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Executive Functioning for School-Aged Children with Autism: Longitudinal Trajectories and Predictors for Growth

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Executive Functioning for School-Aged Children with Autism:

Longitudinal Trajectories and Predictors for Growth

A dissertation submitted in partial satisfaction of the

requirements for the degree of Doctor of Philosophy

in Special Education

by

Sohyun An Kim

2022

ABSTRACT OF THE DISSERTATION

Executive Functioning for School-Aged Children with Autism:

Longitudinal Trajectories and Predictors for Growth

by

Sohyun An Kim

Doctor of Philosophy in Special Education

University of California, Los Angeles, 2022

Professor Connie L Kasari, Chair

Executive functioning (EF) is found to be a powerful predictor for children's school readiness and long-term school outcomes. However, the current research base indicates that children with autism may have an increased likelihood of experiencing deficits in EF or delayed developmental trajectories. Additionally, although there is ample evidence that neurotypical (NT) children undergo a "sensitive period" with high plasticity in EF development in early childhood, and continue to make progress up to early adolescence, it is unclear if such a window of opportunity applies to autistic children in the same way it does for their NT peers, and if the longitudinal trajectory of growth follows a parallel pattern. Study 1 used the Early Childhood Longitudinal Studies-Kindergarten Class of 2011 (ECLS-K: 2011), and unconditional latent growth models were built for working memory and cognitive flexibility to identify the period of high plasticity in EF skills in autistic children and how it differed from that of their NT peers. It

further investigated the relationship between autistic children's initial status in EF skills upon entering kindergarten and their rates of growth throughout their elementary school life. Lastly, it examined how the degree of heterogeneity in autistic children in their EF performances changed over time, and how such changes differed from that of their NT peers. Findings from Study 1 indicate that both autistic and NT children make steeper gains during the first few years of elementary school, and the rates of growth slow down as they get older. However, autistic children appear to have a wider window for high plasticity than their NT peers. Further, autistic children's lower initial status on working memory upon entering kindergarten predicted a higher rate of growth during the last three years of elementary school only, while a lower initial status on cognitive flexibility predicted a higher rate of growth throughout their elementary school years. Lastly, while both autistic and NT children show greater heterogeneity in their EF performances when they are younger, the heterogeneity decreases as they approach their "plateauing" points. However, the overall degrees of heterogeneity were higher in the autistic children than their NT peers, which indicates some degree of continued heterogeneity in their growth during the later years of elementary school.

As indicated in Study 1, EF in autistic children is highly malleable throughout their childhood, and current literature base supports that various student-level and environmental factors play important roles in their development. In Study 2, conditional latent growth models were built to identify possible predictors for autistic children's working memory and cognitive flexibility performance upon entering kindergarten and their relative growth throughout their elementary school years. Findings indicate that socioeconomic status (SES) and students' approaches to learning (ATL) positively predicted autistic children's working memory performance upon entering kindergarten. Having ADHD, receipt of special education services at

school, and students' ATL positively predicted autistic children's rate of growth in working memory during the first three years of their elementary school years, while student-teacher relationship (STR) predicted their rate of growth in working memory during the last three years of their elementary school. In addition, STR and ATL positively predicted autistic children's cognitive flexibility performance upon entering kindergarten, while living in a bilingual home environment positively predicted their rate of growth in cognitive flexibility during the first three years of autistic children's elementary school years. Implications and future directions are discussed.

Author's Note

In order to respect the preference of many autistic self-advocates, 'person-first language' and 'identity-first language' were used interchangeably throughout this dissertation. In addition, the term 'disorder' was not used when describing autism.

The dissertation of Sohyun An Kim is approved.

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DEDICATION

To Daeshin, Sherman, & Chandler Kim

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CHAPTER I

Introduction: Executive Functioning & Overarching Motivations

Executive functioning (EF) is understood as general purposeful mechanisms that govern the operation of various cognitive processes and thereby regulate the dynamics of human cognition (Miyake et al., 2000). EF skills involve staying focused, resisting impulsive responses, mentally manipulating ideas, and changing course of action as needed (Diamond, 2016).

EF skills are consistently found to be a critical factor for children's school success. More specifically, EF skills are found to be more powerful predictors for school success than IQ, pre-literacy skills, or foundational math skills (Diamond, 2016). There is a robust research base that demonstrates that EF development is extremely sensitive to environmental factors, and that EF can be improved from a very young age into adulthood (e.g., Cannon et al., 2011; Diamond & Lee, 2011; Greenberg & Harris, 2012).

While such evidence can be seen as promising, it is also evident that persistent gaps exist in EF skills from a very young age into adulthood based on disability status, such as having autism (Granader et al., 2014; Meltzer & Krishnan, 2007; Otterman et al., 2019), and social determinants such as SES or racial background (Bernier et al., 2010; Hackman et al., 2015; Lengua et al., 2014; Little, 2017). What is more concerning is that these gaps do not tend to narrow on their own, but they persist or widen over time (Chen et al., 2016; Happé et al., 2006; Vogan et al., 2018). Similarly, research consistently finds disability-based disparities in children's school readiness skills, which are closely related to their EF skills, to persist over time (Quintero & McIntyre, 2011; Reardon & Portilla, 2016). As children's school readiness upon entering kindergarten is considered an important stepping stone to children's long term positive school outcomes (Rimm-Kaufman et al., 2000), it is critical to identify factors that influence children's EF trajectories. More importantly, it is important for researchers to understand how these factors influence EF trajectories of children who have developmental disabilities such as autism, and how their trajectories change over time.

Therefore, this dissertation aims to examine the quality of EF developmental trajectories in autistic children and to identify possible contributing factors for their maximal growth. There are two studies within this dissertation: the first study compares longitudinal trajectories of EF of autistic children and their neurotypical peers. The second study investigates predictors for their rate of growth during their elementary school years.

Theoretical Framework & Directions for Current Studies

There has been a steady growth in the literature base regarding the development of children with developmental disabilities such as autism, yet many studies appear to hold an essentialist model. The essentialist model views disability as an inherent characteristic of a person, arising from an impairment (Hosking, 2008). For example, Bottema-Beutel et al. (2017) argue that many researchers point out persistent difficulties in social communication and interaction in children with autism and attribute such difficulties to impairment in their ability to infer and predict the mental state of others, also referred to as the Theory of Mind (Bottema-Beutel et al., 2018). In contrast, Critical Disability Theory (CDT) sees disability as a complex interrelationship between impairment, individual responses to impairment, and barriers imposed by the social environment to the concept of disability by failing to meet the needs of those who do not match the social expectation of 'normalcy' (Hosking, 2008).

