducted since the 2010 Odom review; however, the latter study was conducted outside the U.S.

D'Ella and colleagues (2014) conducted a longitudinal study to examine the effect of a combined home and school TEACCH program in Italy. Thirty preschoolers with ASD in mainstream classrooms were equally assigned to either TEACCH (n=15) or a non-specific intervention program (n=15), based on parents' preference. The two groups showed improvements in autism symptoms and adaptive behaviors over time but did not differ from each other significantly, with children in the TEACCH group making larger gains on the outcomes measures. Moreover, the parents of preschoolers in the TEACCH group showed significantly reduced stress level after six months of the intervention. The effect of the TEACCH program on child outcomes was also confirmed by the Boyd et al. (2014) study.

The evidence reviewed for the above six preschool-based CTMs is promising but not overwhelmingly compelling because of the following: a) only one to two efficacy studies for each intervention model; b) relatively small sample sizes for some studies; and c) less rigorous research designs used in some cases (e.g., quasi-experimental designs and single case studies). Admittedly, it is difficult to implement program-wide CTMs in preschool settings and conduct randomized controlled trials to establish research evidence considering the personnel training and system-level changes needed, as well as the ethical issues involved with only providing treatment to some students in schools (Odom, Cox, Brock &NPDC. 2013). Moreover, implementing CTMs for children with ASD at the program-level is extra challenging, as children with ASD have a great variety of delays and need tailored interventions. Therefore, it is critical to take the heterogeneity of ASD and its influence on responses to intervention into account when evaluating ECSE programs.

The Heterogeneity of ASD

Heterogeneity is a hallmark of ASD, and it refers to the observed variance and diversity in the manifestations of autism-related etiology, phenotypes, and outcomes (Georgiades, Szatmari, & Boyle, 2013; Masi, DeMayo, Glozier, & Guastella, 2017). Heterogeneity in ASD is potentially a result of the complex interactions of genetic-epigenetic-environmental factors (Fava & Strauss, 2014). Recent research progress has identified many candidate genes associated with autism symptoms and related comorbidities (Fava & Strauss, 2014; Jeste & Geschwind, 2014; Ronald et al., 2006). These innate gene mutations set the biological foundation for individual symptom manifestations, and are expressed by the atypical development of brain structure and function at the beginning of life. There have been attempts to connect the observed or behavioral heterogeneity of children with ASD with neural mechanisms. For example, Tager-Flusberg and Joseph (2003) made connections between previous behavioral studies of language and cognitive delays and atypical brain structures and volumes in ASD. They proposed that "structural and functional brain data would help to bridge the connection between genes and behaviors" (p. 311), and thus advance our understandings in the links among genes, brain development, and behavioral phenotypes in ASD.

Beyond the genetic and neurodevelopmental basis of ASD, autism behavioral phenotypes are the symptoms that clinical researchers, educators and practitioners observe and measure. The hope is that by understanding the heterogeneity of ASD, professionals will be better able to evaluate children's development and individualize interventions according to specific needs. Beglinger and Smith (2001) reviewed early studies from 1975 to 2000 investigating different subtypes of ASD, and found both conceptually and empirically derived subtypes. Reviewed studies used measures of different developmental dimensions, such as social/communication, cognitive development, adaptive behaviors, biological development, and language. The authors focused on the studies that used empirical analysis approaches (i.e. cluster or factor analysis) to explore subtypes across dimensions (see Table 1 on p. 414 of Beglinger & Smith, 2001). The findings indicated that differences in cognitive and social development as well as RRBs are likely to explain the most variance in symptom heterogeneity. The subtypes that emerged were consistent across studies even when different measures were used. Among them, the most consistent subtypes were based on the levels of autism severity, especially cognitive and language deficits. Still, no consensus has been established in the number and definition of ASD subtypes that would fully account for all the observed heterogeneity.

It is also essential to study various developmental trajectories of children with ASD, considering the changing nature of autistic symptoms. Fountain, Winter, and Bearman (2012) retrieved a longitudinal dataset of 6975 children with ASD, ages 2 to 14 years old, from the California Department of Developmental Services. As each child included in the analysis had more than four time points of evaluation, the researchers were able to apply trajectory analysis. The study identified six different developmental trajectories for social development, communication, and repetitive behaviors, and also found that the rates of growth were different for different developmental areas. Although children showed positive changes over time, they were likely to remain within their starting groups (i.e., children who started high in social or communication skills remained high over time; whereas, children with low social or communication skills remained low over time). Children's repetitive behavior trajectories did not show as much change over time: the developmental trajectories of approximately 85% of children with repetitive behaviors stayed flat. Importantly, there was a "bloomer" group who showed rapid growth over time in both communication and social development. Further analysis revealed that children in the "bloomer" groups were less likely to have intellectual disabilities and more likely to come from a family with higher socioeconomic status. However, it must be noted, the study did not use standardized measures to evaluate changes in children's development.

Symptom instability complicates the work of subtyping, as it is to be expected that the developmental profile of children will change over time in response to developmental maturation and/or intervention. Georgiades and colleagues followed 280 children from the time they received the diagnosis of ASD to six years of age and conducted analyses to explore homogeneous subgroups based on core autism symptoms at these two time-points (Georgiades et al., 2014). Their findings showed three distinct classes of severity for social communication and repetitive behaviors at the time of diagnosis, with Class 1 as the highest functioning group and Class 3 as the lowest functioning group. However by age six, children with ASD merged into two categories based on their autism severity: children in Class A scored significantly better on all developmental measures (e.g., social communication, RRBIs, adaptive behavior) than those in Class B. In comparison to the Fountains study, some children in this study switched groups by age six: some children in the lower functioning subgroups (65.4% in Class 2 and 81.9% in Class 3) developed to be in the higher functioning subgroup (Class B), while others changed in the opposite direction. Similarly, in a study of 100 toddlers with ASD, Kim and colleagues found that though most children had substantial developmental improvements in verbal and communication skills with different rates of change. The least affected group had the highest proportion (15%) of children who lost their diagnosis, while the most severe subgroup (17%) exhibited limited gains overtime (Kim, Macari, Koller, & Chawarska, 2015). Taken togetherthese shifts indicated that autism symptoms change substantively with natural development and interventions. Further, this underscores the importance of understanding the early predictors and influential factors of later outcomes, which would help professionals and caregivers individualize interventions to achieve better outcomes for all.

Treatment Individualization to Address Heterogeneity

Clinically, children with ASD have individual differences regarding the degree of their delays and symptom severity; therefore, are in need of various levels of support (DSM-5, 2013; Zwaigenbaum et al., 2015b). Fava and Strauss (2014) applied five principles from the conceptual biobehavioral framework (Ramey & Ramey, 1998) to treatment individualization in EI and ECSE for children with ASD. They proposed that professionals should consider: children's developmental timing, program intensity, individual differences in program benefits, program breadth and flexibility, and direct provision of the learning experience. Further, practitioners should take a child/family-centered approach and implement evidence-based practices with consideration of specific needs and intervention goals of the particular child to achieve the optimal intervention effect (Barton, Lawrence, & Deurloo, 2012; Stahmer, Schreibman, & Cunningham, 2011).

However, there is limited empirical evidence directly addressing intervention individualization and providing systematic treatment plans based on intervention responses or nonresponses. The heterogeneity of children with ASD creates extra challenges to treatment planning, as children with different developmental profiles on the spectrum may show different responses to intervention (Sherer & Schreibman, 2005). Yet, learning more about individual differences also could be informative as we better understand the relationships between child characteristics and intervention outcomes (Trembath & Vivanti, 2014). The primary focus of intervention research should shift from examining intervention effectiveness to understanding varied responses to intervention and how that informs treatment individualization (Stahmer, Schreibman, & Cunningham, 2011; Vivanti, 2017). There are now methodological approaches that allow for the examination of individualized treatments within the contexts of larger, group design studies. For example, the Sequential Multiple Assignment Randomized Trial (SMART) design is an innovative and rigorous method for individualizing treatment sequences based on participants' responses to intervention (Almirall, Compton, Gunlicks-Stoeseel, Duan, & Murphy, 2012). Research using SMART design studies can help dissect the underlying mechanisms of intervention and for whom an intervention may work.

In a SMART-design study by Kasari and colleagues (2014), 61 children with ASD, who were minimally verbal and aged 5 to 8 years, were randomly assigned to two blended developmental/behavioral intervention conditions to promote their communication, either with or without speech generating devices (SGD). Then based on their responses in the first intervention stage, interventions for children were modified to enhance the intervention effects. For children who made less progress ("slow responders"), those who did not originally receive a SGD were randomly assigned to either receive the same intervention with an increased intensity or the addition of a SGD; whereas, those who were originally assigned to the SGD group continued to have the same intervention but with higher intensity. The study outcomes showed that the addition of the SGD on top of the blended developmental/behavioral intervention most improved communication outcomes for “slow responders”. More studies such as this are needed to understand “what intervention strategies work for whom” to inform intervention tailoring.

Influential Factors in Child Development and Intervention Outcomes

One important research strand to help explain variability in ASD is the examination of influential factors and potential predictors of later child development and intervention outcomes (Vivanti, Prior, Williams & Dissanayake, 2014; Zachor & Ben-Itzchak, 2017). Further, the identification of influential factors gives insights into the mechanism of change for intervention. These findings also could inform the decision-making of what intervention(s) work for whom (Stahmer, Schreibman, & Cunninghan, 2011). In this section, I review recent studies that have examined the predictive effects of child and family variables, focusing on studies (a) published from 2000 to 2017; (b) included children in early childhood (ages 18 months to 7 years); and (c) explored the effects of variables at intake on later outcomes. For this review, the term “influential factors” is used to refer to variables that are related to or predictive of later child outcomes. Table 1 in Appendix presents brief details of studies reviewed here. Table 2.1 below shows the numbers of empirical studies that provide research evidence for different predictors.

Table 2.1

Number of Empirical Studies Supporting Influential Factors Reviewed

Influential factors/development predictors	Number of Studies
Child Characteristics	
Cognitive ability/IQ	13
Language level	8
RBIs (Object interests, object use, object play)	5
Social communication skills (e.g., joint attention, imitation, play)	5
Intake age	4
Adaptive skills	3
Motor skills (e.g., gross motor, walking onset age)	2
Gender	1
Parent Characteristics	
Parenting stress	1

Other demographic factors	1
Maternal synchronization	2

Child factors associated with intervention outcomes. Understanding the effects of different child attributes on developmental and intervention outcomes helps elucidate mechanisms of change; thus, making it possible and efficient to provide individualized intervention packages for children with ASD. Currently, influential child characteristics cover a range of core autism symptoms, severity indicators, and other accompanying features. Cognitive/intellectual abilities and language are the two influential factors with the most empirical evidence (Vivanti et al., 2014).

Cognitive ability. Cognitive ability is one essential aspect of child development as it sets the foundation for one to make sense of and react to information inputs from the rest of world. Cognitive ability is often quantified by measurements of intellectual abilities (e.g., IQ) or other early learning assessments for young children with ASD. Cognitive ability is frequently cited as a predictor of ABA-based intervention outcomes in children under five, especially for the outcomes of autism severity and adaptive skills (Zachor & Ben-Itzchak, 2017). Details of such studies could be found in Table 2.1 (see Appendix A; Harris & Handleman, 2000; Ben-Itzchak, Watson, & Zachor, 2014; Hedvall et al., 2015; Sallows & Graupner, 2005). Research findings have indicated that children's IQ at intake had a significant positive relationship with IQ at post-test, and children with higher IQ were more likely to be placed in regular classrooms (Harris & Handleman, 2000). Other studies confirmed that for children receiving community-based services, cognitive ability also positively predicted service outcomes (Gabriels et al., 2001; Magiati et al., 2007; Perry et al., 2011; Remmington et al., 2007; Sutera et al., 2007; Thurm, Lord, Lee & Newschaffer, 2007). Moreover, children with higher cognitive levels achieved better adaptive skills after two years of ABA intervention (Ben-Itzchak, Watson, & Zachor, 2014; Hedvall et al., 2015). Overall, current evidence shows that pretreatment cognitive ability is an influential factor on intervention outcomes, with higher cognitive functioning often predicting better intervention outcomes.

However, there are inconsistent findings from studies using different intervention approaches. In the group-based Early Start Denver Model (ESDM) pilot study, Vivanti and colleagues (2013) found that cognitive abilities failed to explain a significant amount of variance in developmental gains after treatment. Vivanti et al. (2014) argued that cognitive ability might be too broad of a construct to pinpoint the underlying factors of response to intervention.

Social communication ability. As reviewed above, social communication deficits are prominent in individuals with ASD, including delays and challenges in social cognition and motivation, language development, and social skills. Prelinguistic social communicative behaviors, such as joint attention and imitation, have been validated as developmental predictors for later communication and intellectual functioning in children with ASD (Poon, Watson, Baranek, & Poe, 2012; Stahmer, Schreibman, & Cunningham, 2011; Toth et al., 2006; Yoder & Stone, 2006a). Sallows and Graupner (2005) applied regression modeling and found that pretreatment imitation, language, and social responsiveness predicted children’s outcomes after 4-years of intensive behavioral treatment. Other studies have examined the influence of specific social communication skills on children’s later outcomes.

First, language ability is an influential factor with the second most research evidence (Bono, Daley, & Sigman, 2004; Boyd et al., 2014; Eldevik, Eikeseth, Jahr, & Smith, 2006; Magiati et al., 2007; Remming et al., 2007; Sallows & Graupner, 2005; Troyb et al., 2016, see study detials in Appendix). Studies have found that children with higher initial language levels make more developmental gains after treatment. However, in two other studies, it was found that children with lower language levels at pretreatment benefitted more from both the joint engagement intervention and the play skill intervention than those who started with more language skills (Kasari et al. 2008; Siller, Hutman, & Sigman, 2013). These inconsistent findings might be because children with lower language skills were likely to benefit more from interventions targeting pre-linguistic non-verbal skills and make further progress in social communication.

Second, joint attention (JA) is a strong predictor of future development and moderates the effect(s) of interventions for young children with ASD (Bono, Daley, & Sigman, 2004; Siller & Sigman, 2008). JA refers to children's ability to "coordinate attention with a social partner around an object or event" (Kaale, Smith, & Sponheim, 2012; p. 97). In a study comparing the effects of Picture Exchange Communication System (PECS) and Responsive Education and Prelinguistic Milieu Teaching (RPMT), Yoder and Stone (2006a) found that children with more initiating joint attention (IJA) acts at Time 1 benefited more from the RPMT intervention, while children with fewer IJA acts benefited more from PECS intervention. Moreover, the joint attention intervention studies show that interventions that increase joint attention skills have positive effects on other child outcomes, such as functional play, adaptive behaviors and language development (Kasari et al., 2010; Schertz, Odom, Baggett, & Sideris, 2013). These studies show that JA is a predictor of intervention outcomes and could be cultivated through intervention: children with improved JA skills are more tuned towards other's attention bids and have more learning opportunities.

Repetitive and restricted behaviors and interests (RRBIs). Several studies have investigated RRBIs as predictors of intervention outcomes. Engagement in RRBIs limits children's opportunities and abilities in social interaction and learning. More severe RRBIs during the preschool years, including object preoccupations, sensory interests, and stereotyped motor movements, predict poorer cognitive and adaptive skills as well as greater autism symptom severity (Anderson, Liang, & Lord, 2014; Troyb et al., 2016).

Two of the behavioral topographies of RRBIs in children with ASD are fixated interests on objects and use of toys/objects in a stimulating fashion. On the contrary, children with appropriate object interest or use and exploration, have higher frequency and diversity of object contact and play (Yoder & Stone, 2006b). Researchers have made an effort to understand how the interests and skills in exploring objects affect children's response to different types of intervention. Vivanti et al. (2013) examined functional object use (i.e., the use of objects for their intended purpose) as a predictor of overall treatment gains for a group-delivered ESDM intervention. They found that children with higher, appropriate initial object use benefited more from the ESDM intervention. Moreover, Schreibman and colleagues (2005; 2009) designed single-case studies to investigate predictive behavioral profiles of PRT for preschoolers with ASD and found that high toy contact was a consistent responder characteristic and moderated PRT intervention outcomes. However, that same responder profile did not predict response to a Discrete Trial Training (DTT) intervention. Yoder and Stone (2006b) also observed the differential influences of object use on responses to different intervention when they compared the effects of PECS and RPMT. They found that PECS promoted the number of non-imitated word use in children with higher object use, while RPMT benefited children with lower initial object use. Similar to the RPMT intervention outcome, in the Hanen More Than Words (HMTW) intervention study, children with lower pre-treatment object interest made more gains in non-verbal communication outcomes (Carter et al., 2010). Taken together, these findings reveal that children with higher, appropriate object interests and better object play skills are more likely to benefit from interventions targeting social interactions, while children with lower object interests could have better intervention outcomes when interventions cultivate their functional play skills around objects.

Other influential child factors with current research evidence include gross motor skills, intake age (i.e., younger children having better outcomes; Harris & Handleman, 2000), gender and adaptive behaviors. Sutera et al. (2007) found that children who achieved the optimal outcome of moving off the spectrum by age 4 presented with better motor skills and adaptive behaviors at age two on standardized measures. Additional research evidence shows that early gross motor skills (i.e., age at onset of walking) are reliable predictors of later language development (Bedford, Pickles, & Lord, 2015; Poon et al., 2012). In a comparative efficacy study, gender showed moderating effects on the communication skills for children in the LEAP group but not the other two groups, with girls showing more improvements in communication skills (Boyd et al., 2014). However, only limited research has tested the predictive effects of these predictors.

Influential parent characteristics. Parents/caregivers are important participants in EI and ECSE services. Therefore, we should examine the influences of parental factors on outcomes in children with ASD when considering intervention mechanism and treatment individualization. To be consistent with the studies reviewed, the term “parents” is used to refer to “caregivers” and “family members”. As parents are usually primary caregivers and sometimes deliverers of the intervention, their behavior and characteristics have inevitable effects on child development and intervention outcomes. The double ABCX model of family adaptation illustrates that different aspects of parent characteristics and behavior (e.g., internal and external resources available to parents [Bb], and their appraisal of stress and coping strategies [Cc]), have influence on each other and moderate child development (Aa), then ultimately affect child and family outcomes (McCubbin & Patterson 1983; application in families with children with ASD see Paynter, Riley, Beamish, Davies, & Milford, 2013). In this review section, I will focus on the two parental factors that has been examined in the autism literature: parental distress and socioeconomic status (SES).

Parental distress. Parents of young children with ASD may experience elevated levels of stress, anxiety, fatigue, and decreased self-efficacy in parenting (Giallo, Wood, Jellett, & Porter, 2011; Hastings & Brown, 2002; Karst & Van Hecke, 2012; Lai & Oei, 2014), as a result of high demands in supporting their children's needs and coordinating services with family life (Salomone et al., 2017). In return, mental health crisis and high levels of distress in parents could interfere with their daily functioning and interactions with their children, and then have a negative influence on child development and outcomes. Here I will discuss the effect of parenting stress, anxiety and depressive symptoms (Firth & Dryer, 2013) on child behavior.

Parenting stress. Several studies have established that parenting stress is concurrently related to higher autism severity and problem behaviors in children (Estes et al., 2009; Salomone et al., 2017), and that level of stress is a strong predictor of child behaviors at a later time (Osborn & Reed, 2009). When examining the effect of parenting stress in the context of intervention, Osborn and colleagues found that high-levels of parenting stress reduce the benefit of community-based early intervention, especially when the intervention is of high time-intensity (Osborn, McHugh, Saunders, & Reed, 2008). Strauss et al. (2011) had similar findings from their Early Intensive Behavioral Intervention (EIBI) study that parenting stress levels predicted child outcome on autism severity, specifically: when parents perceived their child to be more difficult, their children were less likely to benefit. Further, the researchers examined the effect of parenting stress on treatment variables to explore the mechanism of change. They found that when working with parents with higher level of stress, interventionists showed lower treatment fidelity and tended to pick more difficult intervention targets to work on, which interfered with the decision making and treatment planning process, and consequently with child intervention otucomes (Strauss et al., 2011).

Anxiety and Depressive Symptoms. Mental health factors, such as anxiety and depression, are highly correlated with each other (Carter, Martínez-Pedraza, & Gray, 2009) and are inseparable with parenting stress (Karst & Van Hecke, 2012). Under high levels of stress, parents of children with ASD are likely to experience anxiety and depressive symptoms from early on, commonly after receiving the diagnosis (Taylor & Warren, 2012), and these symptoms usually continue throughout the years (Carter, Martínez-Pedraza, & Gray, 2009).

Two studies examined relationships between parental anxiety with child anxiety among youth with comorbid anxiety disorders. While parental anxiety levels were associated with the severity of youth/adolescent anxiety, parent anxiety levels also decreased when their youth/adolescents showed improvements after receiving treatment (Connor, Maddox, & White, 2013; Reaven et al., 2015). Van Steensel and Colleagues (2017) found that youth with comorbid anxiety disorders, whose fathers showed anxiety symptoms, benefit less from the cognitive behavioral therapy (meaning less decrease in anxiety symptoms) than those with non-anxious fathers (Van Steensel, Zeger, & Bögels, 2017). Such findings indicated that parent anxiety might have an negative effect on child intervention outcomes. These studies with parents of adolescence and youth with ASD could provide some implications of the impact of parent mental health in the younger population. However, more studies investigating parental mental health in early intervention is needed to help us better understand the relationship between parental mental health and child development, and therefore provide service and support for parents.

Socioeconomic Status (SES). SES is a measure capturing one's access to social resources and capital, with three primary indicators: income, education and occupation (Singh, Sharma, & Nagesh, 2017). With pervasive developmental delays, children with ASD often need a variety of services. As these services might not be easily accessible and affordable to all families, families with higher SES might be more able to provide needed services, and therefore see better outcomes in their children. For example, Fountain, Winter, and Bearman (2012) found in their analysis of developmental trajectories that children with ASD who make the most developmental gains are more likely from families with high SES. In their study of community-based intervention, Gabriels and colleagues also found that parents of children who did not make much progress after three-years of intervention have reported higher levels of financial strain (Gabriels et al., 2001). As maternal education levels have been recognized as a strong predictor of later child development, Ben-Itzchak and Zachor (2011) confirmed similar findings in the ASD population, that the more educated the mother was, the more cognitive gains children made with one-year of ABA intervention.

Although it is not considered in this study, another parental factor that has been frequently studied is parent synchronization, especially in parent-mediated interventions (Pickles et al., 2015; Siller & Sigman, 2008). Parent synchronization/responsiveness, refers to how well parents sense and respond to child cues. Despite some mixed findings, researchers found that parent responsiveness to children's attention and activity during play predicted the child's rate of language growth after four years of community services (Siller & Sigman, 2008). Parent verbal responsiveness (parent follow-up commenting and expansion of vocabulary) is also a significant predictor of change in spoken vocabulary after communication interventions (McDuffie & Yoder, 2010). Moreover, as was shown in the ABCX model of family adaptations, these aforementioned parent factors may affect each other and together moderate treatment outcomes (Paynter, Riley, Beamish, Davies, & Milford, 2013). For example, higher perceived financial strain may cause increased parental distress (Salomone et al., 2017; Taylor & Warren, 2012), and therefore, parents might be less able to be involved in early intervention and responsive to child cues to facilitate child development (Gulsrud, Hellemann, Shire, & Kasari, 2016; Kasari et al., 2010). Besides, parents from diverse cultural backgrounds may not share the values of some early intervention practitioners, which may result in elevated parental stress and low parent involvement (Dyches et al., 2004; Ravindran & Myers, 2012). Therefore, research needs to operationalize parent characteristics better to fully understand their effect on child outcomes.