Moreover, there is a critique within the field of educational research that too much attention has been given to the "gaps" between students from marginalized identities and their counterparts from non-marginalized identities (Little, 2017). For instance, Ladson-Billings

(2006) asserted that educational researchers' focus should shift from the "achievement *gap* to the educational *debt*," analogous to fiscal debt that accumulates over time (p.4). Therefore, while there is no doubt that gap research provides important contributions to the educational literature base, one important goal of research around students with autism should be to examine ways to allow them to follow their unique and natural developmental trajectories while examining environmental factors that can help maximize their potential and long-term school outcomes.

Accordingly, guided by the CDT, this dissertation attempts to move away from making a parallel comparison of the inherent characteristics between autistic children and their neurotypical peers and pointing out the gap. Instead, I attempt to focus on the heterogeneity of their developmental trajectories, individual differences, contributing factors for maximal growth, and relationship between time points in their development. This way, we can direct our attention towards examining ways to improve the quality of life and support system for this population rather than focusing on the deficits as measured by social norms.

CHAPTER II

Study One: A Comparison of Longitudinal Trajectories of Executive Functioning of Autistic Children and Their Neurotypical Peers: Periods of Plasticity, Rates of Growth, and Heterogeneity of Development

Abstract

Executive functioning (EF) is found to be a powerful predictor for children's school readiness and long-term school outcomes. However, the current research base indicates that children with autism may have an increased likelihood of experiencing deficits in EF or delayed developmental trajectories. Additionally, although there is ample evidence that neurotypical (NT) children undergo a "sensitive period" with high plasticity in EF development in early childhood, and continue to make progress up to early adolescence, it is unclear if such a window of opportunity applies to autistic children in the same way it does for their NT peers, and if the longitudinal trajectory of growth follows a parallel pattern. This study used the Early Childhood Longitudinal Studies-Kindergarten Class of 2011 (ECLS-K: 2011), and unconditional latent growth models were built for working memory and cognitive flexibility to identify the period of high plasticity in EF skills in autistic children and how it differed from that of their NT peers. It further investigated the relationship between autistic children's initial status in EF skills upon entering kindergarten and their rates of growth throughout their elementary school life. Lastly, it examined how the degree of heterogeneity in autistic children in their EF performances changed over time, and how such changes differed from that of their NT peers. Findings indicate that both autistic and NT children make steeper gains during the first few years of elementary school, and the rates of growth slow down as they get older. However, autistic children appear to have a wider window for high plasticity than their NT peers. Further, autistic children's lower initial

status on working memory upon entering kindergarten predicted a higher rate of growth during the last three years of elementary school only, while a lower initial status on cognitive flexibility predicted a higher rate of growth throughout their elementary school years. Lastly, while both autistic and NT children show greater heterogeneity in their EF performances when they are younger, the heterogeneity decreases as they approach their "plateauing" points. However, the overall degrees of heterogeneity were higher in the autistic children than their NT peers, which indicates some degree of continued heterogeneity in their growth during the later years of elementary school. Implications and future directions are discussed.

Executive Functioning in School-Aged Children

EF plays a central role in various aspects of children's development and overall school success (Diamond, 2016). This includes their early social-emotional development, tolerance of delay of gratification (Riggs et al., 2006), self-regulation (Jahromi & Stifter, 2008), understanding others' perspectives (Kouklari et al., 2019), academic skills (Prager et al., 2016), and interaction with peers (Holmes et al., 2016). Accordingly, there has been a growing interest in the past few decades in examining EF skills in children in the field of education, child development, and educational psychology.

Executive Functioning: Integrative Framework

Historically, EF was thought to be a unitary construct which was frequently studied in the field of neuropsychology with adult patients with frontal lobe damage. However, Fletcher (1996) emphasized the importance of studying EF in children to understand the cognitive development of children with developmental disabilities rather than relying exclusively on investigations of brain damage in adults. Consequently, there is a large literature on EF development in children from recent decades. However, researchers historically faced challenges in coming to an agreement on the dimensionality of EF. More specifically, researchers had mixed views on whether EF is a unitary construct or a set of distinct components, and how to delineate these components (Brocki & Bohlin, 2004; Isquith et al., 2004; Miyake et al., 2000). For instance, a recent systematic review of contemporary empirical studies on EF found that researchers identified 39 different components within EF, while many of them were only mentioned once in the literature base. The most frequently mentioned components were inhibition, working memory, and cognitive flexibility, which is often used interchangeably with shifting or set shifting (Baggeta Peter & Alexander, 2016).

Some researchers attempted to operationally define EF and its sub-categories by conducting factor analyses (e.g., Gioia et al. 2002, Miyake et al. 2000), and many recent studies describe EF through an integrative framework. Integrative framework views EF to be a unitary construct with different EF tasks clustering into partially dissociable components. These components are broadly categorized as cognitive flexibility, working memory, and inhibition (Miyake et al. 2000). In fact, EF has been shown to be a unitary construct at an early age, but from around the time when children enter formal schooling (i.e., between 4 and 6 years of age) these three subdomains statistically load as dissociable factors (John et al., 2019).

Working memory involves maintaining and updating incoming information for relevance to the current task, then revising the items by replacing old information with newer, more relevant information (Garon et al., 2008; Miyake et al. 2010; Morris & Jones 1990). Cognitive flexibility is defined as intentionally switching back and forth between multiple tasks, goals and mental sets (Best et al., 2021; Friedman et al., 2006; Monsell 1996). Inhibition refers to one's ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary (Miyake et al. 2000). These three components are moderately correlated with one another as they are thought to stem from a shared underlying skill such as controlled attention (Miyake et al. 2000). The current study will adopt this integrative framework as this model has been shown to reliably apply to school-aged children through confirmatory factor analysis (CFA) (e.g., Huizinga et al 2006; Lehto et al. 2003).

Working Memory

Working memory was found to develop from preschool age and to show consistent development until age 14 before children reach the maturity point (Gathercole et al., 2004).

Researchers also found that the age of mastery in working memory may depend on the degree of task complexity (Conklin et al., 2007; Luciana et al., 2005).