As different studies use different intervention strategies, measures, and analytic methods, this generated list of influential factors may only be predictive for specific interventions which limits generalizability. Further, there are some limitations from the previous studies in identifying developmental predictors and treatment influential factors. First, the influential characteristics tested were mostly chosen out of convenience as proximal variables of the intervention but were not usually theory-driven (Vivanti et al., 2014). Second, the distinction between child characteristics predicting general developmental outcomes and those moderating certain intervention outcomes is limited (Trembath & Vivanti, 2014). Future studies could use controlled comparisons to segment out the effects of intervention from sheer developmental maturation. Third, there is no consensus on the operationalization and measure of current influential factors. Research is needed to address these issues with ongoing efforts to understand better under what circumstances early intervention works best for children with ASD.

Justification for Secondary Data Analysis

To deepen our understanding of how and why interventions work, we need to explore the influence of characteristics on children's responses to different kinds of intervention strategies. Currently, there is a growing body of intervention efficacy research available with sufficient preintervention (i.e. influential factors) and post-intervention data (i.e. child outcomes). Therefore, it is both necessary and efficient to conduct secondary analysis using data from these studies for the exploration of influential factors on intervention responses. This approach is both frugal and efficient because this saves the researcher from having to collect additional data and uses an existing data set to answer a number of important questions. In particular, intervention studies with randomized controlled designs are useful because they have comparison groups which help to control for the effects of developmental maturation. Thus, research groups who have conducted intervention efficacy studies could revisit their existing data to conduct secondary analysis by examining pre-treatment child characteristics, which are often collected as descriptive measures of study samples. Further, in the effort to identify influential factors on intervention responses, most of the studies reviewed above used moderator analysis and correlation analysis to explore the relationships among variables. However, these analytical approaches are limited as they fail to consider both the effects of parent and child factors and often did not control for other confounding variables. Therefore, researchers should explore other statistical analyses to address the complex and comprehensive nature of child development and intervention effects, such as more advanced regression analyses (e.g., structural equation model and regression discontinuity design; Carter et al., 2010; Hopwood, 2007).

In this proposed study, secondary data analysis was conducted using data from the TEACCH-LEAP comparative efficacy study (Boyd et al., 2014). The primary purpose was to compare how subgroups of children with different developmental profiles responded to different intervention models. This analysis can help the field to better understand the combination of child and family factors related to changes based on intervention type; thus, making it possible to move towards more individualized intervention packages for children with ASD.

Chapter 3 Methodology

This study draws data from the four-year TEACCH-LEAP comparative efficacy study (Boyd et al., 2014). The original study was a quasi-experimental study that compared pre- and post-treatment child outcomes across three groups (TEACCH, LEAP, NMS programs) based on data collected at four study sites (North Carolina, Colorado, Florida, and Minnesota). This chapter provides (1) a brief description of the three classroom treatment models, (2) inclusion and exclusion criteria for the teacher, child, and parent participants, (3) descriptions of the child and parent measures collected and used, and (4) the data cleaning and analysis plan to address each research question using descriptive statistics of the current sample and data preprocessing results.

Description of Classroom Treatment Models

Three preschool programs were included in the original study: TEACCH, LEAP, and NMS high-quality programs. The CTMs section in Chapter 2 provides details regarding the philosophy and research evidence of TEACCH and LEAP and discusses the benefits of NMS eclectic programs. The main characteristics of each model are described in the following paragraphs.

The TEACCH program integrates behavioral principles with social-cognitive learning theory and, in practice, uses environmental adaptations to maximize learning opportunities for children with ASD. Although not a stated principle of TEACCH, many classrooms that use this teaching approach operate as self-contained classrooms that serve only students with ASD.

LEAP is an inclusive preschool classroom model that is focused on blending behavioral principles and other developmental strategies to promote social interaction between children with ASD and their typically developing peers.

The NMS classrooms in this project were high-quality preschool classrooms as nominated by local school administrators and confirmed by the Professional Development in Autism Program Assessment for Classroom Quality (Professional Development in Autism Center, 2008) during an initial classroom visit. All the NMS classrooms were recruited from the same school district as the TEACCH and LEAP classrooms, but teachers in the NMS classrooms used an eclectic approach to instruction and did not have a primary or guiding theoretical orientation. Additionally, the NMS classrooms were a mixture of inclusive and self-contained classrooms.

Participants

For the original TEACCH-LEAP study (Boyd et al., 2014), teachers were identified and recruited through local school administrators and then screened based on the following inclusion criteria.

Classroom/teacher inclusion criteria. The inclusion criteria for classrooms were: (1) all classrooms must operate within the public school system with certified teachers; (2) teachers in the TEACCH and LEAP groups must have attended formal training for these programs and have at least two years of teaching experience in their respective classroom type; and (3) teachers must have met predetermined criteria for classroom fidelity and/or quality rating scales, i.e., a score of 3 out of 5 on the program assessment for NMS classrooms and a score of 3.5 for TEACCH and LEAP classrooms on model-specific subscales and items regarding their respective fidelity of implementation measures. These fidelity criteria were predetermined by the study investigators in consultation with the developers of the TEACCH and LEAP programs. All the participating TEACCH and LEAP teachers also received booster training to ensure they met fidelity for the treatment approach they were implementing.

Child/family inclusion and exclusion criteria. As stated in the primary intervention outcome paper (Boyd et al., 2014), children in the recruited classrooms were included in the study if they:

> (1) [w]ere between 3 and 5 years of age at the time of enrollment; (2) had a previous clinical diagnosis or educational label of ASD or developmental delay; (3) met diagnostic criteria on Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999) and/or Social Communication Questionnaire (SCQ; Rutter et al. 2003); (4) had not been previously exposed to the comparison CTM, for example, a child enrolled in a TEACCH classroom could not have been previously enrolled in a LEAP classroom; and (5) must have a minimum of 6 months of exposure to the treatment or control condition. Children with significant uncorrected vision or hearing impairment, uncontrolled seizure disorder or traumatic brain injury were excluded from the study. Families must have been proficient enough in English to participate to complete parent rating scales.
>
> (Boyd et al., 2014, p.369).

Tables 3.1 and 3.2 show the numbers of children, teachers, parents, and classrooms included in this analysis across intervention groups and time points. Specifically, the analysis included 85 children from 25 TEACCH preschool classrooms, 54 from 22 LEAP classrooms, and 59 from 28 NMS classrooms. One lead teacher from each of these classrooms and one caregiver of each child participated in this study.

Table 3.1

Number of Child Participants in the Study by Intervention Assignments and Time Points

Time Points	Pretreatment				Post-treatment			
Intervention	NMS	LEAP	TEACCH	Total	NMS	LEAP	TEACCH	Total
North Carolina	22	0	44	66	20	0	39	59
Colorado	9	17	8	34	9	17	8	34
Florida	15	25	26	66	14	22	25	61
Minnesota	13	12	7	32	11	13	6	30
Total	59	54	85	198	54	52	78	184

Table 3.2

Numbers of Teachers in the Study by Intervention Assignment

Intervention Assignment	NMS	LEAP	TEACCH	Total
North Carolina	10	0	12	22
Colorado	5	6	3	14
Florida	7	9	7	23
Minnesota	6	7	3	16
Total	28	22	25	75

Measures

Child measures. This study includes child data from the measures described below to capture a comprehensive child developmental profile. For the standardized child measures, research staff conducted child assessments at the children's schools or in a clinic, or home setting when necessary. For the parent-report data, parents were mailed assessment packets. They then finished and returned the forms at follow-up home visits that occurred approximately two weeks later. All the forms were completed by primary caregivers when possible. As most of the primary caregivers were parents in the current dataset, for brevity and consistency we refer to 'primary caregivers' as 'parents' in this analysis. Teacher-report data were collected by dropping off and picking up assessment packets at the child's school. As the current study focuses on child and family factors rather than on classroom/teacher factors, the researcher intentionally used the parent-report scores for the three measures used in this analysis to be consistent when both parent-reports and teacher-reports were collected; these measures are Repetitive Behavior Scales-Revised (RBSR; Bodfish, Symons, & Lewis, 1999), Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003), and the SRS. For the current analysis, both subscale scores (if applicable) and the total scores of the child measures were included to capture nuances of different developmental aspects (e.g., changes in receptive versus expressive language).

Childhood Autism Rating Scale (CARS) (Schopler, Reichler, & Renner, 1988; Schopler, Van Bourgondien, Wellman, & Love, 2010) is a diagnostic assessment tool that is aimed at differentiating ASD from other developmental delays in children. For CARS, behaviors such as relating to others, object use, listening response, verbal communication, activity level, body use, emotional response, etc., are observed and then rated. A composite score ranging from 15 to 60 is obtained, with the score of 30 being the cutoff for diagnosing ASD. The severity of ASD also can be categorized as normal or mildly, moderately, or severely autistic. The psychometric properties for CARS are that the internal consistency coefficient ranges from .73 to .94, the inter-rater reliability of the items ranges from .55 to .93, the sensitivity for autism diagnosis ranges from 0.85 to 1, and specificity ranges from .70 to 1.

Mullen Scales of Early Learning (MSEL) (Mullen, 1995) is a standardized, comprehensive assessment tool that measures children's early learning outcomes across visual reception, fine motor, and expressive/receptive communication skills from birth through 68 months. Internal reliability ranges from .71 to .83 across MSEL subtests and .91 for the overall developmental score. Each subscale raw score corresponds to a *T*-score, percentile rank, and age equivalent in months. The early learning composite standardized score is calculated based on the subscale scores. The MSEL scores for children who are older than 68 months are adjusted to fit on the scale with the maximum age of 68 months. Both the standard scores for each subscale and the early learning composite scores are included in this analysis.

Preschool Language Scale-4 (PLS-4) (Zimmerman, Steiner, & Pond, 2003) is a standardized language measure for children aged birth through 6 years, 11 months of age. The assessment measures auditory comprehension and expressive communication to obtain a total language score. The subscale scores' psychometric properties consist of test-retest stability coefficients ranging from 0.90 to 0.97, internal consistency reliability coefficients ranging from 0.66 to 0.95, and an inter-rater reliability coefficient of 0.99 (Zimmerman et al., 2002). The standardized scores for both auditory comprehension and expressive communication, as well as the total scores, are included in the analysis.

Pictorial Infant Communication Scales (PICS) (Delgado et al., 2001) is a parent-report measure of JA. The PICS has 16 items that ask parents to report how frequently their child shows JA behaviors, including initiating joint attention (IJA), responding to joint attention (RJA), and initiating behavior requests (IBR) in the past two weeks using a 4-point Likert scale. In a PICS validation study with 195 preschoolers with ASD, Delgado et al. (2001) found high internal reliability of PICS values ranging from 0.72 to 0.89. The PICS ratings were highly correlated with other measures of JA, language, and autism severity (e.g., PLS-4, MSEL, ADOS, Early Social Communication Scales [ESCS]) (Ghilain et al., 2016). Scores for IJA, RJA, and IBR, as well as the total scores, are included in this study's analysis.

Repetitive Behavior Scales-Revised (RBSR) (Bodfish, Symons, & Lewis, 1999) is a caregiver-report questionnaire that assesses 43 discrete types of repetitive behavior. The TEACCH-LEAP study used the empirically-derived five subscales that Lam and Aman (2007) generated. The psychometrics for RBSR are internal consistency values ranging from 0.78 to 0.91 and inter-rater reliability for subscales ranging from 0.57 to 0.73 (Lam & Aman, 2007). The subscale scores and total score that were calculated based on Lam and Aman's categorization are used in this study's analyses.

Social Communication Questionnaire (SCQ) **(**Rutter, Bailey, & Lord, 2003) is a 40-item (*yes* or *no* binary questions) parent-report questionnaire that is used to screen for symptoms associated with ASD for those with a mental age above two years old. The SCQ has established validity with the Autism Diagnostic Interview-Revised (ADI-R), a gold-standard, validated diagnostic interview tool. Clinically, the cut score for ASD on the SCQ is 15. A receiver operating characteristics curve to examine the psychometric properties of the SCQ revealed a sensitivity of 0.85 and specificity of 0.75. The internal consistency of the SCQ ranges from 0.84 to 0.93 across age groups. The total score on the SCQ is included in this study's analyses.

Sensory Experience Questionnaire 2.0 (SEQ 2) (Baranek, 1999) is a caregiver report that is designed to evaluate behavioral responses to common sensory experiences for children aged six months through 12 years. The SEQ measures hyper- and hypo-responsive patterns across social and nonsocial contexts. The questionnaire produces subscale scores as well as a total score based on 43 5-point Likert scale items. The SEQ is effective in characterizing sensory features in young children with ASD and distinguishing these children from children with developmental delays and typical development (Baranek, David, Poe, Stone, & Waston, 2006). Internal consistency for the SEQ is 0.80 and test-retest reliability for the total score is excellent, with the Intraclass Correlation Coefficient0.92 (Little et al., 2011). This analysis includes the subscale scores for hyper-responsiveness, hypo-responsiveness, and sensory seeking, and the total score.

Vineland Adaptive Behavior Scales-II– Survey Form (VABS) (Sparrow, et al. 1984; Cicchetti, Carter, & Gray, 2013) is designed to assess adaptive behaviors for all age groups. VABS includes the following domains: communication, daily living skills, socialization, motor skills for young children, and problem behaviors on a parent-report form. VABS-II has strong psychometric properties, with split-half and test-retest reliability coefficients ranging from 0.83 to 0.94.

Parent measures. Parent measures also were included in the assessment packet sent to families; these measures include a family demographic form and caregivers' mental health status form (i.e., levels of depression, stress, anxiety). Primary caregivers completed all the forms as well. For the measures of mental health status, only the total score for each measure was included in the current analysis.

Beck Depression Inventory–II (BDI2) (Beck, Steer, & Brown, 1996) is a self-administered scale to assess depression in the population of those aged 13 to 80. BDI2 includes 21 3-point-scale items to assess behavioral symptoms of depression. The validation study with 500 participants showed that the BDI2 has an overall reliability of .92.

Endler Multidimensional Anxiety Scale-Trait (EMAS-T) (Endler, Edwards, Vitelli, & Parker, 1989) is a self-report measure with 60 items designed to assess predisposition for anxiety in multiple types of threatening situations. Specifically, the measure includes items to assess responses to four situations (social evaluation, physical danger, ambiguous, and daily routines), with 15 items for each situation. The internal consistencies of responses for all four situations range from .87 to .96.

Family Demographic Form is a project-developed form to collect basic caregiver information, such as socioeconomic status (SES), family history of developmental delays and disabilities, the child's medical/clinical information, and information about the child's developmental milestones.

Parenting Stress Index Short Form (PSI) (Abidin, 1995) is a parent-report questionnaire that assesses domains of parenting stress, including parental distress, parent-child dysfunctional interactions, and stress associated with having a difficult child. Parents rate their agreement with 36 statements on a 5-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. The PSI reports internal reliability coefficients of 0.80–0.87 for the three subscales (Abidin, 1995) and test-retest reliability of 0.76. The suggested cut-off scores for high-risk samples of mothers are 73^{rd} through 77^{th} percentiles (Barroso, Hungerford, Garcia, Graziano, & Bagner, 2016).

Child outcome measures. Social communication development has always been a primary focus for early childhood special education programs and is of primary interest for this project as well. As such, the SRS was used in this study to examine changes in children's social development, as it is the most appropriate measure used in the original TEACCH-LEAP study for this developmental domain.

Social Responsiveness Scale (SRS) (Constantino & Gruber, 2007) is a 65-item teacher-/parent-report measure where each item is scored from 1 = 'not true' to 4 = 'almost always true'. The instrument assesses the severity of social symptoms, including information about children's social awareness-receptive, social cognition, social communication-expressive, and social motivation, as well as autistic preoccupations. The tool is designed to be used with children aged 4 to 18 years. In the current study, the SRS Preschooler version was used for children who were three years of age at the time of enrollment. As the preschool version and the regular version have a high degree of item overlap, all the SRS data were scored based on the scoring manual for the regular SRS to generate raw scores and t-scores for both subscales and total scale.

The psychometrics of the SRS have been studied extensively and show high quality in capturing autism characteristics. The reliability indicators (e.g., internal consistency, retest reliability) are in the range of 0.80 to 0.96. The validity indicators also show that SRS scores correlate highly with other ASD measures. Also, the SRS has a sensitivity of 0.85 and a specificity of 0.75 (Constantino, 2013). The SRS was examined in a previous study and shown to be sensitive to both the social impairments of ASD and symptom changes over time (Pine, Luby, Abbacchi, & Constantino, 2006). Therefore, this analysis includes the *T*-scores of the subscales and the total *t*-score and uses change scores from pre- to post-treatment as the outcome variables.

Data Analysis Plan

The data analysis methods described below were used to address the research questions. Analyses were conducted using statistical software SAS 9.4 (SAS Institute Inc., Cary, NC). First, descriptive statistics (mean scores and standard deviations) were generated for all the measures to provide an overview of preintervention child and parent characteristics in the current study. Then, correlation matrices were calculated respectively for child measures (e.g., MSEL and SRS) and parent measures (e.g., PSI and EMAS-T) to examine the relationships between the measures. Next, prior to addressing each research question, the problem of missing data was handled using multiple imputation techniques. Then, the process of hierarchical cluster analysis was unfolded for Research Question 1. Lastly, Fuzzy Regression Discontinuity Design (FRDD) to address Research Question 2 was described and data preprocessing (i.e., running variable selection and cut-off score determination) was conducted.

Descriptive statstics for child measures. Among the 198 preschoolers with ASD included in the current study were 165 (83.33%) males and 33 (16.67%) females, which approximates the population gender ratio of 4:1 (see Table 3.3 for detailed demographic information about the three intervention groups). Overall, most participants were Non-Hispanic White (43.94%), followed by Hispanic White (34.85%), Black (12.12%), Asian (4.55%), and Multi-racial (4.04%). The TEACCH group seemed to have the most diverse sample, with the highest proportion of participants being Hispanic (36.47%). Children's ages at enrollment ranged from 2.90 to 5.18 years, with the mean age of 3.99 years.

Table 3.4 presents both the means and standard deviations of the subscale and total scores for all nine child measures at preintervention for each intervention group. Group comparisons were conducted to inform the later selection of variables for the analysis of Research Question 2. One-way ANOVA tests revealed significant group differences in seven out of nine preintervention child measures ($F_{PLS} = 7.53$, $p = .0007$; $F_{PICS} = 4.25$, $p = 0.016$; $F_{MSEL} = 7.48$, $p = .0007$; $F_{CARS} = 12.15$, $p < .0001$; $F_{SCQ} = 5.63$, $p = 0.004$; $F_{VABS} = 6.52$, $p = 0.002$; $F_{SRS} = 3.27$, $p = 0.04$), except SEQ and RBSR ($F_{SEQ} = 1.17$, $p = 0.31$; $F_{RBSR} = 2.72$, $p = 0.069$). Specifically, preschoolers in the TEACCH group differed significantly from preschoolers in the other two groups in terms of PLS4, MSEL, CARS, and SRS scores and differed significantly from preschoolers in the NMS group only on PICS, SCQ, and VABS scores. Table 3.4 presents detailed statistics.

Correlation matrix. Pearson bivariate correlations between child measures were calculated for the total scores of nine measures to examine the relationships among different developmental aspects in children with ASD. As indicated in Table 3.5, many developmental aspects of preschoolers were correlated. The five highest correlation coefficients between variables were: 0.88 between language ability on PLS4 and cognitive ability on MSEL; 0.70 between social communication on SCQ and social development on SRS; 0.65 between sensory development on SEQ and repetitive and restricted behaviors on RBSR; 0.64 between SRS scores and RBS scores; and 0.62 between SRS scores and SEQ scores. Table 3.5 lists these correlations.

Table 3.3

Demographic Information Regarding Children Included in the Analysis

		TEACCH		LEAP		NMS		Total	
		Frequency	%	Frequency	%	Frequency	%	Frequency	%
Gender	Male	71	83.53	42	77.78	52	88.14	165	83.33
	Female	14	16.47	12	22.22	7	11.86	33	16.67
Race/ Ethnicity	White	30	35.29	23	42.59	34	57.63	87	43.94
	Hispanic	31	36.47	23	42.59	15	25.42	69	34.85
	Black	14	16.47	4	7.41	6	10.17	24	12.12
	Asian	5	5.88	1	1.85	3	5.08	9	4.55
	Multi-racial	4	4.71	3	5.56	1	1.69	8	4.04
	Missing	1	1.18	0	0	0	0	1	0.51
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Child age at enrollment (years)		4.01	0.57	3.89	0.72	4.04	0.61	3.99	0.62

Table 3.4

Descriptive Statistics for Preintervention Child Measures

		TEACCH				LEAP				NMS				
Child Measures	Domains Measured	N	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range	*F* test
PLS4	Auditory comprehension	85	62.73	19.40	50-126	54	71.59	24.98	50-129	59	78.44	23.11	50-126	
(Standard)	Expressive communication	85	62.38	17.10	50-135	54	73.43	23.63	50-133	58	74.43	17.57	50-133	
	Total	85	61.45	17.77	50-134	54	71.02	25.32	50-134	58	74.48	20.62	50-133	7.53^{***}

PICS	PICS_IBR	80	1.29	0.47	0-2	51	1.27	0.44	0.33-2	56	1.40	0.40	0.33-2	
	PICS_IJA	80	0.97	0.54	0-2	51	1.13	0.54	0-2	56	1.28	0.38	0.25-2	
	PICS_RJA	80	1.10	0.55	0-2	51	1.31	0.56	0-2	56	1.30	0.46	0-2	
	PICS_Tot	80	1.12	0.44	0.19-1.93	51	1.23	0.44	0.38-2	56	1.33	0.33	0.33-1.88	4.25*
RBS (Lam)	Stereotyped	79	8.44	6.01	0-27	51	5.96	4.63	0-20	58	6.43	4.72	0-25	
	Self-injurious	79	2.43	3.90	0-24	51	1.59	2.62	0-11	58	2.00	2.52	0-11	
	Compulsive	79	3.51	3.39	0-16	51	2.98	3.54	0-16	58	2.83	2.50	0-10	
	Ritual/same	79	6.98	6.69	0-29	51	5.82	5.66	0-23	58	6.23	5.96	0-25	
	Restricted	78	3.56	2.84	0-9	51	2.45	2.01	0-8	57	3.04	2.32	0-9	
	Total Sum	79	24.90	17.60	0-92	51	18.78	13.47	1-56	58	20.58	14.02	0-55	NS
SRS	Autistic mannerism	76	74.75	16.17	44-108	50	68.70	18.98	40-114	58	70.47	16.81	42-120	
(T-score)	Social awareness	76	71.00	11.09	49-97	50	65.98	14.04	39-95	58	65.91	9.71	49-91	
	Social cognition	76	75.89	12.14	50-103	50	70.88	15.10	41-105	57	71.77	13.80	43-106	
	Social communication	76	74.67	12.41	47-99	50	70.10	15.99	42-109	58	69.33	13.31	39-103	
	Social motivation	76	67.93	12.86	42-94	50	63.38	12.19	37-87	58	64.36	13.99	40-94	
	Total	76	76.80	12.88	52-105	50	71.20	16.13	43-103	58	71.59	13.77	42-111	3.27*
MSEL (Standard)	Visual reception	82	28.01	13.39	20-69	54	33.80	16.42	20-79	59	37.78	16.16	20-79	
	Fine motor	84	25.68	11.30	20-79	52	28.02	12.07	20-64	58	33.33	12.89	20-64	
	Receptive language	84	24.74	9.70	20-66	52	30.58	14.52	20-67	59	32.27	13.22	20-69	
	Expressive language	85	24.78	9.35	20-78	52	31.12	12.19	20-64	59	30.75	10.51	20-66	
	Total standard	82	58.34	16.60	49-117	52	66.77	21.66	49-132	58	70.34	19.32	49-136	7.48***
CARS		85	36.10	7.94	18.5-55.5	54	31.69	6.34	15-42	59	30.84	5.76	19.5-45.5	12.15***
SCQ		77	17.36	6.40	5-31	51	13.51	6.31	3-26	55	13.73	5.67	2-25	5.63**

SEQ	Hypersensitivity	61	32.41	7.09	17-54	50	31.02	8.00	17-48	49	32.22	7.13	22-48	
	Hyposensitivity	61	12.31	4.69	6-27	50	14.04	4.17	6-22	49	11.31	3.51	6-21	
	Sensory seeking	70	33.47	9.11	15-60	50	29.02	8.10	14-47	50	31.32	8.51	13-54	
	Total	53	76.72	15.91	51-136	50	72.12	15.94	41-107	44	75.22	14.27	44-109	NS
VABS	Communication	77	70.84	18.58	34-112	50	80.18	19.64	42-123	58	82.83	16.22	42-112	
	Daily living skills	77	74.57	15.14	46-109	50	81.00	15.54	46-115	58	82.67	14.82	48-113	
	Motor skills	76	78.61	14.37	51-121	50	84.54	16.01	61-114	58	83.69	14.09	59-131	
	Socialization	77	74.57	15.45	46-126	50	80.18	15.24	57-110	58	81.36	15.03	55-116	
	Adaptive behavior composite	76	71.86	14.42	45-111	50	79.12	15.90	50-114	58	80.17	13.49	54-105	6.52^{**}

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. Please refer to the list of abbreviations for the full names of the measures.

Table 3.5

Pearson Correlation between Child Measures

	Measures	1	2	3	4	5	6	7	8	9
1	MSEL	1.00								
2	PLS4	0.88^{***}	1.00							
3	PICS	0.15^{*}	0.20^{**}	1.00						
4	RBS	-0.02	-0.14	-0.14	1.00					
5	SCQ	-0.21^{**}	-0.28^{***}	-0.52^{***}	0.48^{***}	1.00				
6	CARS	-0.58^{***}	-0.52^{***}	-0.34^{***}	0.21^{**}	0.33^{***}	1.00			
7	SEQ	-0.10	-0.19^{*}	-0.36^{***}	0.65^{***}	0.50^{***}	0.23^{**}	1.00		
8	VABS	0.57^{***}	0.61^{***}	0.47^{***}	-0.28^{***}	-0.54^{***}	-0.48^{***}	-0.35^{***}	1.00	
9	SRS	-0.10	-0.19^{*}	-0.48^{***}	0.64^{***}	0.70^{***}	0.29^{***}	0.62^{***}	-0.50^{***}	1.00

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. Please refer to the list of abbreviations for the full names of the measures.

Table 3.6

Demographic Information about Parents Included in the Analysis

		TEACCH		LEAP		NMS		Total	
		Frequency	%	Frequency	%	Frequency	%	Frequency	%
Gender	Male	12	14.12	7	12.96	4	6.78	23	11.61
	Female	72	84.71	46	85.19	53	89.83	171	86.36
	Missing	1	1.18	1	1.85	2	3.39	4	2.02
Race/Ethnicity	White	29	34.12	25	46.30	32	54.24	86	43.43
	Hispanic	30	35.29	18	33.33	16	27.12	64	32.32
	Black	14	16.47	6	11.11	5	8.47	25	12.63
	Asian	5	5.88	2	3.70	3	5.08	10	5.05
	Multi-racial	4	4.71	1	1.85	1	1.69	6	3.03
	Missing	3	3.53	2	3.70	2	3.39	7	3.54
Education	High School or lower	21	24.71	11	20.37	11	18.64	43	21.72
	Associate Degree	23	27.06	13	24.07	14	23.73	60	30.30
	Bachelor Degree	24	28.24	19	35.19	16	27.12	59	29.80
	Graduate Degree	15	17.65	10	18.52	16	27.12	41	20.71
	Missing	2	2.35	1	1.85	2	3.39	5	2.53
Occupation	N/A	1	1.18	0	0.00	0	0.00	1	0.51
	Homemaker/Stay-at-home	34	40.00	22	40.74	25	42.37	81	40.91
	Student	3	3.53	3	5.56	1	1.69	7	3.54
	Farm laborer; service worker	4	4.71	0	0.00	0	0.00	4	2.02
	Unskilled worker	3	3.53	0	0.00	0	0.00	3	1.52
	Semi-skilled worker	3	3.53	0	0.00	0	0.00	3	1.52
	Skilled worker	3	3.53	0	0.00	3	5.08	6	3.03
	Smaller business owner	4	4.71	5	9.26	5	8.47	14	7.07
	Semi-professional	5	5.88	7	12.96	1	1.69	13	6.57
	Administrative personnel	11	12.94	2	3.70	7	11.86	20	10.10

	Business manager	3	3.53	4	7.41	5	8.47	12	6.06
	Engineer; involved in natural or hard science related field	3	3.53	0	0.00	4	6.78	7	3.54
	Teacher; Autism Advocate	6	7.06	7	12.96	5	8.47	18	9.09
	Major professional	1	1.18	3	5.56	1	1.69	5	2.53
	Missing	1	1.18	1	1.85	2	3.39	4	2.02
Income	<$20,000	13	15.29	6	11.11	6	10.17	25	12.63
	$20,000-$39,999	17	20.00	8	14.81	10	16.95	35	17.68
	$40,000-$59,999	11	12.94	11	20.37	6	10.17	28	14.14
	$60,000-$79,999	11	12.94	8	14.81	7	11.86	26	13.13
	$80,000-$99,999	8	9.41	5	9.26	6	10.17	19	9.60
	>$100,000	21	24.71	12	22.22	19	32.22	52	26.26
	N/A	3	3.53	3	5.56	3	5.08	9	4.55
	Missing	1	1.18	1	1.85	2	3.37	4	2.02
Marital Status	Married/Coupled	71	83.53	37	68.52	46	77.97	154	77.78
	Separated/Divorced	4	4.71	10	18.52	2	3.39	16	8.08
	Single/Never Married	3	3.53	1	1.85	3	5.08	7	3.54
	N/A	1	1.18	0	0.00	1	1.69	2	1.01
	Missing	6	7.06	6	11.11	7	11.86	19	9.60

Table 3.7

Descriptive Statistics for Preintervention Parent Measures Reported by Caregivers

Parent Measures	Domains Measured	TEACCH N	TEACCH Mean	TEACCH SD	TEACCH Range	LEAP N	LEAP Mean	LEAP SD	LEAP Range	NMS N	NMS Mean	NMS SD	NMS Range
PSI (percentile)	Difficult Child	79	75.39	26.50	1-99	51	69.80	30.13	1-99	57	67.45	32.51	1-99
	Defensive Responding	79	68.13	37.04	1-99	51	70.10	34.46	1-99	57	65.85	35.10	1-99
	Parent/child dysfunction	79	72.95	23.87	5-99	51	66.34	25.07	5-99	57	62.18	26.57	5-99
	Parental Distress	78	58.03	34.06	1-97	51	62.18	31.47	1-99	57	51.71	30.83	1-97
	Total	78	73.74	30.17	3-99	51	71.53	28.22	3-99	57	64.33	33.23	1-99
EMAS-T (percentile)	Ambiguous	76	56.11	31.98	2-99	49	58.45	26.68	4-99	56	52.98	26.14	4-97
	Daily Routines	75	56.25	34.04	5-99	49	59.31	26.20	5-98	56	58.14	27.79	2-98
	Physical Danger	76	46.46	23.82	0-97	49	48.80	27.59	0-97	56	53.34	31.51	0-97
	Social Evaluation	76	49.14	26.84	2-96	49	42.27	25.02	10-98	56	46.13	25.00	8-95
BDI-II		81	9.47	7.11	0-29	53	9.47	7.28	0-33	57	7.84	8.19	0-32

Note: Please refer to the list of abbreviations for the full names of the measures.

Table 3.8

Pearson Correlation between Parent Measures

		BDI-II	PSI	EMAS-T-AM	EMAS-T-DR	EMAS-T-PD	EMAS-T-SE
BDI-II		1.00					
PSI-SF		0.45^{***}	1.00				
	Ambiguous (AM)	0.17^{*}	0.35^{***}	1.00			
EMAS-T (percentile)	Daily Routines (DR)	0.26^{***}	0.28^{***}	0.13	1.00		
	Physical Danger (PD)	0.07	0.05	0.23^{**}	-0.18	1.00	
	Social Evaluation (SE)	0.12	0.36^{***}	0.39^{***}	0.06	0.19	1.00

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$. Please refer to the list of abbreviations for the full names of the measures.

Descriptive statstics and correlation matrix for parent measures. Parents in the study shared similar race/ethnicity characteristics with the children enrolled in the programs (see Table 3.6 for detailed demographic information). Most of the primary caregivers who participated in the study were mothers (86.36%). Parents' educational levels were somewhat evenly distributed among high school or lower (21.72%), associate degree (30.30%), bachelor degree (29.80%), and graduate degree levels (20.71%). As for annual family incomes, the largest percentages of income levels were at both ends of the economic continuum: $100,000 per year or higher (26.26%) and $39,999 or lower (30.31%). With regard to parent occupations, 40.91% of the parents in the study were stay-at-home parents. Table 3.7 provides descriptive statistics regarding parent measures for parental stress, anxiety, and depression. Parents across the three intervention groups showed moderately high stress levels on average comparing to the clinical cut-off PSI scores for high risk sample (Barroso, Hungerford, Garcia, Graziano & Bagner, 2016). The average stress levels for parents of children in the TEACCH is 73.74th percentile; LEAP: 71.53rd percentile; the NMS group: 64.33rd percentile. Parental depression symptoms measured by BDI-II were in the minimal range on average across the three groups. As for anxiety levels measured by the EMAS-T, parents reported medium levels of anxiety (42.27th to 59.31st percentile) on average across all four subscales and three groups. Table 3.8 presents the bivariate correlations between parent measures; the highest correlation of 0.45 ($p < 0.0001$) was found between parental stress on the PSI and depression on the BDI-II.

As the descriptive statistics and correlations provided an overall picture of the current sample, the next step was to prepare the dataset for further analysis by addressing the missing data.

Missing data determination and handling. Missing data are common in education studies (What Works Clearinghouse, WWC, 2017). Based on the literature regarding the handling of missing data, missing data in this study were considered to be 'missing completely at random', meaning that the missing data were not related to any other observed variables (Little, Jorgensen, Lang, & Moore, 2013). Currently, no standard cutoff is available for an acceptable proportion of missing data; however, multiple imputation is a valid and rigorous method that can be employed to generate a set of plausible estimates without restrictions on the proportion of missing data (Cheema, 2014; Dong & Peng, 2013). The multiple imputation method typically is applied to substitute missing values using data from available observations and time points. Referencing the WWC standards, multiple imputation was conducted separately for the three intervention groups (WWC, 2017) in the current study, and the Markov Chain Monte Carlo method (Schafer, 1997) of imputation was applied to deal with the arbitrary missing data pattern. Because this study had less than 6 percent missing data for the overall dataset and no more than 26 percent missing data for any one variable, the number of imputations was set to five in this analysis (five imputations can achieve at least 94% relative efficiency for datasets with 30% or less missing data, according to SAS, 2013). Then, the imputed datasets were used for further analyses to pool for parameter estimates.

Research Question 1: ***Are the subgroups of preschoolers with ASD distinct based on preintervention developmental and behavioral measures? If so, what are the subgroups and their characteristics?***

Previous studies of the heterogeneity of ASD have employed cluster analysis methods to generate subgroups of individuals with ASD based on their developmental and behavioral characteristics. As different clustering methods and child measures were used across studies, the findings are inconsistent. However, most of the studies have generated two to four cluster solutions. In a review by Beglinger and Smith (2001), seven out of nine cluster analysis studies before 2001 generated two to four clusters. Other more recent studies have found three- to four-cluster solutions: three clusters based on ADI-R profiles at diagnosis and two clusters at age 6 (Georgiades et al., 2014); three clusters based on ADI-R profiles among individuals aged 3 to 21 years (Cholemkery, Medda, Lempp, & Frietag, 2016); three clusters of gaze responses to social dyadic scenes in toddlers (Campbell, Shic, Mcari, & Chawarska, 2013); and four clusters of sensory phenotypes among children 2 to 10 years old (Lane, Molloy, & Bishop, 2014). Therefore, for this study, the hypothesis is that: *Based on prior research, three well-separated clusters based on child measures would be generated that feature three subgroups of preschoolers with ASD, including high, medium, and low overall developmental functioning levels.*

To test this hypothesis, a hierarchical cluster analysis was conducted by calculating the Euclidean distance between each pair of observations using Ward's minimum variance method. In this cluster analysis, all subscale standard scores were included from the nine child measures from Time 1, including CARS, MSEL, PLS-4, PICS, RBSR, SCQ, SEQ, SRS, and VABS, to obtain a comprehensive developmental profile of preschoolers with ASD. All the data were standardized into z scores (mean = 0, SD = 1) for further analysis; a positive z-score indicates that the score of the observation is above the sample mean, whereas a negative z-score indicates that it is below the sample mean. Distance matrices for all observations across measures were generated for hierarchical cluster analysis by merging these observations into clusters to best fit the distribution of the dataset.

A dendrogram (or tree plot) can help visualize the process of hierarchical clustering by showing the steps needed to classify all the observations for each cluster. The elbow method (Thorndike, 1953) was applied in this analysis to determine the optimal number of cluster solutions. The elbow method calculates the total within-cluster sum of squares for different numbers of cluster solutions and then plots the variances according to the number of clusters. The location of a bend (elbow) in the plot indicates the appropriate number of clusters. By examining the dendrogram and the elbow plot, the optimal number of clusters to be selected can be determined. To validate the cluster solution, discriminant analysis was conducted to yield two canonical variables to calculate classification accuracy and produce a two-dimensional visual representation of the cluster distribution. Ninety percent of correct classifications is deemed satisfactory (Steinhausen & Langer, 1977). Lastly, analyses were conducted to provide descriptions of the developmental characteristics of the children in each cluster and to examine the distinctiveness of all the different clusters by comparing the cluster means for child measure scores with *post hoc* test results.

Research Question 2: ***What are the child or family factors that influence changes in social development over time for preschoolers in TEACCH, LEAP, and NMS classrooms?***

Based on the literature regarding influential factors of intervention and developmental outcomes (see Chapter 2), the hypotheses are:

1) *Children who have different developmental characteristics and are grouped into different clusters would respond differently to the three interventions. Specifically, higher functioning children would respond better to the LEAP intervention compared to children in the NMS program, whereas children in the lower functioning groups would respond better to the TEACCH intervention compared to children in the NMS group.*

2) *Children of caregivers with different mental health status and SES levels would benefit in different ways from the three interventions. Specifically, children with caregivers who have low levels of stress, anxiety, and depression and high SES would benefit more from LEAP and TEACCH programs than from NMS programs.*

To test these hypotheses, FRDD was applied to examine the effects of different child and family characteristics. Thistlewaite and Campbell first proposed and employed regression discontinuity design (RDD) in their 1960 paper that examined the effects of public recognition on students' attitudes towards intellectualism and their future academic plans (Thistlewaite & Campbell, 1960). Two types of RDD studies are sharp RDD and fuzzy RDD. In sharp RDD analysis, participants are assigned to different groups based strictly on a cut-off score criterion for a given measure (i.e., the running variable) ahead of time. In FRDD analysis, misassignment is allowed, whereby participants in different treatment groups are not assigned based strictly on their cut-off score. The original TEACCH-LEAP comparative efficacy study was a quasi-experimental study with treatments assigned at the classroom level. As is suitable for casual inference for quasi-experimental studies, RDD can be applied with the current dataset. Moreover, at the individual level, students were not initially assigned to intervention programs based on cut-off scores of child measures and, thus, some children who met the retrospectively enforced cut-off scores might have been participants in the comparison program. Therefore, FRDD analysis is a better fit for the current dataset than sharp RDD. Analytically, the estimation of the treatment effect in FRDD is carried out by fitting a regression model using the two-stage least squares (2SLS) method, which takes the probability of receiving the treatment into account when examining the treatment effect.

The following models illustrate how 2SLS analysis can be carried out:

$$\text{First-stage equation: } T_i = \alpha_1 + \gamma_0 D_i + f_1(r_i) + \varepsilon_i$$

$$\text{Second-stage equation: } Y_i = \alpha_2 + \beta_0 T_i + f_2(r_i) + \mu_i$$

Y_i = outcome for individual (i);

T_i = 1 if individual i receives the treatment, and 0 otherwise;

D_i = 1 if individual (i) is assigned to treatment based on the cut-off score of the running variable, and 0 otherwise;

r_i = rating for individual (i);

γ_0 = parameter estimate for the effect of D_i on T_i, indicating how well the actual treatment is predicted by whether or not the participants meet the cut-off scores;

$f_1(r_i)$ = the relationship between the ratings of the running variable and treatment receipt for individual (i);

β_0 = parameter estimate for intervention effect on the outcome;

$f_2(r_i)$ = the relationship between the ratings of the running variable and outcome for the individual (i);

ε_i = random error in first-stage regression; and

μ_i = random error in second-stage regression.

For the current study's secondary analysis, FRDD analysis was conducted as follows: 1) determine the running variables and conduct density tests; 2) determine the cut-off scores of the child and caregiver measures for group assignments; 3) calculate the probability of assignment based on the cut-off scores and actual treatment received; and 4) model relationships between child characteristics and the dependent variable using regression modeling and visual graphs for pairs of the intervention and comparison groups. That is, three intervention models were grouped in pairs for analyses: TEACCH vs. NMS, LEAP vs. NMS, and TEACCH vs. LEAP.

Given the nature of secondary analysis, prior to actual FRDD analysis, the running variables and cut-off scores that ensure the validity and power of the current study needed to be determined. In classic FRDD studies, participants are assigned based on predetermined cut-off scores of a specific running variable, with flexibility for some misassignments. For this study's secondary analysis, the running variables and cut-off scores were retrospectively assigned and determined with extra caution to ensure the validity of the RDD. In the following section, the step-by-step process of determining the running variables and cut-offs is presented in accordance with guidelines in Imbens and Lemieux (2007) to conduct density tests and graph probability plots to inform final decision-making.

Running variable selection. First, candidate running variables were selected. In RDD analyses, the running variables serve as intervention assignment criteria and the independent variables when modeling intervention outcomes. Therefore, potential influential factors were selected as candidate running variables to explore the relationships between influential factors and intervention outcomes. Based on the literature review (Chapter 2), cognitive functioning, language levels, social communication skills, and repetitive behaviors are the influential child factors with the most research evidence (see Table 2.1). These factors were measured by MSEL, PLS4, SRS, CARS, and RBSR in the current study. Moreover, the primary outcome paper on TEACCH and LEAP comparative efficacy (Boyd et al., 2014) also identified that the MSEL and PLS-4 are two moderators of intervention outcomes for the current sample. The SRS scores were included as the outcome variables in the current analysis; therefore, MSEL, PLS4, CARS, and RBSR were selected as candidate running variables for the child measures. As the intervention assignment should be contingent on the scores of the running variables, group differences in the running variables were expected at preintervention to ensure low misassignment rates. So, the

RBSR were excluded with no significant preintervention group differences (see Table 3.4). As for the parent factors, most parents did not meet the cut-off score on the BDI, with only ten in the TEACCH group, seven in the NMS group, and three in the LEAP group scoring above the cut-off. Both the EMAS and SES indicators also were ruled out as no significant preintervention group differences were observed. Therefore, the PSI was selected as the parent factor running variable with the most observed group differences.

Cut-off score determination. Second, cut-off scores were determined for each running variable based on density test results and probability graphs. As the intervention groups would be compared in pairs in the FRDD analysis, the cut-off scores were examined for each pair. The cut-off scores for the child measures were originally set by calculating the mean scores of the medium functioning cluster (Cluster 1): 53 on MSEL, 57 on PLS4, and 33 on CARS. The clinical cut-off score was used for the parent PSI measure: 77th percentile. Then, density curves were graphed to examine whether discontinuity in density distribution was present around the cut-off and to ensure enough cases were assigned according to the cut-off on both sides for further analyses. Discontinuity in density around the cut-off scores might indicate the possibility of manipulation or self-selection; so, no discontinuity around cut-off is preferred in order to rule out confounding factors (Jacob, Zhu, Somers, & Bloom, 2012; McCrary, 2008). Figures 3.1, 3.2, and 3.3 present density curves for all four running variables according to the comparison models; the intervention groups (T_i) were dummy-coded (TEACCH [1] vs. NMS [0], LEAP [1] vs. NMS [0], and TEACCH [1] vs. LEAP [0]). Moreover, Figures 3.4, 3.5, and 3.6 present the probability graphs of the three comparison models and show the actual probability of receiving the intervention (Y-axis) for different scores for the four running variables. As recommended by Imbens and Lemieux (2007), for valid FRDD, no discontinuity in the density curve or discontinuity in the probability graph around the cut-off should be present. The determination process for the cut-off scores for each running variable is provided in the following paragraphs.

The density curves for MSEL (Panels A on Figures 3.1 to 3.3) show a decrease (discontinuity) in density around the standard score of 53. Thus, the cut-off score must be adjusted for the sake of FRDD validity. Sixty was selected as the new cut-off score, as it was the closest score to 53 that included the most cases in the intervention group and the fewest cases (the lowest misassignment rate) across the three models. The reference lines in the MSEL graphs confirm no abrupt decrease in density when the MSEL standard score is 60, and continued decrease is evident for the probability of receiving treatment for those with scores above 60 (Panels A on Figures 3.4, 3.5, and 3.6).

The PLS4 cut-off scores showed discontinuity in density around the cut-off score of 57 (Panels B on Figures 3.1 to 3.3). Using the same criteria as for the MSEL, the new cut-off for PLS-4 was 75, as shown as the reference lines in the PLS-4 graphs. Decreases in receiving intervention were observed for children who scored above the cut-off in both the TEACCH vs. NMS and TEACCH vs. LEAP comparisons.

The CARS scores showed no abrupt drops in density on the density curves around the cut-off score of 33 (Panels C on Figures 3.1 to 3.3). The density curves indicate that most of the observations above the cut-off score were in the intervention group. This observation also is confirmed by the probability graphs (Panels C on Figures 3.4, 3.5, and 3.6), with higher probabilities above the cut-off scores to be assigned in the intervention groups and increases in the probability of actually receiving the intervention around the cut-off.

The density curve for the PSI was continuous around the clinical cut-off score of the 77^{th} percentile across the three comparison models and the density was higher for the intervention group above the cut-off scores (Panels D on Figures 3.1, 3.2, and 3.3). However, no discontinuity or change was observed on the probability graphs (Panels D on Figures 3.4, 3.5, and 3.6), indicating that the probability of receiving intervention was fairly consistent across parents with different levels of stress.