Working memory is found to be associated with positive classroom engagement (Fitzpatrick & Pagani, 2012), academic readiness for preschool children (Swayze & Dexter, 2018), early mathematical skills (Bull et al. 2008; Harvey & Miller, 2016), and language acquisition (Roman et al., 2014) in young children. In addition to academic achievements, children's early working memory skills were found to predict their performance in Theory of Mind tasks a year later (Lecce et al., 2017). As such, children's working memory has been extensively studied by researchers as it has a foundational role in cognitive development and school success.

Working memory is viewed as an information-processing system with finite capacity, and this working memory capacity is commonly measured with memory span tasks. Memory span tasks typically require ordered serial recall of a sequence, and the length of the sequence correctly recalled is used as a measure for working memory capacity. Examples of memory span tasks include forward and backwards digit span (Roman et al., 2014).

Cognitive Flexibility

Impairment in cognitive flexibility is manifest as repetitive or perseverative behaviors, difficulty with transitions between different events, and inflexible adherence to specific routines (Leung & Zakzanis, 2014). Cognitive flexibility is found to be linked to various skills related to school success, such as conceptual or abstract mathematical skills (Purpura et al. 2017), reading comprehension (Cantin et al. 2016), science achievement (Anthony & Ogg 2020), externalizing behavior problems (Schoemaker et al. 2013), and regulating behaviors with delayed gratification (Jahromi & Stifter, 2008). Assessment of cognitive flexibility typically involves having the examinees complete simple tasks such as sorting while alternating the rules. Examples include The Wisconsin Card Sorting Task (WCST; Heaton et al. 1993) and The Dimensional Change Card Sorting Task (Zelazo 2006; Zelazo et al. 2013).

Inhibition and its Complex Relationship with Cognitive Flexibility and Working Memory

Inhibition refers to the capacity to deliberately suppress a salient response in order to achieve cognitive or behavioral goals (Ciairano et al. 2007). Deficits in inhibitory control were found to be related to an increased risk of externalizing problems such as aggressive, disruptive and impulsive behaviors from as early as the preschool years, and this association persists into later school years (Utendale et al., 2011). Inhibition was also found to help children's mathematical skills by suppressing less sophisticated yet familiar strategies and adopting more adaptive and improved strategies (Ren et al., 2019). Inhibition capacity is typically measured by testing children's ability to inhibit a dominant response while correctly following predetermined rules.

Best and Miller (2010)'s review on theoretical and methodological issues in the developmental perspectives on EF explains that most inhibition tasks do not measure the "pure" form of inhibition. The purest forms of inhibitory tasks that do not require working memory or cognitive flexibility develop during infancy (Garon et al. 2008), but many complex inhibition responses require substantial working memory and cognitive flexibility in order to execute. Children show rapid growths of complex forms of inhibition in early childhood (Garon et al. 2008). More specifically, children between ages 3 and 4 were found to make significant gains in complex inhibition tasks (Hughes, 1998) though the age of mastery may depend on the degree of response prepotency when performing inhibition tasks (Diamond & Taylor, 1996). Regardless, preschool age children are shown to possess some ability to inhibit a naturally prepotent response and perform complex inhibitory tasks that are more advanced than their "purest forms" (Best & Miller, 2010), and their inhibition appears to stabilize by the early school years (Lehto et al. 2003).

Miyake et al. (2000) also discuss the complex relationship between cognitive flexibility and inhibition by pointing out that cognitive flexibility may require "the ability to perform a new operation in the face of proactive interference or negative priming" (p.56). Miyake further questioned whether inhibition should be considered a distinct component (Miyake 2009). Consequently, there have been frequent overlaps in measurement tools in measuring cognitive flexibility and inhibition. For example, though The Dimensional Change Card Sort (DCCS™) (Zelazo 2006; Zelazo et al. 2013) is often used to assess children's cognitive flexibility (Kloo et al., 2010; Ramscar et al., 2013) it is also sometimes used to measure children's inhibition (Bialystok & Martin, 2004). Due to such complexity in measurement, the current study will only focus on working memory as measured by numbers reversed tasks and cognitive flexibility as measured by the DCCS.

Development of EF: Working Memory and Cognitive Flexibility

Studies have found that the first 5 years of life are a critical period in the development of EFs. Core components of EF develop during this time, with a developmental spurt between three and five years, which set the foundation for more complex cognitive and emotional processes (Garon et al., 2008)**.** After this "sensitive period" with high malleability, EF continues to develop through elementary school years and early adolescence (Zelazo & Carlson, 2012) in more complex forms. However, the majority of research on the development of EF has focused on narrow age ranges in preschool years (Carlson et al., 2004; Garon et al., 2008; Isquith et al., 2004). Consequently, although EF development has been well-studied in the field of education, child development and educational psychology, less is known about EF development in school-age children, which remains as a limitation in the research base of EF (Best & Miller, 2010).

Longitudinal Trajectories of EF in School-Age Children with Autism and Their NT Peers

Several studies have examined cross-sectional profiles or longitudinal trajectories of EF skills in autistic children and their typically-developing peers. For example, a prior study examined EF skills of children with autism and those without any identified disabilities after matching them on their age and IQ. Both groups showed age-related improvements but the autism group displayed overall delays in most categories when compared to the NT group (Happé et al., 2006). Similarly, a more recent study (Chen et al., 2016) also demonstrated age-related improvements in EF skills in both autism and NT groups throughout their adolescence. However, the autism group showed persistent impairment in working memory regardless of age. Another study's (Andersen et al., 2015) findings corroborate Chen et al.'s (2016) findings in that the performance of autistic children in working memory did not improve after 2 years. Additionally, a more recent longitudinal study (Vogan et al., 2018) demonstrated that autistic children had impaired EF in all domains at both time points, and showed no significant improvement across 2 years. In contrast, a three-year longitudinal study (Pellicano, 2010a) demonstrated that although children with autism showed poorer EF skills at both time points, the autism group made significantly more gains during the three-year period than the NT group. They additionally found that individual differences in early EF performances in autistic children strongly predicted their EF performance 3 years later.

In spite of such mixed findings, one commonality among these studies was that the autism group started significantly lower with EF at the initial time point. Further, the overall trajectory of EF skills was generally lower for the autism group. Such diversity in findings may be due to the heterogeneity of characteristics in autism in general. However, it is also important to note that most studies had small samples (Andersen et al., 2015; Happé et al., 2006; Pellicano, 2010b; Vogan et al., 2018), one study only included boys with high functioning autism in the sample (Happé et al., 2006), and some conducted cross-sectional analyses with two different age groups of children as opposed to following the same group of children (Chen et al., 2016; Happé et al., 2006). Furthermore, the three longitudinal studies (Andersen et al., 2015; Pellicano, 2010a; Vogan et al., 2018) examined two distinct time points, and no data were collected between these two time points in order to analyze the quality of the growth curves. More importantly, except for Pellicano's (2010a) study, the focus of the studies appeared to be on the presence of persistent gaps between autism and NT samples by comparing the group means, and no attention was given to individual differences or an individual child's gains over time within the autism group. More specifically, little is known about the longitudinal trajectories and relative growth of EF abilities among autistic children as compared to their neurotypical peers. Further, no studies were found that examined the quality of the longitudinal trajectories of EF development among autistic children, such as period of high plasticity specific to autistic children, relationship between the initial status of EF upon entering kindergarten and their rate of growth throughout the elementary school years, changes in the degree of heterogeneity in EF across multiple time points and relative growth from one time point to another.

As such, though it is well-established that there is a gap between EF skills in autistic children and their typically-developing peers, and that EF skills play an important role in children's school readiness and long-term school success, there is still much to be learned about longitudinal trajectories of development in children with autism. More specifically, although many studies found early EF performances in children as predictors for their school outcomes, a closer examination is warranted to examine the relative growth of EF skills in children with autism. Further, the longitudinal trajectory of the development of EF skills in typically-developing children has been well studied, but it is unclear if autistic children follow a similar developmental path, if their trajectory is delayed, truncated, or if they reach their "maturity point" in a similar way that their typically-developing peers do. Taken together, it is unclear whether autistic children's EF trajectories undergo their anticipated "sensitive period" for development in a similar way that their NT peers do.

Moreover, making parallel comparisons between children on the autism spectrum and their typically-developing peers by comparing the group means and highlighting possibly persistent gaps may inadvertently reflect ableist ideologies (i.e., beliefs and practices that discriminate against people with disabilities) (Bottema-Beutel et al., 2021). Therefore, this study conducted a close examination of the qualities of EF trajectories (i.e., relative growth, period of plasticity, individual variability) instead of comparing their EF abilities among autistic children and their neurotypical peers.

Research Questions

The current study addressed the following research questions:

1. When do autistic children make rapid growth in working memory (WM) and cognitive flexibility (CF), and at what time point does their growth start to slow down during their elementary school years? How do these time points differ from their neurotypical (NT) peers?
2. How does autistic students' initial status on WM and CF performances upon entering kindergarten predict their rates of growth throughout their elementary school years? How do these relationships differ from their NT peers?

3. How does the degree of heterogeneity in autistic children's WM and CF performances at each time point change over time? How do these changes differ from their NT peers'?

Method

Dataset

This study used the restricted version of the Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011) dataset. This dataset was sponsored by the National Center for Education Statistics (NCES) within the Institute of Education Sciences (IES) of the U.S. Department of Education. ECLS-K:2011 dataset is a nationally representative and longitudinal dataset, which follows the same cohort of children from kindergarten through fifth grade (Tourangeau et al. 2019). In total, approximately 18,170 children across about 1,310 schools and their parents, teachers, school administrators, and before- and after-school care providers participated in the data collection. Data were collected from Fall of kindergarten in year 2010 (T1) through Spring of 5th grade in year 2016 (T9), across nine time points. Table 1 displays the data collection schedule from years 2010 to 2016.

Participants

A parent interview was conducted at each round of data collection from Fall of kindergarten to Spring of 5th grade (i.e., T1 – T9). In Spring 2011 (T2), Spring 2012 (T4), Spring 2013 (T6), Spring 2014 (T7), Spring 2015 (T8) and Spring 2016 (T9), parents were asked to answer the following question: "Did you obtain a diagnosis of a problem from a professional?" Response options included *Yes, No, Refused, and Don't know*. If the response was *Yes*, parents were then asked a follow-up, open-ended question, "What was the diagnosis or were the diagnoses?" Additionally, a special education teacher questionnaire for each child who participated in the data collection was completed in Spring 2011 (T2), Spring 2012 (T4), Spring 2013 (T6), Spring 2014 (T7), Spring 2015 (T8) and Spring 2016 (T9). Special education teachers were asked the following question: "For which of the following disabilities has this child received special education or related services this school year, whether for the child's primary disability or another of his/her disabilities? Mark yes or no on each row." Response options included *speech or language impairments, specific learning disabilities, emotional disturbance, intellectual disability, developmental delay, visual impairments, hearing impairments, orthopedic impairments, autism, traumatic brain injury, deaf-blindness, and multiple disabilities*.

Students were included in the Autism[1]sample in the present study if: 1) parents responded at least once during the six rounds of interview that their child had a diagnosis of autism or 2) the special education teacher responded at least once during the six rounds of survey that the child was receiving special education or related services for a diagnosis of autism. Students were included in the NT sample in the study if: 1) parents reported *No* to the question "Did you obtain a diagnosis of a problem from a professional?" at each of the six rounds of survey.

Measures

Demographic Characteristics

Demographic characteristics of the sample included: 1) race/ethnicity (White, Black, Hispanic, Asian-American / Pacific Islanders / Native Americans (AAPINA), other), 2) sex assigned at birth (male, female), 3) income range (under $20,000, $20,000 to $30,000, $30,000 to $50,000, $50,000 to $75,000, $75,000 to $100,000, $100,000 to $200,000, $200,000 or more), and 4) parent's educational level.

[1] Hereafter, the sample containing autistic children in the current study will be referred to as 'Autism sample' with the capitalization.

Working Memory

Number Reversed subset of the Woodcock-Johnson III (WJ III: Woodcock 2001) was administered to measure working memory (WM) from kindergarten through 5th grade, across nine time points. Students were asked to repeat orally presented strings of numbers backwards, starting with two-number sequences. Five two-number sequences were presented before progressing to three-number sequences. The length of sequence increased after five trials, up to a maximum of eight numbers. If the child responded incorrectly for three consecutive trials, the task ended instead of progressing to a longer number sequence. Each item was scored as “correct,” “incorrect” or “not administered” (Tourangeau et al. 2019).