Children who scored lower than the cut-offs on the MSEL (60) and PLS-4 (75) and higher than the cut-off on the CARS (33) were considered to have high ASD severity levels and in great need of the interventions. Similarly, children of parents with stress levels higher than the clinical cut-off (77^{th} percentile) were considered to be in the intervention group. These children were offered the interventions rather than the comparison programs. Thus, the binary indicator of the running variables (D_i, i.e., the intervention assignment based on cut-off) was dummy-coded as 1 for those children who met the cut-off (i.e., children who scored ≤ 60 on the MSEL, ≤ 75 on the PLS-4, and ≥ 33 on the CARS) and parents who scored ≥ 77^{th} percentile. The binary indicator was dummy-coded as 0 for those children who did not meet the cut-off. However, as expected, not all cases complied with cut-off criteria for the running variables and resulted in misassignments. In the current analysis, the two types of misassignments were cross-overs, i.e., those participants who did not meet the cut-off criteria and received the intervention, and no-shows, i.e., those participants who met the criteria but did not receive the intervention. Table 3.9 presents the cross-over, no-show, and average misassignment rates across the three comparison models. The TEACCH vs. NMS comparison models had the lowest misassignment rates (27.78% - 43.75%), whereas the LEAP vs. NMS comparison models had the highest misassignment rates for all four running variables (41.59% - 48.67%). These percentages are considered high misassignment rates (Price, 2009).

Table 3.9

Misassignment Rates with Cut-Off Scores for Four Running Variables

Cut-off scores	TEACCH vs. NMS			LEAP vs. NMS			TEACCH vs. LEAP		
	Cross-Over	No-show	Average	Cross-Over	No-show	Average	Cross-Over	No-show	Average
MSEL = 60	32.73%	24.72%	27.78%	37.50%	44.62%	41.59%	40.00%	33.03%	34.53%
PLS4 = 75	40.82%	31.58%	34.72%	40.82%	46.88%	44.25%	50.00%	34.34%	38.85%
CARS = 33	40.85%	23.29%	31.95%	41.67%	41.46%	41.59%	49.15%	30.00%	38.13%
PSI = 77th	53.23%	36.59%	43.75%	46.30%	50.85%	48.67%	56.90%	35.80%	44.60%

Once the cut-off scores for the running variables were established, the D_i and r_i were set accordingly for each running variable. The actual treatment group assignments were dummy-coded for the variable T_i for each pair of group comparisons (i.e., TEACCH [1] vs. NMS [0]; LEAP [1] vs. NMS [0]; TEACCH [1] vs. LEAP [0]). The SRS change scores were calculated as the outcome variable Y_i. To investigate the intervention effects and their functional relationships with the influential factors, group comparisons were conducted for the SRS change scores for each pair and then fitted by linear regression using 2SLS methods. Regression discontinuity plots were drawn accordingly for each regression model. Both the statistical parameters and the regression discontinuity plots were examined and are presented in detail in Chapter 4.

Figure 3.1

Density Graph for Four Running Variables in TEACCH (1) vs. NMS (0) comparisons

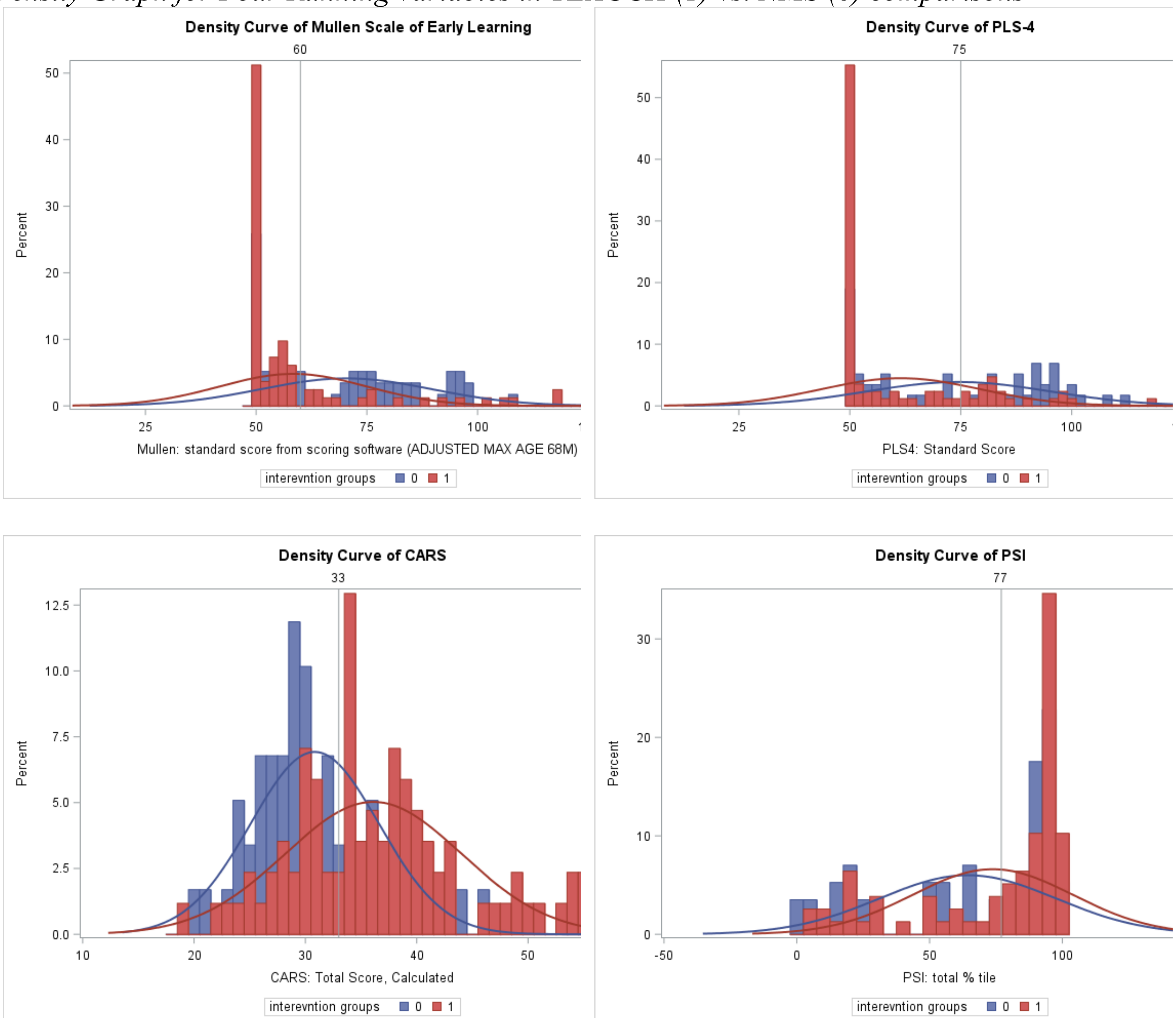


Figure 3.2

Density Graph for Four Running Variables in LEAP (1) vs. NMS (0) comparisons

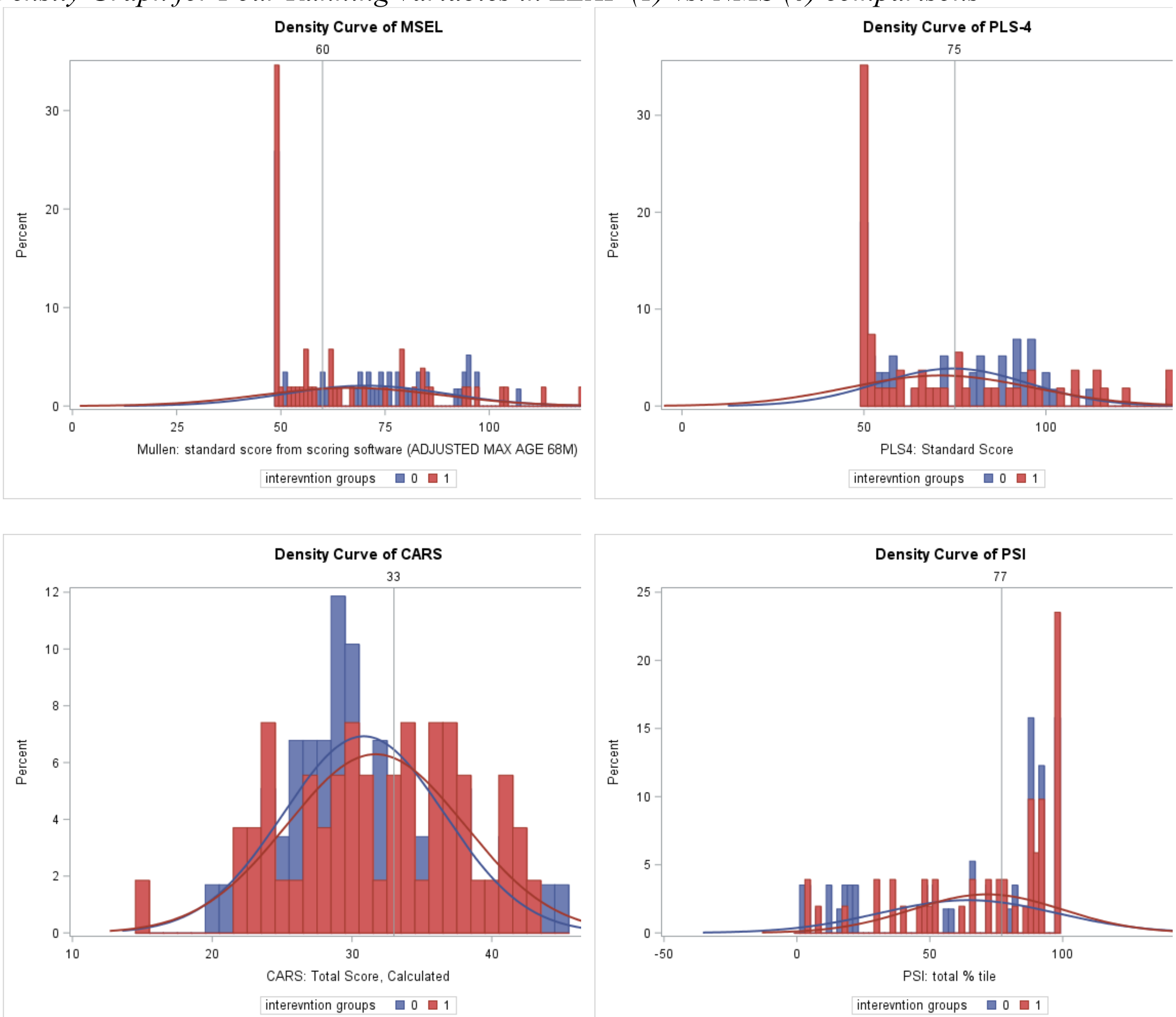


Figure 3.3

Density Graph for Four Running Variables in TEACCH (1) vs. LEAP (0) comparisons

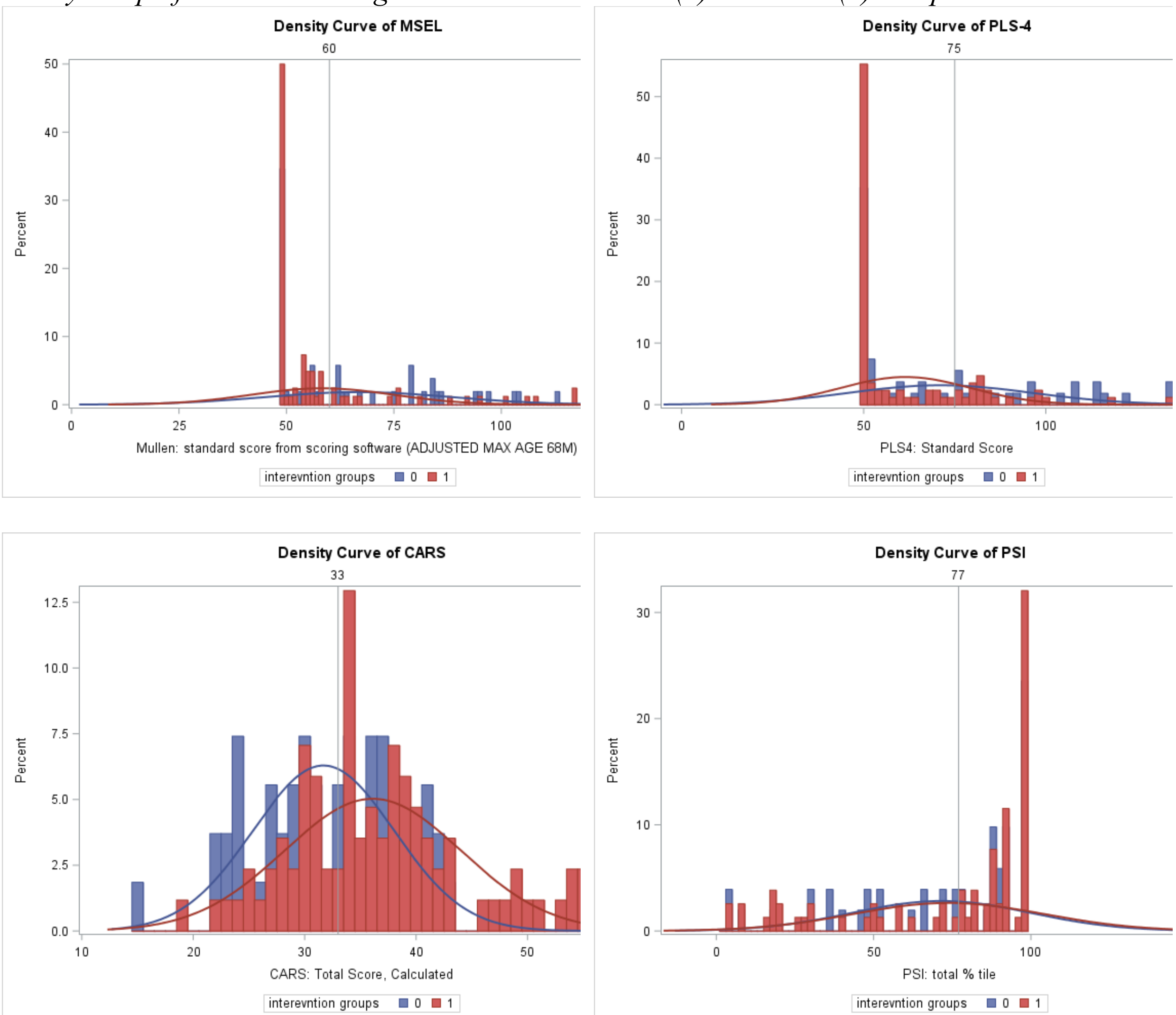


Figure 3.4

Probability Graphs of Intervention Assignment for Four Running Variables in TEACCH (1) vs. NMS (0) comparisons

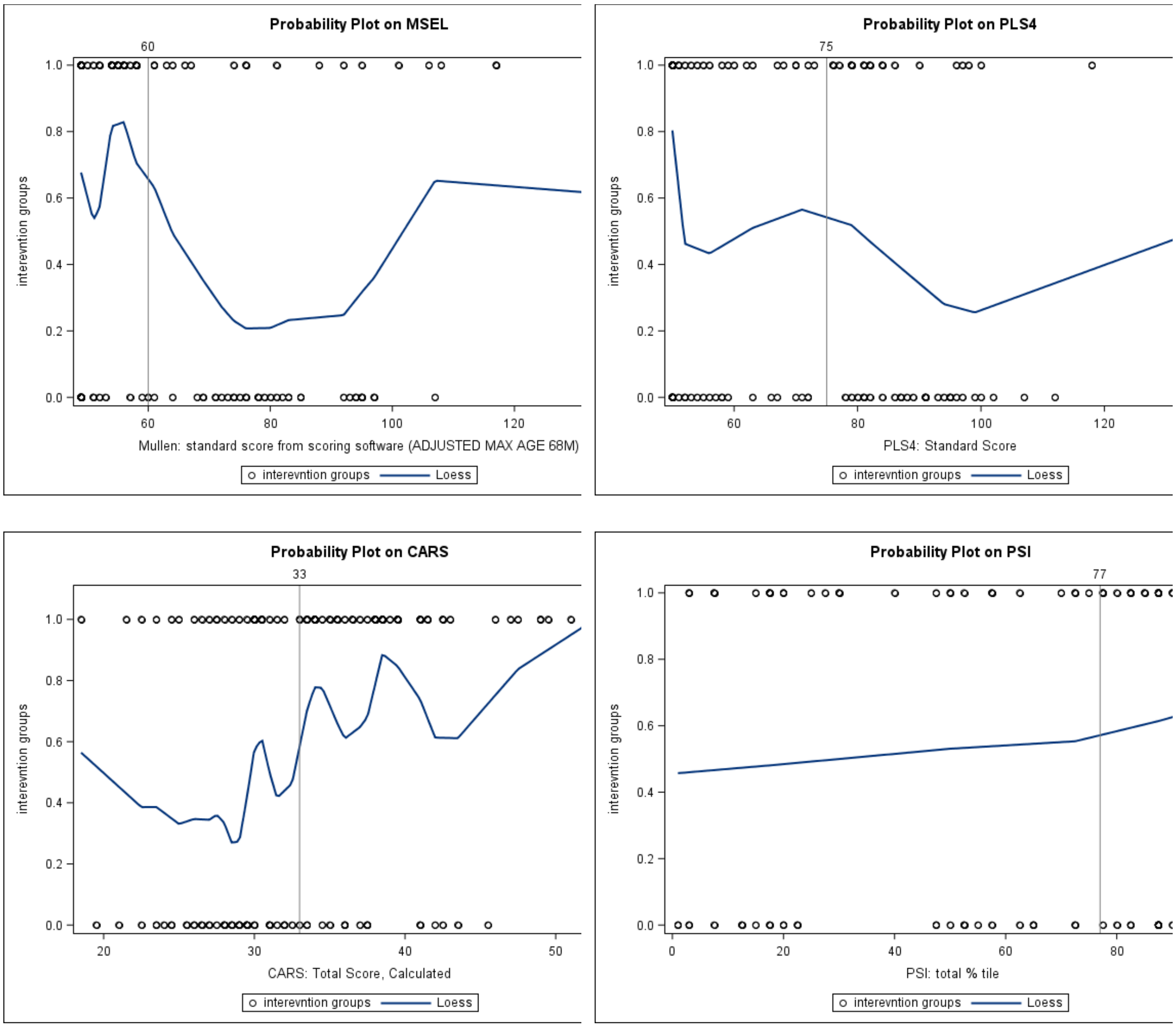


Figure 3.5

Probability Graphs of Intervention Assignment for Four Running Variables in LEAP (1) vs. NMS (0) comparisons

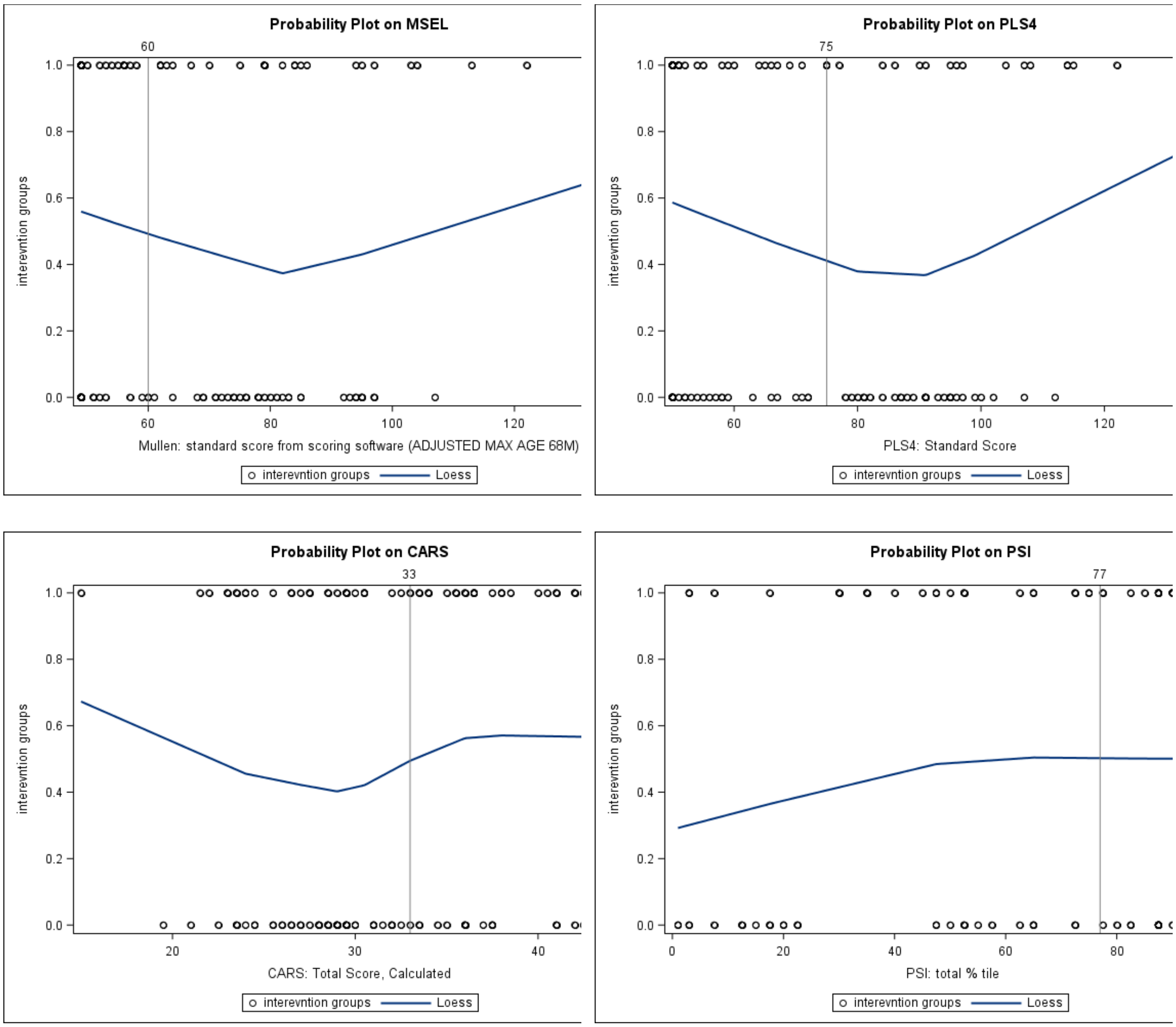
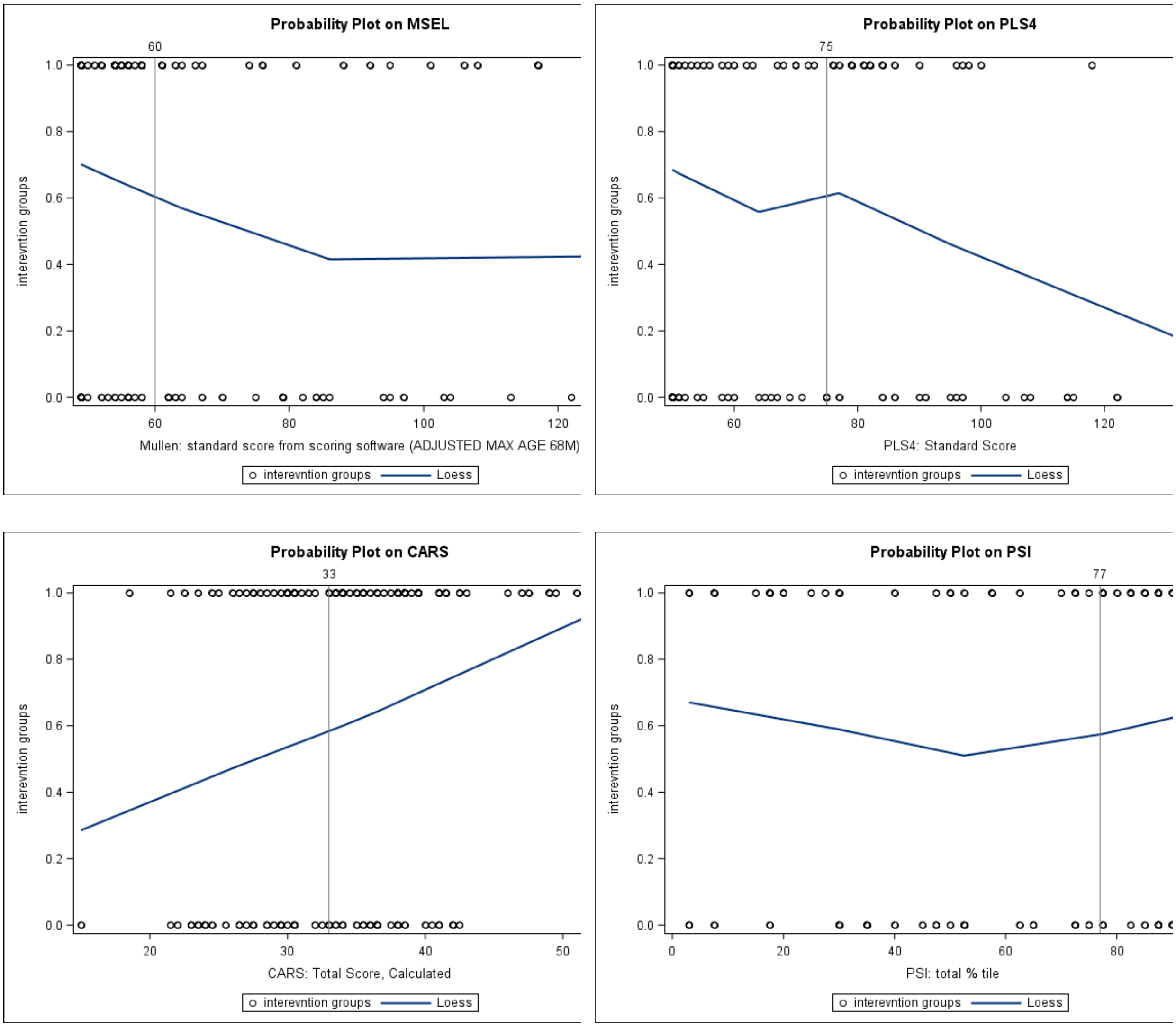


Figure 3.6

Probability Graphs of Intervention Assignment for Four Running Variables in TEACCH (1) vs. LEAP (0) comparisons



Chapter 4 Results

This study's purpose was to identify subgroups of preschoolers with ASD and their different responses to interventions based on their developmental and family profiles. Specifically, the research questions were as follows: *1) Are the subgroups of preschoolers with ASD distinct based on preintervention developmental and behavioral measures? If so, what are the subgroups and their characteristics? 2) What child or family factors influenced changes in social development over time for preschoolers in TEACCH, LEAP, and NMS classrooms?* This chapter presents the study's primary findings from analyses to address each research question. The cluster analysis results of the current sample are used to answer Research Question 1. FRDD analysis results of the children's responses to interventions are used to address Research Question 2.