For the purposes of this study, the *W* score for the Number Reversed subtask was used. The *W* score is a standardized equal-interval score that represents both a child’s ability and the item difficulty. It is particularly suited for longitudinal analyses, regression and correlation (Tourangeau et al. 2019).

Cognitive Flexibility

The Dimensional Change Card Sort (DCCS™) (Zelazo 2006; Zelazo et al. 2013) was used in ECLS-K: 2011 to collect information on children’s cognitive flexibility (CF) from kindergarten through 5th grade, across nine time points. In this test, children were asked to sort cards by either color or shape. These sorting rules were intermixed across 30 trials. For example, a child may be asked to sort by shape for four trials in a row, then to sort by color on trial 5, and then to sort by shape on trials 6 and 7. Therefore, this test is not designed to test children’s ability to sort by shape or color, but to measure their ability to switch between tasks accurately and rapidly (Tourangeau et al. 2019).

The computerized version of DCCS™ was developed as part of the National Institute of Health Toolbox for the Assessment of Neurological and Behavioral Function and it is determined to be appropriate for ages 3 to 85. The computerized task had been under development during the planning phases for the earliest rounds of the ECLS-K:2011 and became available in time to be incorporated into second-grade data collection. For this reason, in kindergarten through first grade, students took the tabletop version of the DCCS™ with a different number of questions. The main difference between the two versions is that the computerized version collected data on accuracy as well as reaction time. Consequently, the tabletop version of the DCCS™ was scored based only on accuracy. The computerized version of the DCCS™ was scored based on accuracy and reaction time. More specifically, the accuracy score was used if the score was less than or equal to 80 percent. If the accuracy score was greater than 80 percent, it was scored based on accuracy and reaction time (Tourangeau et al. 2019). However, in order to create equivalency between these two versions, the raw accuracy scores from all time points were converted to a percentage, and this percentage score was used for the analysis. In other words, children's reaction time from the computerized version was not taken into account in the analysis.

Analyses

Case-Control Matching

An attempt was made to case-control match the Autism sample to the NT sample based on their quartile scores in the reading and math assessment at Fall of kindergarten (T1), using the case control fuzzy procedure in SPSS version 28. However, approximately one-third of the students in the Autism sample did not have their reading and math scores at T1, while only 11% in the NT group was missing their reading or math scores at T1. Consequently, the matched sample only consisted of approximately 200 of the 310 students with autism, and more than 100 autistic students were excluded from the matched sample. Based on the disparities of missingness between the Autism and NT group, it was hypothesized that the reading and math scores within the Autism sample may not be missing completely at random (MCAR). Therefore, Little's test of missing completely at random (Little, 1988) was conducted after excluding T3 and T5 for both reading and math scores using SPSS version 28. Neither reading or math domain passed the Little's MCAR test with χ^2=202.937 ($p < 0.001$) and χ^2=204.942 ($p < 0.001$) respectively. It was concluded that only including the autistic students who have the reading or math scores when the missingness may be missing not at random (MNAR) may not provide findings that are representative of the autistic student population. Therefore, a decision was made to retain the entire sample of the Autism and NT group.

Missing Data

Missingness in the WM and CF scores within the Autism sample ranged from 14.61% (T2) to 39.61% (T9) except for Fall of 1st grade (T3) and Fall of 2nd grade (T5). In Fall of 1st grade, 73.38% of the data was missing and in Fall of 2nd grade, 73.38% of the data was missing within the Autism sample. Similarly, missingness in the WM and CF scores within the NT sample ranged from 1.67% (T2) to 11.33% (T1) except for Fall of 1st grade (T3) and Fall of 2nd grade (T5). In fall of 1st grade, 63.43% of the data was missing and in Fall of 2nd grade, 64.84% of the data was missing within the NT sample. Due to such high levels of missingness in Fall of 1st grade and Fall of 2nd grade, these two time points (i.e., T3 & T5) were excluded from further analyses. Table 2 displays percentage of missingness for each time point.

Little's test of missing completely at random (Little, 1998) was conducted after excluding T3 and T5 using SPSS version 28. For the NT sample, both the WM and CF domains passed

Little's MCAR test with χ^2=140.767 (p = 0.106) and χ^2=154.782 (p = 0.076) respectively. For the Autism sample, the WM domain passed Little's MCAR test with χ^2=133.860 (p = 0.584) but the CF domain did not pass the MCAR test with χ^2=265.163 ($p < 0.001$). However, it is hypothesized that the CF domain for the Autism sample at least meets the assumption of Missing-at-Random (MAR) as the missingness is likely due to other information about the child such as the eligibility criteria for the assessment for example (e.g., their IEP precluding from taking the assessment), but not the missing information itself (e.g., due to their true standing in the CF scores). Taken together, it was assumed that both the Autism group and the NT group at least met the assumption of MAR. Missing data within the remaining seven time points was handled by Full Information Maximum Likelihood (FIML) as this method is shown to be robust with structural equation models (SEMs) under the assumption of MAR (Allison, 2003).

Multivariate Normality

Mardia's skewness and kurtosis test was conducted for both Autism sample and NT sample to test the assumption of multivariate normality (Kres, 1983; Mardia, 1980). Neither the Working Memory nor Cognitive Flexibility scores from the seven time points met the assumption of multivariate normality ($p < 0.001$). Therefore, the "MLF" estimator (maximum likelihood estimation with standard errors based on the first-order derivatives) was used when building the latent growth model for each domain for both subgroups.

Latent Growth Modeling

To address the first aim of the study, unconditional latent growth models were created using Lavaan package (Rosseel, 2012) in R statistical environment for cognitive flexibility and working memory domains separately. Latent growth model (LGM) is one of the most appropriate models when estimating longitudinal trajectory while capturing individual variabilities in their growth (Flora, 2008). More specifically, LGM model estimates individual variabilities in the starting point and the rate of growth of the trajectory (McArdle & Epstein, 1987). Therefore, LGM models were adopted to estimate the EF trajectories for each subgroup in this study.

Model Evaluation Criteria. The current study adopted the "cut-off" criteria for the maximum likelihood (ML) method in structural equation modeling proposed by Hu & Bentler (1999). Hu & Bentler suggest that the CFI value close to or higher than 0.95, SRMR value close to or higher than 0.08, and RMSEA value close to or higher than 0.06 are necessary in order to consider that the data fits the model relatively well. Models with a CFI below 0.95 may be useful in some cases but they are likely to lead to inappropriate solutions. Therefore, substantiative inferences should not be made from models with fit indices lower than the aforementioned criteria (Hu & Benter, 1999).

Unconditional Model: Working Memory

First, unconditional latent growth models for the Autism group and the NT group for the working memory domain were developed. The characteristics of WM developmental trajectory (i.e., starting point and rate of growth) for each subgroup were modeled as latent variables. Working memory was assessed throughout nine time points in the dataset, and each time point except for T3 and T5 served as a manifest variable in the model.

Linear Model vs. Piecewise Model: Working Memory. In order to determine the best fitting latent growth model (LGM) for both subgroups on their WM development, a linear model was built first for each group. Loadings for the latent intercept were fixed to one, and loadings for the latent slope started at zero for the first time point, then increase by one for subsequent loadings. Each whole number increment reflected one semester. If the assessments were done 1 year apart (e.g., Spring 4th grade and Spring 5th grade), the loading increased by two, which reflects twice as much time passing between data collection periods. The fixed factor loading matrix is:

$$\Lambda = \begin{bmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 2 \\ 1 & 3 \\ 1 & 4 \\ 1 & 5 \\ 1 & 7 \\ 1 & 9 \\ 1 & 11 \end{bmatrix} \begin{matrix} \text{Fall of kindergarten (T1)} \\ \text{Spring of kindergarten (T2)} \\ \text{Fall of 1}^{\text{st}}\text{ grade (T3)}^{2} \\ \text{Spring of 1}^{\text{st}}\text{ grade (T4)} \\ \text{Fall of 2}^{\text{nd}}\text{ grade (T5)} \\ \text{Spring of 2}^{\text{nd}}\text{ grade (T6)} \\ \text{Spring of 3}^{\text{rd}}\text{ grade (T7)} \\ \text{Spring of 4}^{\text{th}}\text{ grade (T8)} \\ \text{Spring of 5}^{\text{th}}\text{ grade (T9)} \end{matrix}$$

These two linear models demonstrated a poor fit. The LGM of working memory development in the Autism group (Model 1) had χ^2=134.779, df = 23, CFI = 0.896, RMSEA = 0.132, SRMR = 0.114). The LGM of WM development in the NT group (Model 2) had χ^2=2181.057, df = 23, CFI = 0.730, RMSEA = 0.166, SRMR = 0.124). Both models demonstrated fit indices far below the aforementioned criteria (Hu & Bentler, 1999).

In order to improve the model fit, a piecewise LGM was built for each subgroup. Piecewise linear models are a flexible and parsimonious approach to estimate nonlinear longitudinal trajectories (Flora, 2008). Piecewise models capture nonlinearity by adding another latent slope factor to estimate two "pieces" of linear change over time. The piecewise model is

$$Y_{it} = \alpha_i + \lambda_{1t}\beta_{1i} + \lambda_{2t}\beta_{2i} + \varepsilon_{it}$$

With piecewise models, a decision needs to be made for the transition point, or a "knot" representing a time point when the two linear slopes meet.

Final Model for Working Memory in Autism Group. To estimate the optimal location of the "knot," sample means for each time point were plotted. Upon visual examination of the

[2] T3 and T5 are excluded from the analysis due to high missingness

WM trajectory of the Autism sample, either T6 or T7 appeared to be a good location for the knot. Therefore, two piecewise models were developed with a knot at T6 and with a knot at T7 (Model 3 and Model 4 respectively) for the Autism group. Both models improved the fit indices significantly as compared to the linear model. The fit indices were χ^2=36.618, df = 19, CFI = 0.984, RMSEA = 0.058, SRMR = 0.040 for Model 3, and χ^2=54.652, df = 19, CFI = 0.967, RMSEA = 0.082, SRMR = 0.065 for Model 4. Because Model 3 met the model evaluation criteria outlined previously, this model was chosen as the final model for the Autism group. The fixed factor loading matrix for the final model (Model 3 with knot at T6) is:

$$\Lambda = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 2 & 0 \\ 1 & 3 & 0 \\ 1 & 4 & 0 \\ \mathbf{1} & \mathbf{5} & \mathbf{0} \\ 1 & 5 & 2 \\ 1 & 5 & 4 \\ 1 & 5 & 6 \end{bmatrix} \begin{matrix} \text{Fall of kindergarten (T1)} \\ \text{Spring of kindergarten (T2)} \\ \text{Fall of } 1^{st} \text{ grade (T3)[3]} \\ \text{Spring of } 1^{st} \text{ grade (T4)} \\ \text{Fall of } 2^{nd} \text{ grade (T5)} \\ \textbf{Spring of } \mathbf{2^{nd}} \textbf{ grade (T6) - knot} \\ \text{Spring of } 3^{rd} \text{ grade (T7)} \\ \text{Spring of } 4^{th} \text{ grade (T8)} \\ \text{Spring of } 5^{th} \text{ grade (T9)} \end{matrix}$$

Final Model for Working Memory in NT Group. Upon visual examination of the WM trajectory of the NT group, T4 appeared to be a good location for the knot. Therefore, a piecewise model was developed with a knot at T4 (Model 5) for the NT group. This model improved the fit indices significantly as compared to the linear model. The fit indices were χ^2=268.236, df = 19, CFI = 0.969, RMSEA = 0.062, SRMR = 0.033. As this model met the model evaluation criteria very closely, this model was chosen as the final model for the NT group. The fixed factor loading matrix for the final model (Model 5 with knot at T4) is:

[3] T3 and T5 are excluded from the analysis due to high missingness

$$\Lambda = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 2 & 0 \\ \mathbf{1} & \mathbf{3} & \mathbf{0} \\ 1 & 3 & 1 \\ 1 & 3 & 2 \\ 1 & 3 & 4 \\ 1 & 3 & 6 \\ 1 & 3 & 8 \end{bmatrix} \begin{matrix} \text{Fall of kindergarten (T1)} \\ \text{Spring of kindergarten (T2)} \\ \text{Fall of 1}^{\text{st}}\text{ grade (T3)}^{4} \\ \textbf{Spring of 1}^{\textbf{st}}\textbf{ grade (T4) - knot} \\ \text{Fall of 2}^{\text{nd}}\text{ grade (T5)}^{5} \\ \text{Spring of 2}^{\text{nd}}\text{ grade (T6)} \\ \text{Spring of 3}^{\text{rd}}\text{ grade (T7)} \\ \text{Spring of 4}^{\text{th}}\text{ grade (T8)} \\ \text{Spring of 5}^{\text{th}}\text{ grade (T9)} \end{matrix}$$

Fit indices for all unconditional Latent Growth Models built for the Working Memory domain are summarized in Table 3.