Research Question 1: Subgroups of Preschoolers with ASD

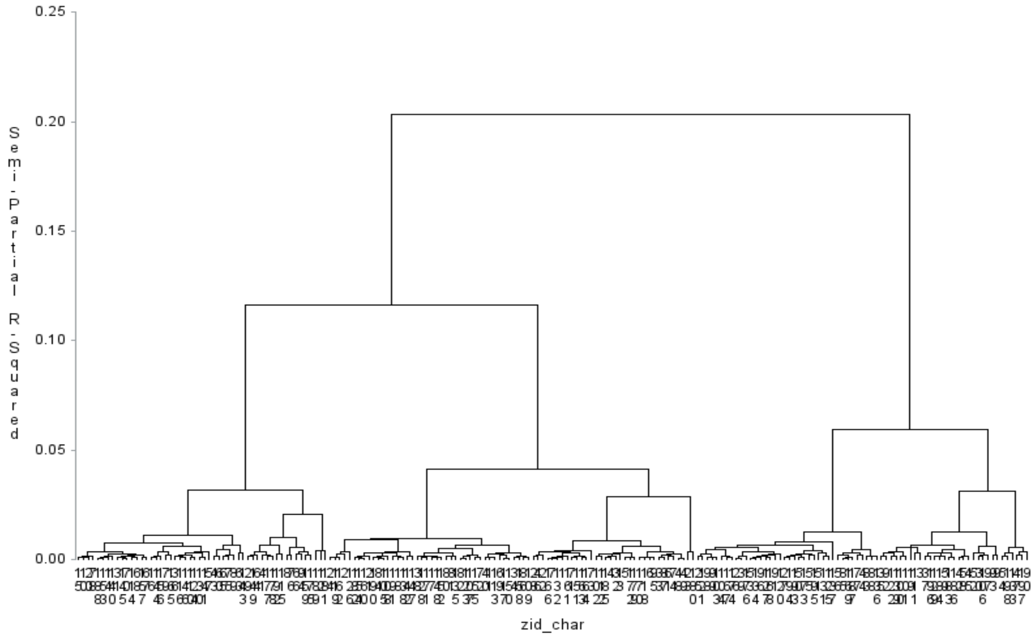
To answer Research Question 1, cluster analysis was applied to identify distinct subgroups of preschoolers with ASD based on preintervention developmental and behavioral measures. First, to ensure that scores across measures were comparable, imputed subscale scores from all nine child measures were converted to *z*-scores. Then, the Euclidian distance between observations was calculated for cluster analysis. During the clustering process, one outlier observation was identified that could not be classified into any cluster until the last level of clustering. Therefore, this specific observation was excluded from the cluster analysis. As a result, the final sample size in the hierarchical cluster analysis was 197.

The hierarchical cluster analysis generated a three-cluster solution based on a dendrogram (Figure 4.1) and elbow graph (Figure 4.2). The dendrogram shows the stepwise process of case grouping and the variances (semi-partial R^2) that are explained by each hierarchy, as cases with similar characteristics are clustered together. The dendrogram clearly shows that the cases merge into three clusters at the third to last hierarchy, although two of the three clusters are grouped together at the second to last hierarchy. Therefore, the elbow graph is a necessary step to determine the number of clusters. The elbow graph shows plots of the variances (R square) by the number of clusters and shows a bend in the plotted line when the number of clusters is three. When the number of clusters increases from two to three, the amount of variance explained increases from 0.20 to 0.32, whereas the four-cluster solution does not explain much more variance (0.38). Therefore, the three-cluster solution was deemed the best fit for the current sample. The three-cluster solution indicates 76 preschoolers in Cluster 1 (38.58%), 69 in Cluster 2 (35.03%), and 52 in Cluster 3 (26.4%). To examine the accuracy of the classification and visualize the clustering, two canonical variables based on the Euclidian distance between variables were generated. Discriminant analysis of the canonical variables revealed that 91.88% of participants were classified into the right clusters on average, with 92.11% of the participants correctly classified into Cluster 1, 94.2% of participants correctly allocated to Cluster 2, and 88.46% to Cluster 3 (see Figure 4.3). The high classification accuracy (greater than 80%) shows that the three-cluster solution is plausible.

Cluster comparisons. The means and standard deviations were calculated for subscales and total scale *z*-scores across nine child measures by cluster (see Table 4.2). Group comparisons were conducted to determine whether the clusters were well-separated in terms of core characteristics. Considering the increase in the Type I error rate due to multiple tests, the significance level, α, was set as .001. Significant differences were evident among the clusters observed on all the subscales and total scores across all nine child measures with *p*-values lower than .0001, except for the RBSR compulsive behavior subscale ($F_{RBSR\text{-}compulsive} = 5.35$, $p = .006$) and SEQ hypersensitivity subscale ($F_{SEQ\text{-}hyper} = 4.12$, $p = .018$). Table 4.7 presents detailed statistics. To identify the differences among clusters more explicitly, *post hoc* tests were performed to capture the characteristics of the three clusters (Table 4.2). Taken together, three subgroups of preschoolers with different developmental and behavioral profiles were among the sample. The mean total *z*-scores of the nine child measures by cluster were used to generate a radar plot (Figure 4.4) that gives a visual representation of child characteristics across clusters.

Figure 4.1

Dendrogram of Hierarchical Clustering



Note: The x-axis is unique identification numbers for each case.

Figure 4.2

The Elbow Method Plot for Cluster Number Determination

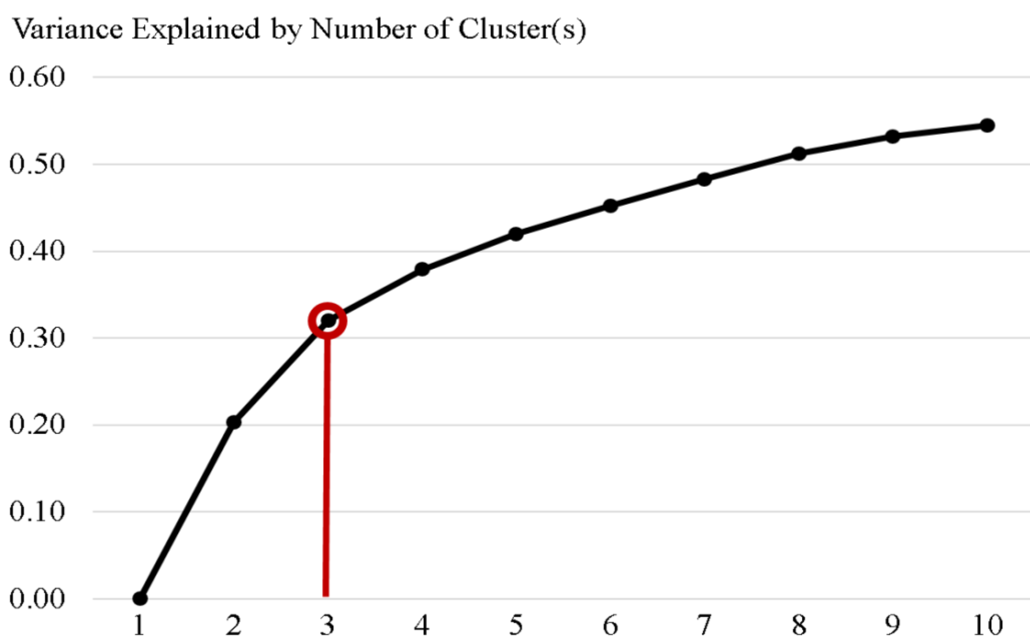


Figure 4.3

Scatter Plot of Canonical Variates by Cluster

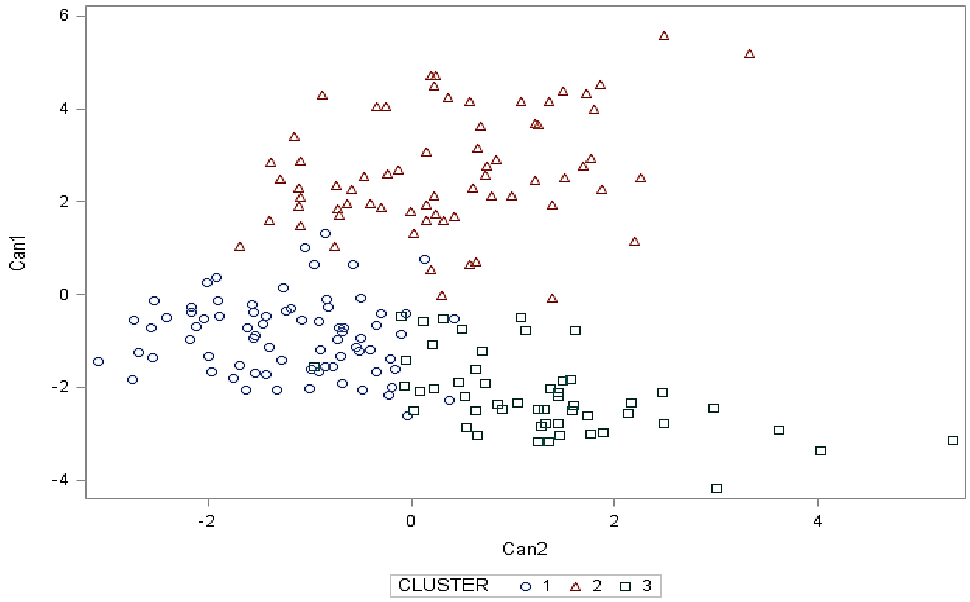
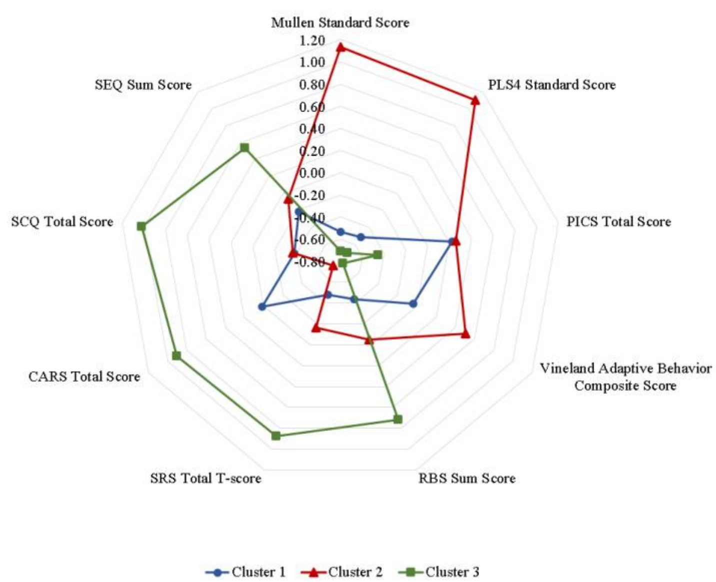


Figure 4.4

Radar Plot of Developmental and Behavioral Profiles by Cluster



Note: Higher scores on the following scales indicate higher levels of ability/functioning: MSEL standard score; PLS4 standard score; PICS total score; VABS adaptive behavior composite score. Higher scores on the following scales indicate more autism severity: RBS sum score; SRS total t-score; CARS total score; SCQ total score; SEQ sum score.

The profile for each cluster is described below.

Cluster 1 includes children with moderate autism severity with unbalanced profiles across developmental characteristics. These children had low levels of cognitive and language abilities and moderate levels of adaptive behaviors among the current sample. However, children in Cluster 1 showed the lowest levels of social difficulties as measured by the SRS and the least repetitive behaviors as measured by the RBSR, with the lowest scores for both measures (Table 4.2). Moreover, Cluster 1 contains the highest percentage of girls (22.2%) among the three clusters.

Cluster 2 is comprised of preschoolers with the highest levels of functioning in the sample. As observed on the radar plot and evidenced by previous analyses, children in Cluster 2 had comparatively high cognitive and language abilities and exhibited good parent-reported adaptive behaviors. They also showed the lowest levels of autism severity scores as measured on the CARS (evidenced by negative *z*-scores in Table 4.2). However, children in Cluster 2 had moderate levels of severity in the two core ASD characteristics: social abilities and repetitive behaviors. Unlike children in the other two clusters, most children in Cluster 2 were enrolled in high-quality NMS classrooms.

Cluster 3 includes children who exhibited the highest levels of autism severity on both CARS and SCQ. Children in Cluster 3 also showed the most delays across all aspects of development in the current sample. They had the lowest cognitive scores on MSEL and the lowest level of language abilities on PLS-4 as well as the most repetitive behaviors, social development delays, and atypical sensory profiles. Children in Cluster 3 constituted 71.15% of those from minority race/ethnicity groups, with the most children being Hispanic (46.15%).

Specifically, the ANOVA results for the child measures across the three clusters are described according to each developmental aspect as follows.

1) For *Cognitive Abilities* measured on the MSEL, preschoolers in Cluster 2 had significantly higher scores than children in the other two clusters across all four subscales and total standard scores, whereas children in Cluster 1 and Cluster 3 did not differ from each other across any of the subscales and scores.

2) For *Language Abilities* measured by the PLS4, children in Cluster 2 had the highest level of language abilities among the three clusters. This finding is consistent with the receptive and expressive language skills measured by the MSEL. Children in Cluster 1 had significantly higher scores than children in Cluster 3 on both subscales of auditory comprehension and expressive communication. However, differences were not observed in terms of total score. Similar patterns also were observed for prelinguistic *Joint Attention* on the PICS, where children in Cluster 3 had significantly lower scores than children in the other two clusters.

3) For *Restricted and Repetitive Behaviors* on the RBSR, preschoolers with ASD in Cluster 3 exhibited the highest severity levels of repetitive behaviors, including stereotyped, self-injurious, restricted behaviors, and insistence on ritual and sameness. Children in Clusters 1 and 2 did not differ on any of the subscales, but children in Cluster 2 presented a higher level of total repetitive behavior than children in Cluster 1.

4) For *Social Development* on the SRS, children in Cluster 3 showed the highest level of severity across all the subscales and the total scale of social responsiveness among all three clusters. Moreover, preschoolers in Cluster 2 showed higher scores in mannerisms associated with ASD, social awareness, social motivation, and total social responsiveness than preschoolers in Cluster 1.

5) Children in Cluster 3 showed the highest levels of *Autism Severity* on the SCQ and CARS compared to children in the other two clusters, and children in Cluster 2 exhibited the lowest severity level on the CARS.

6) The levels of *Adaptive Behaviors* measured by the VABS of the three clusters showed consistent patterns across all subscales and total adaptive behavior composite and were ranked as Cluster 2 > Cluster 1 > Cluster 3.

7) For *Sensory Profiles* on the SEQ, preschoolers in Cluster 3 showed the most atypical sensory patterns overall for both the hyposensitivity and sensory-seeking subscales. No significant differences were observed between children in Clusters 1 and 2 in term of sensory profiles.

Table 4.3 presents demographic information about the clusters. The three clusters share similar demographic profiles regarding gender characteristics (primarily male) and age at enrollment (Cluster 1: 3.56 years of age; Cluster 2: 3.68; Cluster 3: 3.48). With regard to race and ethnicity, children in both Clusters 1 and 2 were primarily non-Hispanic White, but children in Cluster 3 were primarily Hispanic. Significant group differences in race and ethnicity were found across clusters ($\chi^2(2) = 12.15$, $p = 0.002$; the lowest functioning Cluster 3 children were mostly from minority groups (69.23%) and the highest functioning Cluster 2 children were mostly non-Hispanic White (62.32%). When examining the cluster differences in diagnostic categories on the ADOS, children across Clusters 1, 2, and 3 were mostly classified as autistic (94.74%, 82.61%, and 92.31%, respectively), with a portion of children in Cluster 2 categorized as on the autism spectrum (14.49%). However, children from the three clusters were enrolled in different types of intervention programs, with most of the children in Cluster 1 (50%) and Cluster 3 (57.69%) enrolled in TEACCH programs and in Cluster 2 (49.28%) enrolled in high-quality NMS programs. Chi-square test results revealed that children in the three clusters differed significantly with regard to the intervention programs in which they were enrolled (χ^2 (4) = 23.68; $p < .0001$).

In summary, the cluster analysis identified three distinct developmental subgroups of preschoolers with ASD (see Table 4.1 for levels of developmental aspects by cluster). Children in Cluster 2 constituted the highest functioning subgroup with the least autism severity and the highest levels of cognitive and language abilities and adaptive behaviors. However, children in Cluster 2 exhibited more social delays and repetitive behaviors than those in Cluster 1. Cluster 3 was the lowest functioning subgroup, with children with the most autism severity and social delays and repetitive behaviors.

Table 4.1

Levels of Developmental Aspects by Cluster

	Cluster 1	Cluster 2	Cluster 3
Ability Level			
Cognitive Ability	Low	High	Low
Language Ability	Low	High	Low
Joint Attention Skills	Medium	Medium	Low
Adaptive Skills	Medium	High	Low
Severity Levels			
Social Impairments	Low	Medium	High
RRBIs	Low	Medium	High
Sensory Atypicality	Low	Low	High
Social Communication Deficits	Low	Low	High
Autism Severity	Medium	Low	High

Table 4.2

Cluster Comparisons of z-Scores for Developmental and Behavioral Characteristics

		Cluster 1 (N = 76)		Cluster 2 (N = 69)		Cluster 3 (N = 52)		GLM Results		Post Hoc Tests *
Measures	Domains Measured	Mean	SD	Mean	SD	Mean	SD	F	*p*	
PLS4	Auditory comprehension	-0.50	0.51	1.12	0.73	-0.73	0.38	207.76	<.0001	2>1>3
	Expressive communication	-0.42	0.59	1.01	0.85	-0.70	0.45	123.87	<.0001	2>1>3
	Total	-0.51	0.47	1.10	0.82	-0.70	0.34	183.16	<.0001	2>1; 2>3
PICS	PICS_IBR	0.24	0.60	0.08	0.56	-0.23	0.52	10.77	<.0001	2>3; 1>3
	PICS_IJA	0.15	0.55	0.31	0.43	-0.40	0.56	30.13	<.0001	2>3; 1>3
	PICS_RJA	0.25	0.80	0.38	0.77	-0.78	0.82	36.78	<.0001	2>3; 1>3
	PICS_Tot	0.22	0.48	0.26	0.51	-0.46	0.54	36.13	<.0001	2>3; 1>3
RBS (Lam)	Stereotyped	-0.36	0.70	-0.26	0.76	0.87	1.15	37.00	<.0001	3>2; 3>1
	Self-Injurious	-0.29	0.59	-0.13	0.63	0.60	1.52	14.90	<.0001	3>2; 3>1
	Compulsive	-0.19	0.84	-0.06	0.96	0.37	1.17	5.35	NS	
	Ritual/Same	-0.44	0.56	0.19	1.16	0.40	1.05	14.76	<.0001	3>1; 2>1
	Restricted	-0.29	0.84	0.01	1.00	0.42	1.07	8.41	0.0003	3>2; 3>1
	Total Sum	-0.44	0.63	-0.05	0.95	0.72	1.12	26.31	<.0001	3>2>1
SRS	Autistic Mannerism	-0.48	0.64	-0.03	0.90	0.61	0.77	30.57	<.0001	3>2>1
	Social Awareness	-0.42	0.84	-0.13	0.98	0.82	0.74	32.68	<.0001	3>2>1
	Social Cognition	-0.24	0.57	-0.25	0.63	0.48	0.48	30.54	<.0001	3>1; 3>2
	Social Communication	-0.36	0.77	-0.17	1.01	0.80	0.82	29.55	<.0001	3>1; 3>2
	Social Motivation	-0.34	0.73	0.02	0.78	0.63	0.60	28.04	<.0001	3>2>1
	Total	-0.48	0.69	-0.16	1.03	0.88	0.71	42.96	<.0001	3>2>1
MSEL	Visual Reception	-0.50	0.47	1.09	0.84	-0.69	0.34	173.14	<.0001	2>1; 2>3
	Fine Motor	-0.39	0.54	0.92	1.07	-0.64	0.36	84.00	<.0001	2>1; 2>3
	Receptive Language	-0.55	0.32	1.09	0.94	-0.63	0.20	175.73	<.0001	2>1; 2>3
	Expressive Language	-0.44	0.56	0.99	0.96	-0.66	0.32	112.26	<.0001	2>1; 2>3
	Total Standard	-0.54	0.30	1.13	0.86	-0.71	0.23	221.60	<.0001	2>1; 2>3
CARS		0.01	0.65	-0.73	0.64	0.90	1.02	67.78	<.0001	3>1>2
SCQ		-0.38	0.76	-0.36	0.88	1.02	0.73	58.45	<.0001	3>2; 3>1
SEQ	Hypersensitivity	-0.18	0.86	0.12	0.84	0.24	0.89	4.12	NS	
	Hyposensitivity	-0.13	0.64	-0.05	0.41	0.47	0.51	21.27	<.0001	3>2; 3>1

	Sensory Seeking	-0.17	0.99	-0.21	0.76	0.52	1.13	10.43	<.0001	3>2; 3>1
	Total	-0.21	0.86	-0.07	0.68	0.54	0.86	14.43	<.0001	3>2; 3>1
VABS	Communication	-0.11	0.70	0.71	0.66	-0.88	0.74	77.44	<.0001	2>1>3
	Daily Living Skills	0.05	0.86	0.59	0.79	-0.92	0.69	53.90	<.0001	2>1>3
	Motor Skills	-0.02	0.69	0.18	0.52	-0.41	0.50	15.03	<.0001	2>1>3
	Socialization	0.03	0.82	0.47	0.76	-0.80	0.49	45.45	<.0001	2>1>3
	Adaptive Behavior Composite	-0.04	0.74	0.51	0.64	-0.77	0.48	58.46	<.0001	2>1>3

Note: Please refer to the list of abbreviations for the full names of the measures.

Table 4.3
Demographic Information about Children by Cluster

		Cluster 1		Cluster 2		Cluster 3	
		Frequency	%	Frequency	%	Frequency	%
Gender	Male	59	77.63	62	89.86	44	84.62
	Female	17	22.37	7	10.14	8	15.38
Race/Ethnicity	White	31	40.79	41	59.42	15	28.85
	Hispanic	28	36.84	17	24.64	24	46.15
	Black	9	11.84	7	10.14	7	13.46
	Asian	3	3.95	2	2.90	4	7.69
	Multi-racial	4	5.26	2	2.90	2	3.85
Intervention Groups	TEACCH	38	50	16	23.19	30	57.69
	LEAP	23	30.26	19	27.54	12	23.08
	NMS	15	19.74	34	49.28	10	19.23
ADOS Diagnostic Rank	0: not on spectrum	0	0	2	2.90	1	1.92
	1: autism spectrum	4	5.26	10	14.49	3	5.77
	2: autism	72	94.74	57	82.61	48	92.31
Child age at enrollment (years)		Mean	SD	Mean	SD	Mean	SD
		3.56	0.56	3.68	0.60	3.48	0.47

Research Question 2: Differential Intervention Responses

With the knowledge that the preschoolers in this study could be categorized into distinct subgroups, the next step in the analysis was to address Research Question 2 regarding children's different responses to interventions. FRDD was employed retrospectively to explore whether preschoolers with different characteristics show different social developmental outcomes when assigned to one of the three intervention programs (TEACCH, LEAP, or NMS). This section is organized into two parts: (1) analyses of social development outcomes measured by the SRS change scores and (2) FRDD group comparison results by pairs (TEACCH vs. NMS, LEAP vs. NMS, and TEACCH vs. LEAP).

Intervention outcomes on the SRS. The SRS change scores were calculated by subtracting the pre-intervention total *t* scores on the SRS from the post-intervention total *t* scores: $SRS_D = SRS_{post} - SRS_{pre}$. The SRS scores indicate the severity levels of social delays/difficulties; the negative change scores indicate decreases in social difficulties, which are increases in social functioning, whereas positive change scores indicate that children had more delays at post-intervention. The descriptive statistics for the intervention outcomes for all three intervention groups were calculated and are shown in Table 4.4. All three groups show decreases in social delays, indicating that the social development of the children improved as evidenced by the negative change scores. No significant group differences are evident in the SRS changes scores from pre-intervention to post-intervention ($F = 0.20$, $p = 0.82$).

Table 4.4
Intervention Outcomes Measured by SRS Change Scores

	TEACCH	**LEAP**	**NMS**	**Overall**	
N	59	46	51	156	$F = 0.20$ $p = 0.82$
Mean	-2.4	-1.2	-2.2	-1.99	
SD	11.5	7.9	9.5	9.88	
Range	-34 -30	-17-16	-24-35	-34-35	

Further, the intervention effects were examined using FRDD analysis that considered the effects of child and parent factors (i.e., scores on the MSEL, PLS4, CARS, and PSI). Results from regression modeling analyses with two-stage least squares (2SLS) were calculated and examined statistically:

$$\text{First-stage equation: } T_i = \alpha_1 + \gamma_0 D_i + f_1(r_i) + \varepsilon_i$$

$$\text{Second-stage equation: } Y_i = \alpha_2 + \beta_0 T_i + f_2(r_i) + \mu_i$$

As noted in Chapter 3, the model parameters (γ_0, β_0) and functional forms statistics (f_1, f_2) of interest in the current analysis are:

$\boldsymbol{\gamma_0}$ = parameter estimate for the effect of D_i on T_i, indicating how well the actual intervention status is predicted by whether or not participants meet cut-off scores;

$\boldsymbol{\beta_0}$ = parameter estimate for intervention effect on SRS change scores;

$\boldsymbol{f_1(r_i)}$ = relationship between the ratings for the running variable and intervention receipt; and

$\boldsymbol{f_2(r_i)}$ = relationship between the ratings for the running variable and the SRS change scores.

Specifically, β_0 and f_2 address Research Question 2 by indicating whether significant intervention effects are evident and whether scores for the running variables (i.e., the influential factors of interest, MSEL, PLS4, CARS, and PSI scores) significantly predict intervention outcomes. Moreover, regression discontinuity plots were generated to visualize the relationships between the influential factors (both child and parent measures) and outcome variables using a linear functional fit for each intervention group. Then, the regression discontinuity plots were inspected for the presence of discontinuity and functional relationships between the influential factors and the outcomes. All the FRDD analyses were performed using the running variables and cut-off scores that were determined in Chapter 3, i.e., MSEL: 60, PLS4: 75, CARS: 33, and PSI: 77th. The following section presents the findings by comparison pairs.

TEACCH vs. NMS comparison. In the analysis for this comparison, TEACCH was dummy-coded as the intervention group ($T_i = 1$) and NMS as the comparison group ($T_i = 0$). The 2SLS regression models were applied using the four running variables respectively. Table 4.5 presents the parameter estimates and Figure 4.5 presents the regression discontinuity plots.

Child Measures. The 2SLS model with MSEL as the running variable and 60 as the cut-off shows that the status of the above or below cut-off scores (D_i) significantly predicted the actual treatment receipt (T_i) at the first-stage regression ($\gamma_0 = 0.4$, $p = 0.002$). However, neither treatment receipt ($\beta_0 = 6.26$, $p = 0.52$) nor the cognitive levels measured on the MSEL ($p = 0.33$) predicted the intervention outcome. Discontinuity at the cut-off can be observed on the regression discontinuity plot (Panel A on Figure 4.5), with children in the TEACCH program showing fewer changes in the outcome and those in the NMS showing more decreases in SRS scores. The functional lines on both sides of the cut-off are nearly parallel to the x-axis, indicating that the changes of cognitive scores had little effect on the social development outcomes on the SRS.

When PLS4 was entered as the running variable and 75 as the cut-off, the model showed that none of the factors in the model were significant predictors for the intervention outcomes, D_i ($\gamma_0 = 0.08$, $p = 0.62$), T_i ($\beta_0 = 6.26$, $p = 0.52$), or language abilities on the PLS4 ($p = 0.64$). On the regression discontinuity plot (Panel B on Figure 4.5), discontinuity was observed at the cut-off, with children in the TEACCH program showing fewer decreases and those in the NMS showing more decreases in SRS scores. The functional line left of the cut-off shows that, for the TEACCH intervention, children with higher language scores had more decreases in SRS scores. However, in the NMS group, the opposite change patterns were observed.

The model with CARS as the running variable and 33 as the cut-off shows that D_i significantly predicted the actual treatment receipt (T_i) at the first-stage regression ($\gamma_0 = 0.24$, $p = 0.048$); however, neither treatment receipt ($\beta_0 = 9.78$, $p = 0.48$) nor the autism severity scores on CARS ($p = 0.87$) predicted the intervention outcome. No apparent discontinuity around the cut-off is observed on the regression discontinuity plot (Panel C on Figure 4.5). The linear function fit indicates that children with lower levels of autism severity had greater decreases in social delays at post-intervention, especially in the NMS program when the CARS score was below 33.

Parent Measures. The 2SLS model with PSI as the running variable and 77th percentile as the cut-off shows that D_i significantly predicted the actual treatment receipt (T_i) at the first-stage regression ($\gamma_0 = 0.36$, $p < 0.001$). The effect of treatment receipt ($\beta_0 = 11.73$, $p = 0.07$) is marginally significant, indicating that receiving the TEACCH treatment increased the SRS scores (i.e., more social delays) for those children of parents with stress levels that were higher than the cut-off scores of the 77th percentile. Moreover, parent stress levels measured on the PSI ($p = 0.008$) significantly predicted the intervention outcomes, with the negative parameter estimate (-0.10) indicating that increases in parent stress level predicted decreases in social development on the SRS. On the regression discontinuity plot (Panel D on Figure 4.5), discontinuity at the cut-off and a descending linear fit in the NMS group can be observed. It is worth noting that this pattern did not extend above the cut-off for the TEACCH program, with a consistent outcome score even when the parent stress level increased.

LEAP vs. NMS. In this comparison, LEAP was the intervention group ($T_i = 1$) and NMS was the comparison group ($T_i = 0$). Table 4.6 presents the parameter estimates from the 2SLS regression model and Figure 4.6 presents the regression discontinuity plots. Details are described below.

Child Measures. For the model with MSEL as the running variable, no significant effects were evident in predicting social development outcomes: D_i ($\gamma_0 = 0.29$, $p = 0.09$), T_i ($\beta_0 = -9.99$ $p = 0.47$) or the cognitive levels on the MSEL ($p = 0.10$). A regression discontinuity plot with the MSEL (Panel A on Figure 4.6) similar to the TEACCH vs. NMS comparison is shown, but with less discontinuity at the cut-off. Children in the LEAP group had fewer changes in outcomes (i.e., the SRS change score averaged close to 0) than children in the NMS group. The functional lines on both sides of the cut-off are nearly parallel to the x-axis, indicating that the changes in MSEL scores had little influence on the outcomes measured by the SRS change scores.

When PLS4 was entered as the running variable, no significant effects of the predictors on the intervention outcomes, D_i ($\gamma_0 = 0.21$, $p = 0.26$), T_i ($\beta_0 = -2.84$, $p = 0.88$), or language abilities on PLS4 ($p = 0.30$) were evident. No apparent discontinuity can be observed at the cut-off in the regression discontinuity plot (Panel B on Figure 4.6). The functional line to the left of the cut-off shows that, in the LEAP intervention, children with higher language abilities had more decreases in SRS scores. In the NMS group, the opposite change patterns are shown, suggesting that preschoolers with higher language abilities above the cut-off had more social delays at post-intervention.

The model with CARS as the running variable showed similarly that none of the parameter estimates in the model were significant when examining the intervention outcomes, D_i ($\gamma_0 = 0.34$, $p = 0.052$, marginally significant) T_i ($\beta_0 = 11.50$, $p = 0.32$), or the CARS severity scores ($p = 0.67$). Discontinuity can be seen around the cut-off on the regression discontinuity plot (Panel C on Figure 4.6). The linear function fit for the LEAP group above the cut-off in the current LEAP vs. NMS comparison is similar to that for the TEACCH group above the cut-off in the TEACCH vs. NMS comparison (Panel C on Figure 4.5). However, the linear fit in the NMS group in the current comparison shows a descending trend, suggesting that, for children with autism severity below the CARS cut-off scores, when the children's autism severity level increased, they benefited more from the intervention and showed greater decreases in social difficulties. It is also worth noting that the change pattern here in the NMS group is the opposite from that in the TEACCH vs. NMS comparison. This pattern could be the result of using different weights for different observations when fitting the linear functional forms and not capturing all the observations on both plots.

Parent Measures. No statistically significant effects were observed in the model with PSI as the running variable for the LEAP vs. NMS comparison, D_i ($\gamma_0 = 0.16$, $p = 0.10$), T_i ($\beta_0 = 18.34$, $p = 0.26$), or parent stress levels on the PSI ($p = 0.21$). Like the TEACCH vs. NMS comparison (Panel D on Figure 4.5), similar change patterns are shown on the regression discontinuity plot (Panel D on Figure 4.6), i.e., discontinuity at the cut-off and a descending linear fit for the NMS group. Moreover, a descending linear fit also is seen for the LEAP group above the PSI cut-off. This plot shows that the higher the parent stress levels, the more decrease in SRS scores after intervention.

TEACCH vs. LEAP. In this comparison, TEACCH was coded as the intervention group ($T_i = 1$) and LEAP as the comparison group ($T_i = 0$). The 2SLS regression models were applied using the four running variables, respectively. Table 4.7 presents the parameter estimates and Figure 4.7 presents the regression discontinuity plots.

Child Measures. In the model with MSEL as the running variable, no statistically significant effects, D_i ($\gamma_0 = 0.18$, $p = 0.42$), T_i ($\beta_0 = -42.44$, $p = 0.51$), or cognitive levels on the MSEL ($p = 0.10$) were found. However, discontinuity is observed at the cut-off on the regression discontinuity plot (Panel A in Figure 4.7), with children in the TEACCH group showing fewer changes in the outcome and those in the LEAP group showing more decreases in SRS scores. An ascending linear fit is observed on both sides of the cut-off, indicating that children with higher cognitive levels benefit less from either intervention group, with the SRS change scores approximating zero as the MSEL scores increase.

When PLS4 was entered as the running variable, the model showed that none of the factors in the model were significant predictors for the intervention outcome, D_i ($\gamma_0 = -0.19$, $p = 0.30$), T_i ($\beta_0 = -26.73$, $p = 0.45$), or language abilities on the PLS4 ($p = 0.27$). On the regression discontinuity plot (Panel B in Figure 4.7), discontinuity is observed at the cut-off. The functional line to the left of the cut-off shows that, in the TEACCH intervention, children with higher language scores had more decreases in SRS scores. However, for children in the LEAP group who scored above the cut-off, the opposite change patterns are observed.

The model with CARS as the running variable shows that none of the factors (D_i : $\gamma_0 = -0.01$, $p = 0.93$; T_i: $\beta_0 = 26.30$, $p = 0.99$; CARS severity score: $p = 0.99$) significantly predicted the intervention outcome on the SRS. Moreover, no discontinuity is seen around the cut-off on the regression discontinuity plot (Panel C on Figure 4.7). However, the linear function fit indicates that children with lower levels of autism severity had more decreases in social delays at post-intervention in the TEACCH program with CARS scores above 33.

Parent Measures. The 2SLS model with *the* PSI as the running variable shows that D_i significantly predicted the actual treatment receipt (T_i) at the first-stage regression ($\gamma_0 = 0.21$, $p = 0.01$). The effect of treatment receipt ($\beta_0 = 9.03$, $p = 0.37$) is not statistically significant. Parent stress levels measured on the PSI ($p = 0.02$) predicted the intervention outcome, with the negative parameter estimate (-0.09) indicating that increases in parent stress level predicted more SRS decreases. Similar patterns can be observed on the regression discontinuity plot (Panel D on

Figure 4.7), with little discontinuity at the cut-off and a descending linear fit for both the LEAP and TEACCH groups, indicating that higher parent stress levels are associated with more decreases in social outcomes on the SRS.

The current analyses only fit the data with linear functional forms for the purpose of results interpretability. However, the mis-specification of functional forms is one of the greatest threats to RDD validity (Bloom, 2012) and the linear function fit lines do not capture all the data points on the regression discontinuity plots (Figures 4.5, 4.6, and 4.7). Thus, the linear functional form might not be the best fit for the datasets in the current study. Higher orders of the polynomial form (i.e., quadratic and cubic) were applied to rule out the possibility of finding bias due to mis-specification. Neither the quadratic nor cubic functional forms revealed any significant findings across running variables or comparison pairs.

In summary, no statistically significant intervention effects on SRS outcomes were found in the three FRDD comparisons using the 2SLS model across all four running variables (i.e., MSEL, PLS4, CARS, and PSI). However, the levels of parent stress significantly affected intervention outcomes in the group comparisons of TEACCH vs. NMS and TEACCH vs. LEAP, indicating that children of parents with higher stress levels had greater decreases in social difficulties/impairments as measured by SRS change scores (i.e., improvement in social functioning and development). Further examination of the regression discontinuity plots (Figures 4.5 to 4.7) reveal the following:

(1) Cognitive abilities did not significantly affect social developmental outcomes for children with ASD within each intervention group. However, on average, children with MSEL scores above 60 at pretreatment showed more decreases in social difficulties as measured by the SRS change scores than those who scored below 60.

(2) For children with PLS4 scores below the cut-off, they had greater decreases in the SRS severity scores as their language level increased, with children in the LEAP group showing the greatest changes in outcome. For those children with PLS4 scores above the cut-off, smaller decreases in social difficulties were observed for those with higher pretreatment PLS4 scores.

(3) As for the CARS scores, no clear discontinuity was observed for the TEACCH vs. NMS and TEACCH vs. LEAP comparisons, indicating that no intervention effect occurred around the cut-off. Overall, children with higher autism severity levels on the CARS tended to show less progress in social development. However, surprisingly, discontinuity on the plot for LEAP vs. NMS suggests a positive effect of the NMS intervention, and the descending linear fit indicates that children who scored below the cut-off severity score benefited more from the NMS program when they presented a higher autism severity level.

(4) The regression discontinuity plots of the PSI scores confirmed the regression analysis results, i.e., that higher parent stress levels are associated with more decreases in SRS scores. Increases in the SRS change scores at the cut-off were observed for both TEACCH and LEAP groups when compared to the NMS group.

Table 4.5

Parameter Estimates of 2SLS Model for Intervention Comparisons of TEACCH vs. NMS Groups

RVs	MSEL			PLS4			CARS			PSI		
Parameters	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$
1st Stage	0.42			-0.08			0.24			0.36		
2nd Stage		6.26	-0.11		-5.23	-0.21		9.78	0.05		11.73	-0.10
p	0.002	0.52	0.33	0.62	0.93	0.64	0.048	0.48	0.87	<0.0001	0.07	0.008

Note: RV = running variable and is the binary indicator of assignment based on cut-off scores. All the parameter estimates are pooled estimates from five imputations.

Table 4.6

Parameter Estimates of 2SLS Model for Intervention Comparisons of LEAP vs. NMS Groups

RVs	MSEL			PLS4			CARS			PSI		
Parameters	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$
1st Stage	0.29			0.21			0.34			0.16		
2nd Stage		-9.99	-0.11		-2.84	-0.06		11.50	0.09		18.34	-0.07
p	0.09	0.47	0.10	0.26	0.88	0.30	0.052	0.32	0.67	0.10	0.26	0.21

Table 4.7

Parameter Estimates of 2SLS Model for Intervention Comparisons of TEACCH vs. LEAP Groups

RVs	MSEL			PLS4			CARS			PSI		
Parameters	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$	D_i	T_i	$f_2(r_i)$
1st Stage	0.18			-0.19			-0.01			0.21		
2nd Stage		-42.44	-0.31		-26.73	-0.21		26.30	-0.31		9.03	-0.09
P	0.42	0.51	0.42	0.30	0.45	0.27	0.93	0.99	0.99	0.01	0.37	0.02