Unconditional Model: Cognitive Flexibility

Next, unconditional latent growth models for the Autism group and the NT group for the Cognitive Flexibility domain were developed. The characteristics of CF developmental trajectory (i.e., starting point and rate of growth) for each subgroup were modeled as latent variables. Cognitive Flexibility was assessed throughout nine time points in the dataset, and each time point except for T3 and T5 served as a manifest variable in the model.

The same procedures were followed when determining the best fitting LGM for both groups on their CF development. Linear models were built first for the Autism group and the NT group (Model 6 and Model 7 respectively). However, both linear models demonstrated a poor fit. The linear LGMs of cognitive flexibility development had χ^2=587.476, df = 21, CFI = 0.841, RMSEA = 0.119, SRMR = 0.104 for the Autism group (Model 6), and had χ^2=1410.591, df = 23, CFI = 0.831, RMSEA = 0.074, SRMR = 0.055 for the NT group (Model 7). Both models

[4] T3 and T5 are excluded from the analysis due to high missingness

demonstrated fit indices far below the aforementioned criteria (Hu & Bentler, 1999). In order to improve the model fit, a piecewise LGM was built for each subgroup.

Final Model for Cognitive Flexibility in Autism Group. To estimate the optimal location of the "knot," sample means for each time point were plotted. Upon visual examination of the CF trajectory of the Autism sample, T6 appeared to be a good location for the knot. Therefore, a piecewise model was developed with a knot at T6 for the Autism group. This model (Model 8) improved the fit indices significantly as compared to the linear model. The fit indices were χ^2=28.695, df = 19, CFI = 0.983, RMSEA = 0.043, SRMR = 0.051. This model was chosen as the final model for the Autism group.

Final Model for Cognitive Flexibility in NT Group. Similar to the other piecewise models built, sample mean plot was visually examined. It appeared that T4 may be a good location for the knot, although it was less clear with visual examination alone. A piecewise model was built with a knot at T4 first for the NT group. This model (Model 9) improved the fit indices when compared to the linear model, but still demonstrated a poor fit (χ^2=369.592, df = 19, CFI = 0.831, RMSEA = 0.074, SRMR = 0.055). Therefore, another piecewise model with three slopes (i.e., two knots) was built, with knots at T4 and T7. This model (Model 10) demonstrated the fit indices that were superior to the previous models but still did not meet the cut-off criteria (χ^2=188.896, df = 14, CFI = 0.916, RMSEA = 0.061, SRMR = 0.039). Further, a quadratic model was also built (Model 11). This model did not meet the cut-off criteria either (χ^2=236.404, df = 19, CFI = 0.895, RMSEA = 0.058, SRMR = 0.044). Although Model 10 and Model 11 demonstrated improved fit indices when compared to Model 9, Model 9 was chosen as the final model. The rationales for such a decision was as follows: 1) As is case with Model 9, Model 10 and Model 11 also did not meet the cut-off criteria and therefore these models may lead to inappropriate solutions (Hu & Bentler, 1999), and 2) As the LGMs for the NT group were built for comparison purposes only, having a model with different internal structures (e.g., different number of "knots," linear vs. quadratic) would not yield useful comparison against the Autism group.

Taken together, findings from this model (Model 9) should be interpreted with extreme caution due to the fit indices not meeting the recommended criteria. Though the statistical findings from this model are reported in this study, substantiative comparisons were not made between the Autism group and the NT group in depth on their CF trajectories. Fit indices for Unconditional Latent Growth Models of Cognitive Flexibility are summarized in Table 4.

Results

Demographic Characteristics

A total of approximately 18,170 students participated in the ECLS-K: 2011 data collection. Of those, approximately 310 students were identified as having a diagnosis of autism. In addition, approximately 3,410 students were identified as having no known diagnosis. Students' race and parents' educational levels did not differ significantly ($p > 0.05$) among the Autism group and the NT group. However, students' sex assigned at birth and the family's income levels differed significantly ($p < 0.05$). The group difference was most pronounced in the students' sex assigned at birth, such that in the Autism group, only 18% of the students were female while 54% of the students were female in the NT group. Demographic characteristics of the Autism sample and the NT sample are illustrated in Table 5.

Parameter Estimates: Working Memory

Several factors were examined to assess the working memory trajectory within the Autism group and the NT group. First, the time point where the rate of growth in the WM development decreases (i.e., the “knot”) in the piecewise model as well as the rates of growth (i.e., latent slopes) were identified for each subgroup. In the Autism group, the first latent slope spanned from Fall of kindergarten (T1) to Spring of 2nd grade (T6), and the slope was 7.806 ($p<0.001$). The “knot” was identified at T6, and the second latent slope spanned from Spring of 2nd grade (T6) to Spring of 5th grade (T9). The second slope was 4.131 ($p<0.001$). In the NT group, the first latent slope spanned from Fall of kindergarten (T1) to Spring of 1st grade (T4), and the slope was 11.132 ($p<0.001$). The “knot” was identified at T4, and the second latent slope spanned from Spring of 1st grade (T4) to Spring of 5th grade (T9). The second slope was 3.922 ($p< 0.001$).

Next, the relationship between the starting point (i.e., latent intercept) and the latent slopes in the WM trajectories were examined. In the Autism group, the correlation between the intercept and the first slope was not statistically significant ($p=0.852$). However, the correlation between the intercept and the second slope (T6-T9) was statistically significant with the standardized coefficient of -0.270 ($p=0.013$). Moreover, the correlation between the first latent slope and the second latent slope was not statistically significant ($p=0.167$). In the NT group, the correlation between the latent intercept and the first latent slope was statistically significant ($p<0.001$) with the standardized coefficient of -0.786, and the correlation between the latent intercept and the second latent slope was also statistically significant ($p=0.002$) with the standardized coefficient of -0.119. However, the correlation between the first and the second latent slopes was not statistically significant ($p=0.693$).