Figure 4.5

RDD Plot with Four Running Variables in TEACCH (1) vs. NMS (0) comparisons

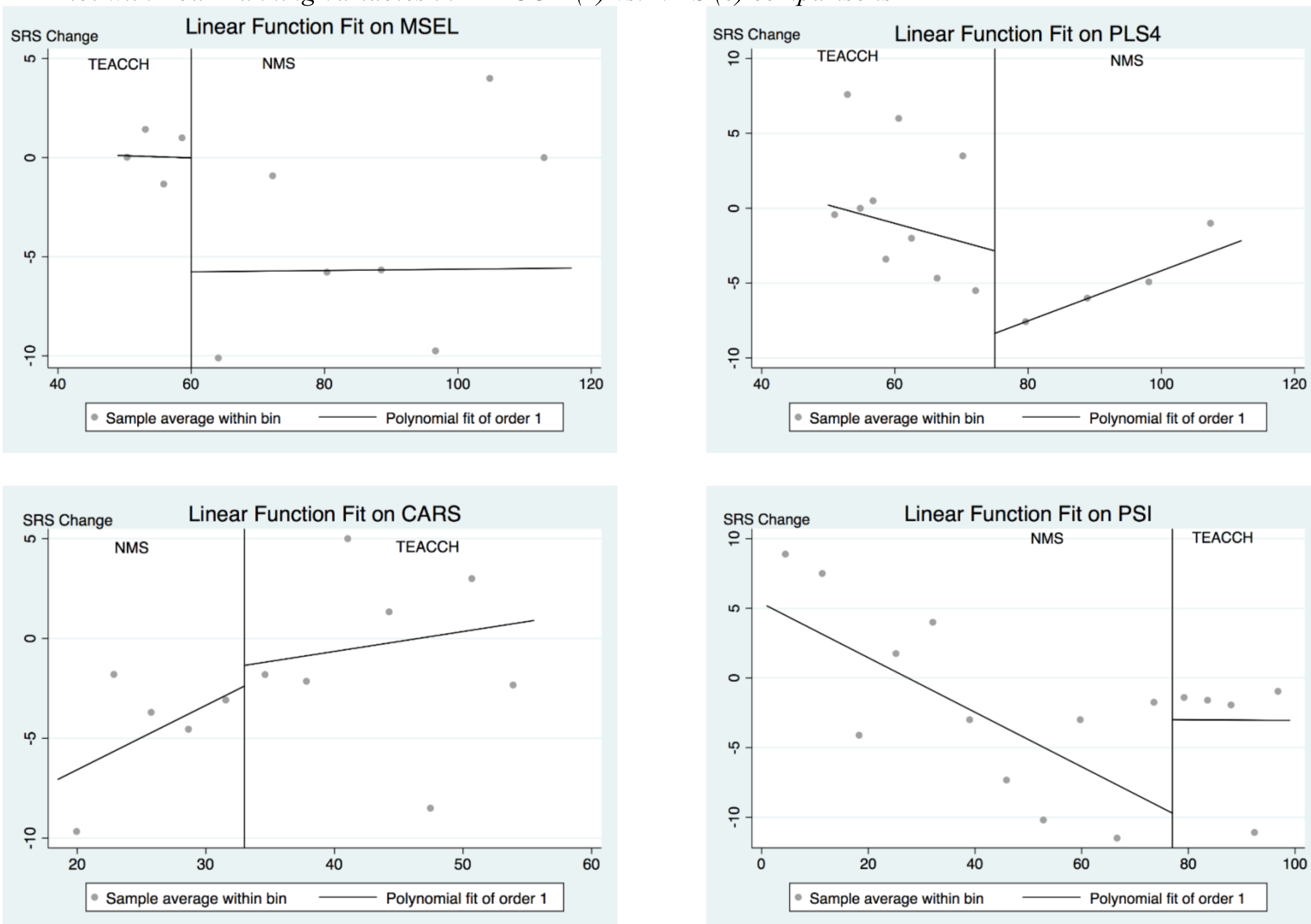


Figure 4.6

RDD Plot with the Four Running Variables in LEAP (1) vs. NMS (0) comparisons

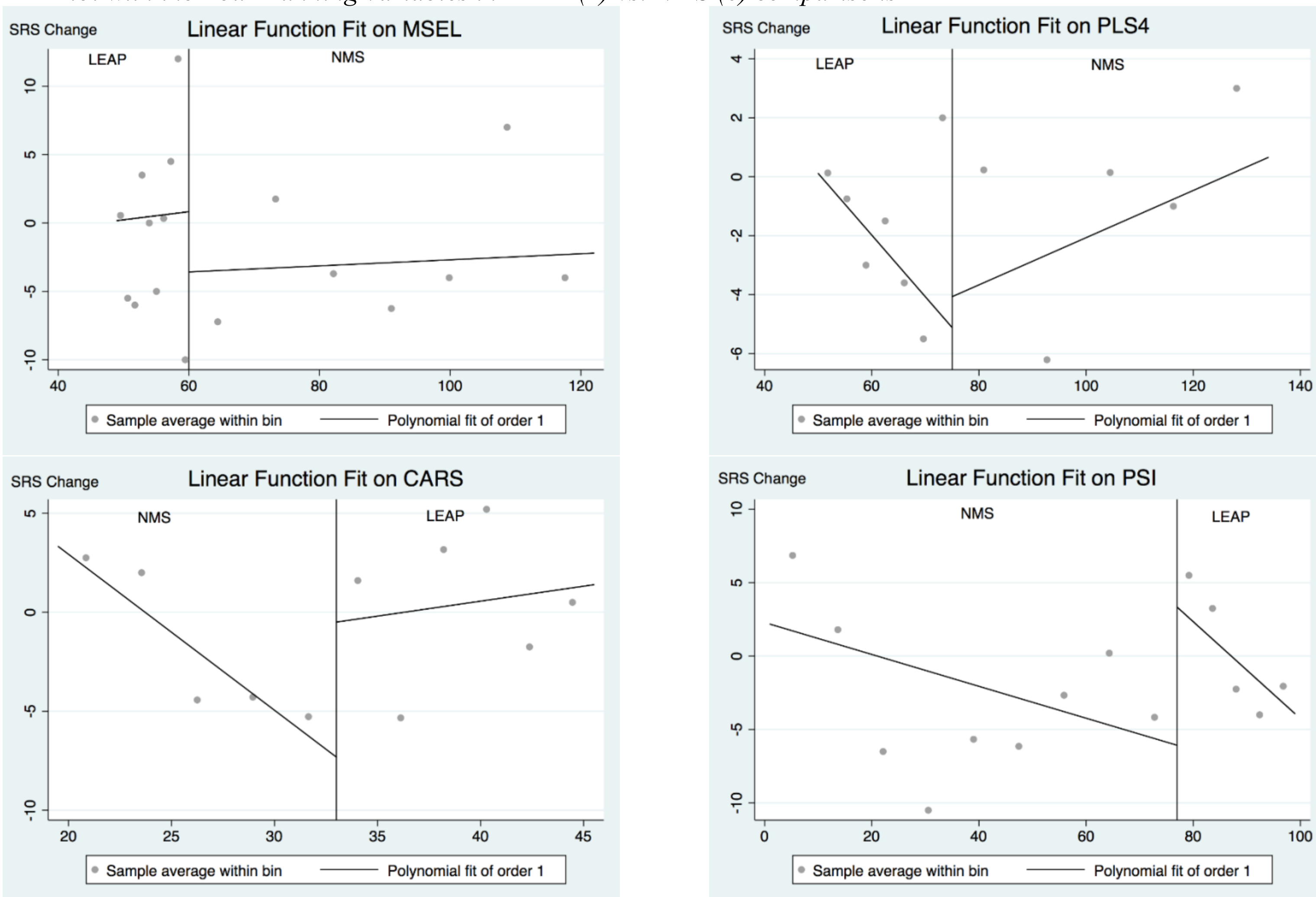
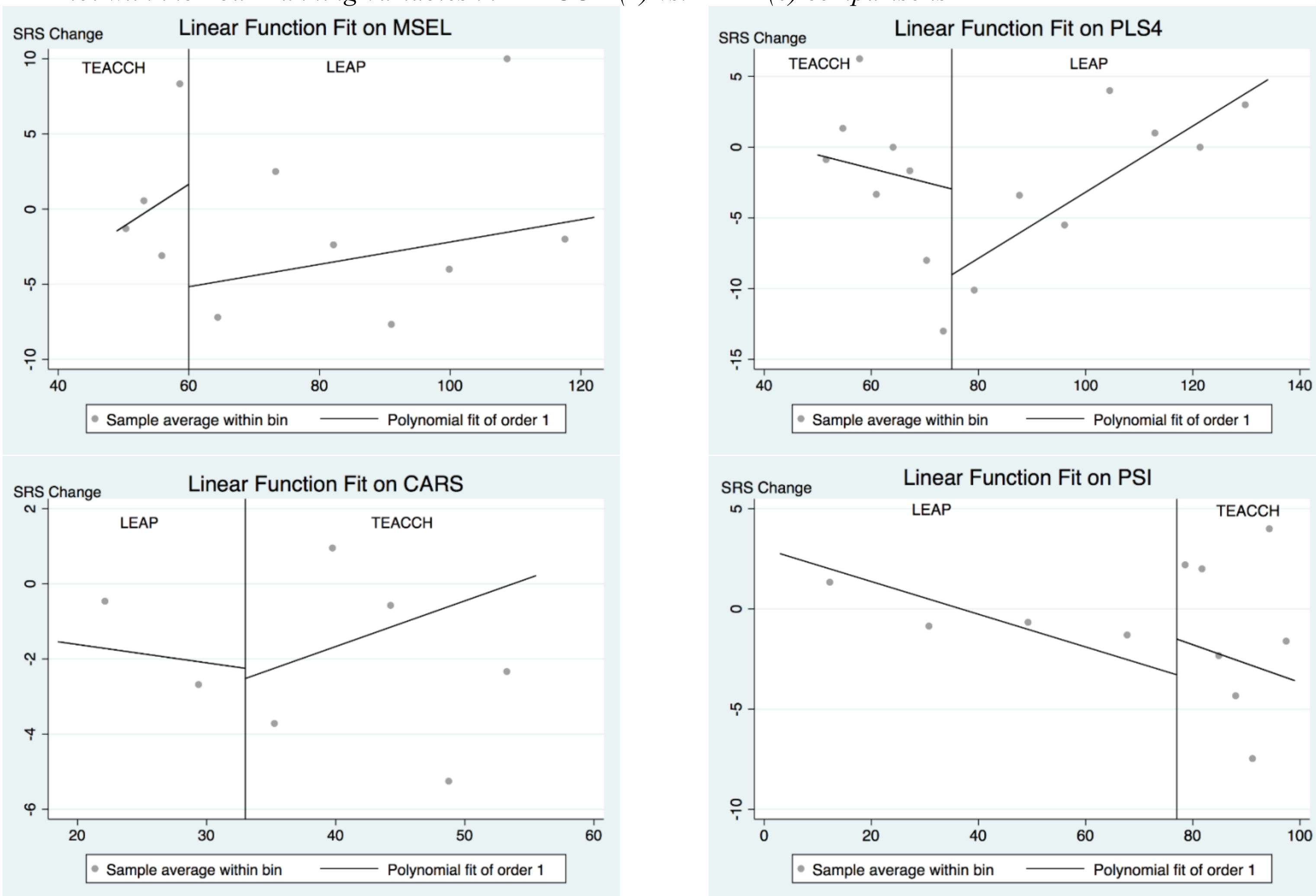


Figure 4.7

RDD Plot with the Four Running Variables in TEACCH (1) vs. LEAP (0) comparisons



Chapter 5 Discussion

This study addressed treatment individualization for young children with ASD by examining the heterogeneity of ASD symptoms and exploring whether different preschool intervention programs work differently for children with distinct child and caregiver characteristics. This chapter briefly summarizes the findings for each research question and interprets and discusses the results in the context of previous research findings and literature. Limitations of the study are examined, along with implications for future research and clinical practices.

Identified Subgroups of Preschoolers with ASD

Findings from the cluster analysis that addressed Research Question 1 reveal three distinct developmental subgroups of preschoolers with ASD within the current sample. These findings are consistent with previous studies with regard to identifying three subgroups on the spectrum (Beglinger & Smith, 2001; Cholemkery, Medda, Lempp, & Frietag, 2016; Georgiades et al., 2014). Specifically, the results confirm a high functioning group (Cluster 2) and low functioning groups (Cluster 1 and Cluster 3) that are distinguished by cognitive and language abilities. This finding indicates that cognitive and language abilities are important developmental characteristics to consider when examining subgroups on the autism spectrum. Also, this finding supports the inclusion of Criterion E on the DSM-5 (2013), which specifies “with or without accompanying intellectual impairment” and “language impairments”.

The children in this study were evenly distributed across the clusters (38.58% preschoolers in Cluster 1, 35.03% in Cluster 2, and 26.40% in Cluster 3), with the smallest proportion of preschoolers in the lowest functioning group (i.e., Cluster 3). Here, the characteristics of clusters are discussed in the following order of overall functioning level from low to high: Cluster 3, Cluster 1, and Cluster 2.

Preschoolers in Cluster 3 had the highest autism severity levels and the most delays across all developmental domains for the current sample. The findings captured more delays for this specific group: beyond these children's delayed cognitive and language abilities, children in Cluster 3 also had pervasive challenges in terms of social, communication, and adaptive behavior skills, sensory issues, and repetitive behaviors. Because most previous cluster and factor analyses have focused on items from only one or two ASD diagnostic measures (ADI-R and ADOS; Cholemkery, Medda, Lempp, & Frietag, 2016, Georgiades et al., 2014; Klopper, Testa, Pantelis, & Skafidas, 2017), their depictions of the lowest functioning group may present only a partial picture of core ASD symptoms and may not be sufficient to capture other specific delays, such as atypical sensory processing patterns or adaptive behaviors. Therefore, the current study expands previous research findings by including more developmental and behavioral measures and thus captures a more comprehensive profile of children on the spectrum. The pervasive delays of children in Cluster 3 highlight the importance of comprehensive developmental assessments in order to capture children's needs across all aspects of development.

Cluster 1 was the second cluster of children with low cognitive and language abilities, but this group exhibited very different characteristics with regard to other developmental aspects compared to children in Cluster 3. This finding indicates that two distinct groups of children are on the autism spectrum who have low levels of cognitive and language abilities, which is consistent with previous findings. Klopper and colleagues also found two clusters of children aged 5 through 14 years who were diagnosed with ASD and had intellectual disabilities based on ADOS and ADI-R scores (Klopper et al., 2017). Children in Cluster 1 exhibited the medium level of autism severity on CARS and adaptive skills on VABS, but displayed the fewest social delays and repetitive behaviors. When examining the developmental profiles closely, although they scored low for cognitive and language abilities, children in Cluster 1 had good joint attention skills on the PICS and low severity scores in social communication measured on the SCQ. With a high correlation between the severity scores on the SCQ and SRS ($r = 0.70$), the presence of prelinguistic and social communicative skills may be a better indicator of social development than verbal language development for these preschoolers. For example, during a learning session in a preschool classroom, a child with good joint attention and emerging social communication skills would be able to follow the attention cues of the teacher to learn and respond by pointing and gesturing. Therefore, even though a child's cognitive and language abilities might be delayed, the child can still participate in learning activities. These types of interactions allow children to engage with peers and adults socially and to be less likely to engage in repetitive and restricted behaviors.

Children in Cluster 2 had the highest levels of cognitive and language abilities, the lowest levels of autism severity, and the highest levels of adaptive skills, but they exhibited a substantial number of core autism symptoms on the SRS and RBSR. It is worth noting that, with prelinguistic and social communicative skills that were comparable to those of children in Cluster 1, children in Cluster 2 still had significantly more reported impairments in both core autism symptoms than children in Cluster 1. Thus, disparity between Cluster 1 and Cluster 2 is evident and requires more in-depth exploration. One potential explanation for this disparity is that the nature of different types of measures may have captured different aspects of symptom presentation. In this study's analysis, the cognitive measure (MSEL) and the language measure (PLS4) are both standardized measures that are administered by trained professionals, whereas the social development measure on the SRS and repetitive behaviors and restricted interests (RRBIs) measured on the RBRS are parent-report measures. Because preschoolers in Cluster 2 had significantly higher cognitive and intellectual abilities than children in the other clusters, their social delays and atypical repetitive behaviors and interests may seem more salient to caregivers. Furthermore, their parents may tend to refer to children with similarly high levels of cognitive and language functioning (likely typically developing children) and compare their child's impacted social development and frequent RRBIs to their typically developing peers. Therefore, parents may have reported lower social abilities and skills and perceived their children's RRBIs as more problematic than may have been the actual case. However, for children in Cluster 1, given that they exhibited low cognitive and language abilities and had lower levels of adaptive skills compared to children in Cluster 2, their parents might have perceived lower levels of social difficulties and fewer repetitive behaviors in them when compared to their peers with pervasive delays across developmental aspects (e.g., those in Cluster 3).

These findings of the cluster analyses add to the current literature in understanding early developmental profiles and provide insights into the presentations of autism-related symptoms in subgroups of preschoolers with ASD. In summary, this study's results provide evidence that three factors, i.e., cognitive and language abilities along with two highly correlated core autism factors (social communication delays and RRBIs), account for heterogeneity on the autism spectrum. The findings also indicate that CARS is an accurate measure to capture the three subgroups with significantly different severity scores (Cluster 3 > Cluster 1 > Cluster 2) by including items for all three factors. (Refer to Table 4.1 for an overview of levels of developmental aspects by cluster.)

When examining demographic information across the clusters, this study found significant differences in the race/ethnicity characteristics of the clusters. The lowest functioning children in Cluster 3 were mostly from racial minority groups (69.23%) and the highest functioning children in Cluster 2 were mostly non-Hispanic White (62.32%). These findings support the previously reported disparities among race/ethnicity groups. Studies have consistently reported that African American and Hispanic children with ASD are often underdiagnosed and are more likely to be diagnosed with intellectual disabilities compared to Caucasian children (Center for Disease Control and Prevention, 2014; Mandell, Listerud, Levy, & Pinto-Martin, 2002; Tek & Landa, 2012; Travers & Krezmien, 2018). The disparities in symptom presentations and diagnoses between non-Hispanic White and minority groups could be a result of the long-existing racial gaps of SES and access to healthcare in the U.S. (Federal Interagency Forum on Child and Family Statistics, 2017; Nehring, 2007; Hanson & Lynch, 2010): it is possible that with limited accessible resources, only when children show severe delays and impairments can they receive the serves they need. Moreover, this study found significant differences in parent education levels across clusters, with parents of children in Cluster 3 having the lowest education levels among all three clusters. This finding indicates a possible association between child symptom presentations and the education levels of primary caregivers. Parent education level is also a complex construct that reflects and correlates with many different factors, such as SES and parents' awareness and knowledge of ASD (Pickard & Ingersoll, 2016). Therefore, taken together with the racial gap, these findings present a picture of health disparity across racial and SES groups and call for system level changes to address this gap.

Additionally, the children in the different clusters disproportionately attended different preschool programs, as children in Cluster 2 were primarily in NMS classrooms, and children in both Cluster 1 and Cluster 3 were mostly in TEACCH classrooms. Child characteristics might affect the parents' or school district's choice of intervention program for the child (Bowker, D'Angelo, Hicks, & Wells, 2011). For example, children with lower cognitive and language abilities (e.g., those in Clusters 1 and 3) are more likely to need more classroom support, and parents may choose the TEACCH program with more structures to support children who have difficulties communicating and understanding instructions. However, further studies are needed to provide evidence for whether subgroups of children might benefit differently from different intervention programs as well as for the factors that influence parents' and school districts' decision-making in choosing interventions for their children. Further, services and resources available to children with ASD and their families vary school to school, district to district and state to state (Stahmer & Mandell, 2007). For example, children from different states in the current study did not have equal access to interventions (see Table 3.2; e.g., there is no LEAP program in North Carolina). Hence, researchers should also take state and district level policies and factors (e.g., resources and fundings) when investigating intervention decision making processes and making recommendations to practitioners and parents.

Differential Intervention Responses in Social Development

This study did not identify any statistically significant main effects of intervention types, which is consistent with the primary outcomes from the original study (Boyd et al., 2014). In the exploration of influential factors with regard to intervention responses, findings from the FRDD analyses revealed that no child factor had a statistically significant effect on the social developmental outcomes but indicated that parental stress level was the only factor that had significant influence.

Parent stress level on intervention outcomes. Levels of parent stress had a significant effect on the intervention outcome, regardless of intervention group, which indicated that children of parents with higher stress levels have greater decreases in social difficulties/impairments as measured by the SRS change scores. These scores indicate a significant improvement in children's social skills. For example, parents who were more stressed, as measured by the PSI, had children whose social skills improved as a result of the interventions. The regression discontinuity plots also confirm the findings from the regression analysis, i.e., that higher parental stress levels are associated with more decreases in SRS severity scores (i.e., improvement in social skills) across groups. These results establish the critical effect of parent stress levels on child development and intervention effects, but are inconsistent with previous studies because this study identified a positive relationship between parent stress and social development outcomes.

Previous studies that examined the effects of parent stress levels found that high stress levels had a negative impact on intervention effects and child outcomes (Osborn, McHugh, Saunders, & Reed, 2008; Osborn & Reed, 2009; Strauss et al., 2011). These previous studies were conducted primarily within the context of community-based early intervention programs or home-based parent-mediated interventions. These intervention programs differ from current classroom-based intervention programs both in the contexts of intervention delivery and parental role. Thus, parent stress levels might affect child outcomes differently for different intervention delivery models when the levels of parent involvement in the intervention differ. For example, as parent-mediated early interventions demand a considerable amount of parental input and involvement, a parent with high parental stress levels might experience mental health issues and emotional stress (Carter et al., 2009; Karst & Van Hecke, 2012). Therefore, high parental stress could interfere with the quality of parent-child interactions and the fidelity of parent-mediated intervention delivery, which could result in reduced intervention effects. For classroom-based intervention programs, the intervention is delivered primarily in the classroom by teachers and related service providers. Although parent engagement is essential and is always emphasized in early childhood special education programs, parent stress and mental health issues might not have an equivalently negative impact on the benefits of these interventions. The inconsistency of the findings might be explained by the possibility that some parents with high stress levels may tend to overcompensate and become very attentive to their children's behaviors and development, and involved with intervention planning and communications with classroom teachers and service providers, which may ultimately transfer to better child outcomes. Considering the previous findings of parent stress levels, it is possible that the effect of parent stress levels on child outcomes takes the form of a reversed U-shaped curve, with an optimal level of parent stress that have the most positive effect on the intervention outcomes for children with ASD. That is, when parents experience little or low levels of stress, they might not pay much attention to child development or devote enough time and effort to make a difference to intervention outcomes (like those below the cut-off in the current study); if the levels of parent stress exceed the optimal level, then it may disrupt parents' daily functioning and participation in intervention planning and delivery (like those in the previous studies). It is also necessary to consider potential mediators between parent stress levels and child intervention outcomes, such as coping strategies, and other related factors like parent education levels and knowledge of ASD and related services (Karst & Van Hecke, 2012; Zaidman-Zait et al., 2018). However, this proposed theory needs to be examined by empirical studies to help identify the actual transactional effects of parent stress and mental health issues on intervention and child development in the contexts of the different intervention models, child developmental stages, and individual family functioning.

Moreover, in the current study, the intervention outcome was the change scores in social impairment severity measured by the SRS, whereas previous studies focused mainly on autism severity and child behaviors. However, the goal of the current analysis was not to explore ways that parental stress might affect intervention effects and child outcomes measured by different tools. Further research is needed to examine the transactional effects of parental stress on child development and intervention outcomes.

Effects of child developmental factors on intervention outcomes. Among the three child factors measured on the MSEL, PLS4, and CARS and examined via FRDD analysis, none of the factors had a statistically significant effect on the social developmental outcomes measured by the SRS scores. These nonsignificant findings were unexpected because previous studies had provided evidence that cognitive and social communication abilities and autism severity affected intervention outcomes (see Table 2.1 and Appendix). Potential reasons for these unexpected results are that (1) the intervention models (e.g., behavioral interventions) examined in the current analysis are different from the ones used in previous studies and (2) decreases in social developmental impairments are included in this study as a single intervention outcome, which is also different from previous studies.

Nonetheless, the regression discontinuity plots show patterns of change between child factors and social developmental outcomes that are worth noting and have clinical meaningfulness and implications for future research directions. First, children with MSEL scores above 60 at pretreatment showed a little more decreases in social difficulties measured by the SRS change scores after interventions than children who scored below 60. This finding indicates the possibility that, when their cognitive abilities meet a certain threshold (above 60 on the MSEL in this analysis), children with ASD could have better social outcomes on average than those who have lower levels of cognitive abilities. Admittedly, this finding supports the idea that subgroups of children on the autism spectrum show developmental and intervention outcomes differently. Thus, further examination is needed to confirm and dissect the effects of cognitive abilities on child development and varied intervention outcomes.

As for the effect of language abilities, children with language abilities below the cut-off score had some more decreases in SRS severity scores as their language levels on the PLS4 increased, specifically so for children in the LEAP group. These findings imply that increased language abilities have a positive effect on social developmental outcomes, but this result was observed only for children with low language levels. This could be that children with lower language abilities had more room to make progress in language development (Kasari et al. 2008; Siller, Hutman, & Sigman, 2013). Based on the qualitative results from the RD plot, the children with a medium level of language abilities around the cut-off seem to have benefited the most from the interventions, especially if they were in the LEAP group (see Figures 4.6 and 4.7). The LEAP classrooms are likely to provide opportunities for preschoolers with ASD to interact with typically developing peers in an inclusive classroom. Also, children with some language skills may be able to interact better with peers and, in turn, gain more social benefits. However, though not statistically significant, for children above the cut-off, smaller decreases in social impairments were observed as language abilities increased. Reflecting on the characteristics of the three clusters in the current sample, children with the highest levels of language and cognitive abilities (Cluster 2) had more social delays and impairments than children with low language abilities in the medium range of language abilities (Cluster 1). It is possible that children in Cluster 2 with PLS4 scores above the cut-off began with fewer social skills and made less progress. On the contrary, children in Cluster 1 with PLS4 scores around or right below the cut-off, might have more initial social skills that allowed them to engage in more social interactions, thereby resulting in more gains in social development. However, this is only one potential explanation based on the results of the current sample and should not be regarded as conclusive.

Moreover, though not significant in the regression model, the CARS regression discontinuity plots indicate that children with higher autism severity on CARS tend to make less progress in social development outcomes, which is consistent with previous findings. Nonetheless, the descending linear fit on the plot for the LEAP vs. NMS comparison (Figure 4.6) is puzzling in that it shows that, for children who have severity scores below the cut-off, they benefited more from being in the NMS group when they had higher levels of autism severity. One potential explanation for this finding is that children with low autism severity scores below the cut-off might not display easily observable autism symptoms and thus do not receive as much support as they actually need, whereas those children with higher severity scores are more likely to receive instructional help and support in the NMS classrooms where no specific ASD intervention program is in place.

In summary, this study revealed three distinct subgroups of preschoolers with ASD in the current sample and found that children with different characteristics do show varied intervention outcomes. Overall, children with high cognitive abilities, medium language abilities, and low autism severity and children of parents with high parental stress levels seem to benefit more from interventions, as evidenced by a decrease in their social delays at post-intervention. However, these findings and interpretations should be viewed with caution, as they are exploratory and preliminary rather than conclusive.

Limitations

Discussion of the limitations of the current study includes sample size, child developmental measures, intervention models studied, and overall study design and analysis methods. The current study included a relatively large sample (N = 198) compared to other ASD studies of preschoolers. However, an even larger sample could increase the robustness of both the cluster analysis and the FRDD analysis in this study. First, to study autism heterogeneity, a larger sample would potentially capture more cases with different characteristics and increase the possibility of sufficient sampling to cover all possible subgroups (Lombardo, Lai, & Baron-Cohen, 2018). Second, as a type of unsupervised statistical learning, cluster analysis also would benefit from more cases to allow cross-validation with subsamples of training data and test data. Similarly, the robustness and accuracy of the regression modeling for the FRDD would be enhanced with more cases that could contribute to specifying the functional relationships of influential factors and intervention outcomes.

Another limitation is that, although this study included more child developmental factors in the analyses than most previous studies, the analyses used only a limited number of factors that had been collected for the original studies. For Research Question 1, the heterogeneity contributed by other factors, such as age/development, gender, and the presence of comorbid disorders, was not considered (Masi, DeMayo, Glozier, & Guastella, 2017). The cluster analysis was performed only at enrollment with the current preschool sample, so interpretation of the findings is limited to this specific age group. Although focusing on one specific age group helped control for developmental factors that contribute to heterogeneity, it limits generalization to other age groups, especially considering that previous studies found similar subgroups across the age span (Cholemkery et al., 2016; Campbell et al., 2014) and identified longitudinal changes and distinct developmental trajectories (Fountain et al., 2012; Georgiades et al., 2014). Importantly, gender is another known factor that affects autism symptom manifestation; specifically, males and females with ASD present very different social communication development and other symptoms (Jamison, Bishop, Huerta, & Halladay, 2017). In addition, comorbid conditions, such as Attention Deficit Hyperactivity Disorder (ADHD), anxiety, and depression, are somewhat prevalent in ASD populations and affect autism symptom presentation (Matson, 2015). Therefore, examining heterogeneity over time and taking gender and comorbid conditions into account would have revealed more information about subgroup characteristics on the autism spectrum.

For Research Question 2, only four factors were examined (i.e., scores on MSEL, PLS4, CARS, and PSI) as the running variables. Their relationships with the outcomes were tested across intervention groups. Other potential influential factors were not included in the analysis. As mentioned in Chapter 3, some candidate factors were not good indicators of group assignments based on cut-off scores and therefore were not eligible for inclusion in the FRDD analysis. Also, the analysis was limited to the three intervention models used in the current study, i.e., TEACCH, LEAP, and NMS high-quality preschool classrooms. Moreover, the current analysis did not differentiate among the active ingredients of each program and did not consider the characteristics of intervention programs or teachers, which are both important fidelity indicators that affect intervention effectiveness. For example, a TEACCH program integrates not only core structured teaching principles (such as visual support and work systems), but also other evidence-based practices (e.g., incidental teaching). Each TEACCH program is as different as teacher characteristics and intervention fidelity differences, which makes it hard to replicate any positive findings of interventions for children with ASD. The current study did not identify the active intervention components for intervention programs or test the optimal combination of intervention strategies and program characteristics that could benefit different subgroups of children. In sum, the number of factors (both child and intervention program) examined and intervention models included in the analysis limited the generalizability of the current findings.

Furthermore, considering the nature of secondary data analysis, weaknesses are inherent in the study's design and analytic methods. First, the participants were not prospectively assigned to treatment groups according to a designated running variable or a cut-off score, as is the case for most RDD studies, but instead were retrospectively enforced. This situation resulted in inevitably high misassignment rates and was a significant threat to the power and validity of the FRDD analysis (Price, 2009)**.** Second, the cut-off scores for the running variables in the analysis were derived based on current data with the intention to ensure the validity of the FRDD analysis. Therefore, the cut-off scores included might not be clinically meaningful to practitioners and parents.

With regard to the interpretation of the FRDD findings obtained from this study, only one significant statistical finding was derived for the PSI, and other findings were extrapolated and interpreted based on graph analyses. Therefore, the findings from the visual examination of the graphs should be viewed with caution and need further examination to identify their particular effects on social development outcomes.

This study's focus on social development outcomes was based solely on parent-reports on the SRS. Because parents did not observe their children's social interactions in the classroom, their perceptions of their children's social development may be limited and may not comprehensively reflect the intervention benefits gained from the three classroom-based intervention models.

Despite the limitations of this study, the findings reveal significant implications, especially regarding the heterogeneity of ASD and the need for individualized treatment. Implications for future research and practice are discussed in the following sections.

Implications for Future Research

Based on this study's findings and limitations, it offers implications for future research to examine the heterogeneity of ASD in more depth and to explore treatment individualization for young children on the autism spectrum. First, future studies need to examine subgroups of children with ASD using larger datasets over time. Here, a larger dataset should include more cases as well as more developmental variables measured. As mentioned earlier, datasets with larger sample sizes could provide a more holistic picture of the heterogeneity of children with ASD with sufficient sampling and reveal more information about all potential subgroups than from smaller datasets. Moreover, the inclusion of more developmental variables from a set of commonly used measurements (McConachie et al., 2015) could take more factors into account when examining children's profiles. For example, researchers could pool data from different autism research registries and research centers (e.g., Autism Speaks and Autism Science Foundation) to compile a large dataset with samples across centers. This availability of big data would then allow the use of advanced analytic methods, such as machine learning, to produce accurate categorizations of subgroups on the autism spectrum and lead the field to arrive at a better understanding of autism heterogeneity.

In addition, the longitudinal explorations that examine classification stability of cluster groupings over time also constitute a necessary step in understanding the effects of child development and intervention (Fountain et al., 2014; Georgiades et al., 2014). This study's analysis did not examine subgroup stability across time points, as the current dataset only had limited time points and duration of data collection. Ideally, longitudinal studies that follow individuals with ASD from early childhood to adulthood and document their development and services received at different time points should be conducted. This type of research could provide insights into some pressing research questions, such as (1) depictions of developmental trajectories of individuals on the autism spectrum, (2) identification of subgroups based on developmental trajectories and profiles, (3) examinations of the effects of different intervention types on different subgroups, and (4) explorations of the interaction effects of child characteristics, natural development, and interventions received. However, longitudinal studies are often expensive and time-consuming. Therefore, researchers could take advantage of currently available longitudinal national education datasets (e.g., the Special Education Elementary Longitudinal Study and National Longitudinal Transition Study) to conduct secondary analyses.

Second, relationships among child and parent characteristics need further examination. Based on this study's results, child characteristics seem to interrelate and play different roles in determining developmental profiles that distinguish subgroups within the ASD population and responses to interventions. Future studies could investigate ways that some child factors might predict or be associated with other factors by looking within and between subgroups over time.

For example, researchers could compare the developmental trajectories of children who share similar developmental profiles but differ in terms of social communication skills to examine the effects of social communication skills on other developmental aspects. Moreover, as proposed in the conceptual framework (Figure 2.1) and confirmed by the analysis results, parent characteristics (e.g., parental stress levels) also affected child developmental factors. Research is needed to dissect the transactional effects of child development and parent characteristics on each other, within or without the context of intervention. For example, Longitudinal Structural Equation Modeling could be a potential approach to explore the relationships among factors by identifying and collapsing latent variables and determining the size of the effect that each factor has on the other across time. The attempt to identify main factors that describe and distinguish clinically meaningful subgroups could inform the development of evaluation and progress monitoring tools and then guide the selection of intervention strategies to target specific developmental areas of needs.

Third, building on the understanding of the interactions among child and parent factors, the next step should be to identify the active ingredients of current intervention programs and tailor them to target specific subgroups with specific child and family characteristics. Although the current study yielded some preliminary findings to inform the treatment individualization process, more research is needed to understand the mechanisms of how and why certain interventions work better for different subgroups of children. For example, researchers could begin by categorizing evidence-based practices and intervention programs based on philosophies and characteristics of intervention strategies and programs. Then, researchers would be able to purposefully sample a homogenous group of children with ASD and assign them to different categories of interventions to examine the intervention effects.

Finally, researchers should situate treatment individualization studies in community-based settings for increased ecological validity and more clinical implications. For example, children need to meet predetermined severity cut-off criteria for ASD in order to access publicly funded intervention services in the community. This status quo provides a natural opportunity to apply RDD with clinically meaningful running variables and cut-off scores and group assignments. Therefore, researchers are encouraged to conduct community engagement projects in collaboration with local service and education agencies for children with ASD to develop RDD to track the development and intervention outcomes for children who did or did not receive intervention and then to evaluate the effectiveness of those ASD intervention programs in the community.

Implications for Practice

This study's findings provide guidance for service delivery and intervention practices to serve children with ASD and their families. First, comprehensive evaluations for children should be completed at intake to collect information for comprehensive developmental profiles, and their family's needs and priorities should be determined. As shown in the descriptions of each cluster, children have varied symptom presentations across all developmental aspects. In clinical settings, this study recommends that practitioners administer different developmental and behavioral measures and collect parent-report information to capture child development needs across settings. In addition, service providers who work closely with families must be aware of and responsive to family backgrounds and well-being and be willing to meet families where they are. Then, the profiles of the children and their families' needs and priorities should be able to help guide intervention planning and individualization.

Cluster analysis of child profiles proves that distinct subgroups of preschoolers with ASD exist. Thus, it is important for all ECSE service providers and practitioners to receive professional development regarding evidence-based interventions for children with ASD and to learn ways to tailor interventions to meet the needs of subgroups of children and families accordingly. Reflecting on this study's findings concerning intervention responses, some brief recommendations are provided below to guide the beginning steps for intervention individualization for subgroups of children with different characteristics.

For children with high social skills but low cognitive and language abilities (i.e., Cluster 1), practitioners could adopt strength-based models that capitalize on the children's prelinguistic and social skills to promote the learning of cognitive and language skills. Teachers and service providers could tailor interventions to target early language and cognitive skills through interaction in dyads or small groups, such as dialogic book reading for early learning skills. This subgroup of children might also benefit from inclusive classroom-based interventions through interactions with typically developing peers while building on their strong social and prelinguistic skills (e.g., joint attention). Moreover, because cognitive ability at age three predicts post-secondary outcomes (Anderson, Liang, & Lord, 2014), early childhood intervention programs could play a vital role in preparing for future outcomes by strengthening cognitive and language abilities early in a child's life.

For children with high cognitive and language skills with social skill challenges (i.e., Cluster 2), practitioners could focus on cultivating social skills more intentionally from early on. For example, because these children have sufficient cognitive and language abilities, practitioners could use social stories and narratives to help children understand social context and teach them social skills and strategies to use when interacting with others. It is also recommended to target social development from a young age to set a strong foundation for later development, and not to miss essential opportunities during early childhood (Crais & Watson, 2014; Dawson, 2008). Clinically, this subgroup of children could be easily missed in the public education and intervention service system, because their high cognitive and language abilities might mask their social delays. As observed in the current study, good language skills do not necessarily mean strong social skills. Teachers, service providers and parents should evaluate children's social development carefully above and beyond their language and cognitive abilities, and purposefully advocate for social skills intervention for this subgroup of children when necessary.

Children with pervasive delays across developmental aspects (i.e., Cluster 3) would undoubtedly need more support than other children with ASD. These children are likely to benefit from highly intensive interventions that provide support and structure to facilitate their daily interactions with other people and the environment. For example, TEACCH programs would be a good fit for children in Cluster 3 because such programs provide visual supports and schedules, individual work systems, and a structured environment. As for specific intervention foci, practitioners could work to promote children's prelinguistic skills (e.g., joint attention, gesture use, and social play) first, as these skills set the foundation for social communication development (Mundy & Sigman, 2015; Toth et al., 2006).

In addition to individualized support for children in the classroom, practitioners should also collaborate closely with parents and adopt family-centered practices to support families' functioning and to build families' capacity to promote healthy child development (DEC Recommended Practices, 2014). The field of ECSE has long emphasized child and family-centered practices, but the needs of parents themselves are still often regarded as secondary or sometimes even neglected altogether. As shown in previous studies and this study, parents of children with ASD experience high levels of stress and are at risk for mental health problems. Thus, their well-being has an impact on child development and outcomes (Karst & Van Hecke, 2012). Although our knowledge of the exact relationships of parent factors and intervention outcomes for children with ASD is still limited, a transactional effect between child development and family functioning is nonetheless evident. Therefore, the outcomes for the whole family could be improved by offering external support and resources (e.g., counseling services for parents, and parent support groups) and helping parents cope with stress (the ABCX model, McCubbin & Patterson, 1983; Paytner et al., 2013). Thus, it is critical to raise ECSE practitioners' awareness of parent mental health issues, and provide training to prepare the practitioners to identify community resources for parents and link families to those resources when needed are critical objectives.

Finally, the current findings also have implications for serving families of low SES and diverse backgrounds. As indicated by the characteristics of children in Cluster 3, children with severe and pervasive delays are more likely to be from low-resourced families (e.g., minority backgrounds and with parents with low education levels). This phenomenon highlights the need to make high-quality services accessible to them. As intervention and education resources for children with ASD and their families arre unevenly distributed across communities, children and families may not have access to the interventions that work the best for them. Therefore, it is important to make school and district level policies that help provide families with sufficient informations and services that allow informed decision-making and ensure equal access to high-quality programs and services. One practice recommendation would be to equip practitioners and providers in low-resourced and/or diverse communities with knowledge and skills of different evidence-based practices and programs to serve children with ASD and their families. For example, local early intervention and Head Start (EHS/HS) programs deliver individualized intervention and early childhood education to children from diverse and low SES families and are mandated to enroll at least 10 percent of children with disabilities and suspected delays (Head Start Program Performance Standards, 2016). Therefore, EHS/HS programs are likely to be a positive venue to reach children with the most needs but the least access to high-quality autism-specific programs. Service providers, especially those working with low-resourced families (e.g., in local EHS/HS programs), should receive professional development in the application of evidence-based practices and culturally responsive interventions for children with ASD to meet the needs of children and families. Another implication for practices would be providing families with available evidence on individualized programs and making intervention recommendations based on their profiles, with references to the practice recommendations noted above.

In conclusion, understanding the heterogeneity of ASD and different responses to intervention programs are essential steps towards treatment individualization for children with ASD. This study identified three distinct subgroups of preschoolers with ASD and the study's findings should be taken into consideration when evaluating symptom presentation and designing individualized intervention plans. Moreover, this study found a significant impact of parent stress levels on child intervention outcomes in terms of social development and thus calls for more research and practice advancements to address parental mental health *and* positive child developmental outcomes.

Appendix

List of Studies of Influential Factors and Predictors of Treatment and Developmental Outcomes

	Participants	**Study Design**	**Intervention Method**	**Factors Identified**	**Effects on Child Outcomes**
Anderson, Liang, & Lord, 2014	N = 85 with ASD recruited at age 2 and followed up at age 19.	Prospective study, separated into three groups based on verbal IQ scores and diagnosis at age 19	N/A or community-based intervention	Cognitive ability and adaptive skills	1) Lower cognitive and adaptive abilities and more autism symptoms at age 2 predicted membership in less able group at age 19. 2) Greater reduction in repetitive behaviors from age 2 to age 3 predicted retention of ASD diagnosis for cognitive able individuals at age 19.
Bedford, Pickles, & Lord, 2015	N = 209 with ASD and general developmental delays, assessed at 2, 3, 5, and 9 years of age.	Longitudinal study	N/A	Gross motor skills and age of walking onset	1) Gross motor skills at age 2 significantly predicted both receptive and expressive language abilities development at later ages in addition to walking onset age. 2) The parent-report age of walking onset significantly predicted the rate of language development.
Ben-Itzchak, Watson, & Zachor, 2014	N = 46 with ASD, aged 17-33 months	Longitudinal study with three repeated	ABA-based intervention	Cognitive ability measured by MSEL	After two years of intervention, only children in the low cognition group made significant gains in

		measures over two years			fine motor and receptive language scores, whereas the high cognition group made significant gains in adaptive skills and better generalization of social communication skills in daily functioning.
Bono, Daley, & Sigman, 2004	N = 29 with ASD, aged 31-64 months	Pre-and post-assessment over a year	Community-based intervention	JA and initial language skills	Children's intake language age and response to joint attention skills significantly predicted their language gain over one year.
Boyd et al., 2014	N = 185 with ASD (TEACCH:85; LEAP:54; Control:59), aged 3-5 years	Quasi-experimental study with pre- and post-assessment	TEACCH, LEAP, and NMS preschool programs	Gender, cognitive and language abilities	1) Pretest cognitive and language scores had an impact on the rate of improvement in cognitive ability and autism severity for children in the TEACCH group. 2) Gender showed moderating effects on communication skills of children in the LEAP group.
Carter et al., 2010	N = 62 with ASD, aged 15-25 months	Randomized control trial	HMTW Intervention; 8 group sessions and three in-home individual sessions over 3.5-month period	Object interest	Time 1 object interest moderated the effect on communication variables; children with higher object interests made more gains.
Eldevik, Eikeseth, Jahr, & Smith, 2006	N = 28 with ASD (13-behavioral treatment. 15-eclectic treatment, aged 36 to 68 months	Group comparison design	Behavioral treatment and eclectic treatment	Cognitive functioning, language comprehension,	Pearson correlations showed that cognitive functioning and language abilities at intake were positively

				and expressive language	associated with post-treatment outcomes (e.g., intellectual functioning and language proficiency).
Flanagan et al., 2012	N = 142 with ASD (79 in the intervention group), aged 3 to 5 years	Waitlist comparison study	Community-based intensive behavioral intervention	Adaptive skills, intake age	Regression analyses indicated that younger initial age predicted better cognitive outcomes in the IBI group but not the Waitlist group. Higher initial adaptive skills predicted better outcomes similarly in the two groups.
Gabriels and colleagues (2001)	N = 17 with ASD (9 in the better outcome groups with higher Time 2 IQ), aged 20-47 months	Retrospective study with group comparison	Eclectic community interventions	IQ, financial strain, and family social support	The higher outcome group showed higher initial IQ scores and significant increases in IQ scores over time; they also had less financial strain and more extended family social support than the lower outcome group.
Harris & Handleman, 2000	N = 27 with ASD, aged 31-65 months	Pre-and post-assessment	ABA	IQ and intake age	Children with higher IQ scores and lower age at intake were more likely to be placed in a regular classroom at follow-up.
Hedvall et al., 2015	N = 53 with ASD, aged 24-45 months	Repeated assessment over two years	ABA-based program	Cognitive level, age at referral, failing 18-month milestones, autistic type	Group comparison between those who gained the most and who lost the most showed that the group members differed significantly in age at

				behavior problems, and regression	referral, behavior problems, regression, and speech and cognitive levels. However, the only cognitive level at Time 1 made a unique significant contribution to predicting outcome group membership.
Magiati et al., 2007	N = 44 with ASD, aged 23-53 months	Prospective follow-up study	Autism-specific nursery provision or home-based EIBI in a community setting	IQ and language level	Intake IQ and language level best predicted overall progress after two-year community-based interventions.
Osborne, McHugh, Saunders, & Reed, 2007	N = 65 with ASD, aged 2.6-4.0 years	Pre- and post-treatment repeated measure design with 9-10-month duration..	Community-based eclectic models, including reinforcement-based interventions, nursery placements, speech and language therapy and parent education	Parenting stress	Parenting stress reduced the effectiveness of early interventions as children of parents with lower stress made more gains than those of parents with higher stress; high levels of parenting stress also counteracted the positive effects of high intervention intensity.
Perry et al., 2011	N = 332 with ASD, aged 2–7 years		Community-based Intensive Behavioral Intervention program	Age at entry, IQ, adaptive scores, and autism severity	Children who were most successful in the program, achieved the average level of functioning and had higher developmental levels at intake were considerably younger than the rest of the children and were in treatment longer than

					children in other outcome categories.
Poon, Watson, Baranek, & Poe, 2012	N = 29 with ASD, aged 9-12 and 15-18 months	Retrospective video analysis	N/A	Prelinguistic skills (joint attention, imitation, object play); age when the child began to walk	1) Prelinguistic skills (joint attention, imitation, object play) during infancy was significantly positively associated with children's social communication and intellectual functioning at ages 3-7. 2) The age when the child began to walk was associated with prelinguistic social communicative behaviors.
Remmington et al., 2007	N = 44 with ASD, aged 26-42 months	Group comparison design	Home-based EIBI or intervention from local education authorities for two years	IQ, adaptive skills, communication and social skills	Children who responded better to intervention had higher IQ scores, higher mental age, higher Vineland Composite, Communication and Social Skills scores, lower Vineland motor skills scores, more behavioral problems, and more autistic symptoms than children who did not respond well to intervention.
Sallows & Graupner, 2005	N = 24 with ASD, aged 35-37 months	Randomized control trial	Either clinic-directed or parent-directed intervention	IQ, language, and social skills	Treatment outcome was best predicted by pretreatment imitation, language, and social responsiveness, thus expanding most of the intervention gains.

Schreibman, Stahmer, Barlett, & Dufek, 2009	Six children, aged 2-4 years	Single-subject design	Pivotal Response Training (PRT); Discrete Trial Training (DTT)	Toy contact/object interest, avoidance of people proximity	Children with higher interests in toy contact responded well to PRT intervention even when they did not match other characteristics of the responder profile. Neither of the two factors predicted children's response to DTT.
Sherer & Schreibman, 2005	11 children for profile analysis; 6 children for the prospective study, aged 3-6 years		PRT: 90 min of one-on-one PRT 4-5 times a week. Responders receive intervention for 6 months and non-responders only five weeks	Interests in toys, tolerance of people proximity, social avoidance, self-stimulatory behaviors	1) In the prospective study, children with a responder profile showed positive changes across developmental measures: cognitive, language, play, and social behaviors. 2) Responders had more interest in toys, higher tolerance of people proximity but low social avoidance, more verbal self-stimulatory behaviors but fewer nonverbal stimulatory behaviors than non-responders.
Sutera et al., 2007	N = 60 with stable ASD diagnosis (ASD-ASD); N = 13 with original ASD diagnosis and lost the diagnosis at age 4; N = 17 without ASD	Longitudinal study; group comparison	N/A	Motor skills	In the group comparison, children who later moved off the autism spectrum had better motor skills at the initial evaluation at age 2.

Thurm, Lord, Lee & Newschaffer, 2007	N = 59 with autism, N = 24 with PDD-NOS, 35 with non-spectrum developmental disabilities	Longitudinal study followed from age 2 to 5	N/A	Cognitive ability, communication	Regression analysis results showed that both nonverbal cognitive ability and communication at age 2 and communication score at age three significantly predicted language level at age 5.
Toth et al., 2006	N = 60 with ASD, aged 34-52 months at Time 1	Longitudinal study with repeated measures	N/A	Joint attention, imitation, and toy play	Regression analyses revealed that: 1) at age 3-4, joint attention initiation and immediate imitation were significantly associated with language ability; and 2) early toy play and deferred imitation skills were the best predictors of rate of communication development from age 4 to 6.5 years.
Troyb et al., 2016	N = 40 with ASD, beginning ages of 1-2 years	Longitudinal study	N/A	RRBs; cognitive and language functioning	1) More severe RRBs at age 3-5 predicted less developed cognitive and adaptive functioning and greater autism symptom severity at ages 8-10. 2) Cognitive and language at age 1-2 predicted adaptive functioning at ages 8-10 and cognitive and language functioning at ages 3-5 predicted cognitive

					functioning and autism severity at ages 8-10.
Vivanti, Dissanayake, Zierhut, Rogers, & ASELCC Team, 2013	N = 21 with ASD, aged 2 to 5 years	Pre-and post-assessment	Group-based Early Start Denver Model for one year	Functional use of objects task, goal understanding, social attention, imitation	In the regression analysis, advanced skills in the functional use of objects, goal understanding, and imitation explain most of the developmental gains after treatment. Other child and intervention factors were not associated with treatment gains in this study.
Yoder & Stone, 2006	N = 26 preschooler with ASD	Randomized control trial	Picture Exchange Communication System (PECS); Responsive Education and Prelinguistic Milieu Teaching (RPMT) for six months	Initiating joint attention	Exploratory analysis showed that children with more IJA acts at Time 1 benefited more from RPMT intervention, whereas children with fewer IJA acts benefited more from PECS intervention.

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