Parameter Estimates: Cognitive Flexibility

Latent intercepts, latent slopes and locations of the “knots” were identified for the CF domain for the Autism and NT group. In the Autism group, the first latent slope spanned from

Fall of kindergarten (T1) to Spring of 2nd grade (T6), and the slope was 3.389 ($p<0.001$). The "knot" was identified at T6, and the second latent slope spanned from Spring of 2nd grade (T6) to Spring of 5th grade (T9). The second slope was 1.447 ($p<0.001$). In the NT group, the first latent slope spanned from Fall of kindergarten (T1) to Spring of 1st grade (T4), and the slope was 3.196 ($p<0.001$). The first "knot" was identified at T4, and the second latent slope spanned from Spring of 1st grade (T4) to Spring of 5th grade (T9). The second slope was 0.540 ($p<0.001$). Taken together, the locations of the "knot" in the CF trajectories coincided with the "knot" in the WM trajectories for both the Autism and NT group.

Next, the relationship between the starting point (i.e., latent intercept) and the latent slopes in the CF trajectories was examined. In the Autism group, the correlation between the intercept and the first slope was statistically significant with a standardized coefficient of -0.738 ($p<0.001$). Further, the correlation between the intercept and the second slope (T6-T9) was also statistically significant with a standardized coefficient of -0.537 ($p<0.001$). Moreover, the correlation between the first latent slope and the second latent slope was not statistically significant ($p=0.828$). In the NT group, the correlation between the intercept and the first slope was statistically significant with a standardized coefficient of -0.873 ($p<0.001$). Further, the correlation between the intercept and the second slope was also statistically significant with a standardized coefficient of -0.633 ($p<0.001$). Lastly, the correlation between the first latent slope and the second latent slope was statistically significant with a standardized coefficient of 0.272 ($p<0.001$). Parameter estimates for the WM and CF domains are summarized in Table 6.

Heterogeneity in the Developmental Trajectories

In order to address the third research question, random effects, or the variance terms for the latent slopes and the estimates at each time point were estimated. These variances reflect the degree of individual differences of the rate of growth, and their performances at each time point respectively. It is important to note that, since the Autism group and the NT group had vastly different sample sizes, direct between-group comparisons on the variances are not to be made. Instead, the changes in the variability over time within each group, and the overall trend of the variability at each time point are analyzed.

Heterogeneity in the Rates of Growth. First, individual differences (i.e., variances) for the latent slopes in the WM trajectories were estimated. The model-implied variances were 20.861 for the first slope and 11.885 for the second slope within the Autism group. For the NT group, the model-implied variances were 33.118 for the first slope and 2.178 for the second slope. Figure 1 illustrates the individual variability of the latent slopes of these two groups.

Second, the individual differences for the latent slopes in the CF trajectories were estimated. The model-implied variances were 15.442 for the first slope and 3.094 for the second slope within the Autism group. For the NT group, the model-implied variances were 5.300 for the first slope, and 0.196 for the second slope. Figure 2 illustrates the individual variability of the latent slopes of these two groups.

Heterogeneity at Each Time Point. Lastly, the trend in the individual differences at each time point from T1 to T9 for both groups in their WM trajectories were examined. The model-implied variances for the Autism group in their WM trajectory started at 258.156 at T1, but fluctuated throughout the trajectory, and ended with 176.236 at T9. However, the variances for the NT group in their WM trajectory were more predictable: It started at 371.513 at T1, then decreased to 137.205 at T9.

With the CF trajectories, variances in the Autism group started at 323.642, then showed a decreasing trend with a minor fluctuation in T2 and T4. It ended with 24.131 at T9. The variances for the NT group again demonstrated a more predictable trend: It started at 162.424 at T1, then consistently decreased to 8.961 at T9. These variances are displayed in Figures 3 through 6.

Discussion

The current study explored the quality of longitudinal trajectories of working memory and cognitive flexibility development in children on the autism spectrum, and compared those trajectories with their NT peers. More specifically, I explored how their rates of growth changed over time during their elementary school years, and how their growth rates were related to their initial status in their development. In addition, I investigated how the degree of heterogeneity in autistic children's WM and CF performances at each time point changed over time, and how they compared to their NT peers.

Broadly, the present study found that the developmental trajectories of WM and CF for both autistic children and their NT peers were not linear. In line with previous literature, both groups made steeper gains when they were younger, and the rate of growth slowed down as they got older. However, some unique qualities in the developmental trajectories of autistic children were found, such as when their rate of growth starts to slow down, how their performances at school entry were related to their overall growth, and how their heterogeneity in their performances changed over time.

Non-linear Developmental Trajectories of Working Memory and Cognitive Flexibility

The current study adds to the literature base on children's development in executive functioning in that it explored the age range beyond the narrow preschool-age range that is commonly studied in the field of education, child development and educational psychology (Best & Miller, 2010). As hypothesized, children made substantial gains in their WM and CF development during their elementary school years. However, the development in neither the Autism group nor the NT group were linear – their rate of growth started to slow down as they got older, while the time point where the rate of growth started to slow down differed among the Autism group and the NT group.

Rates of Growth and Locations of the "Knot."

In both domains of EF examined in this study, the NT group appeared to make a rapid gain during the first two years of their elementary years (Fall of kindergarten to spring of 1st grade), then their gains started to slow down beyond that point. While Spring of 1st grade was identified as the "knot" for the NT group, the Autism group continued to make rapid growth in their WM and CF performances for another year until the end of the 2nd grade before they started to slow down. For instance, although the Autism group's rate of growth in the WM trajectory before the "knot" was slower than that of the NT group, it spanned across a longer period of time. Moreover, the rates of growth in both domains beyond the "knot" (i.e., slope 2) for the Autism group were higher than those of the NT group. This implies that autistic children continue to make relatively rapid growth while the rates of growth in their NT peers declines substantially once they reach the "knot." Taken together, we can infer that autistic children may be making slower-but-steady gains in EF which allows for a larger window of opportunities for growth. Consequently, such a window allows for researchers, educators and interventionists to examine ways to maximize their growth during these "sensitive periods."

Relationship Between Initial Status and Rates of Growth: Working Memory

In the working memory domain, autistic children's initial status at Fall of kindergarten was found to be negatively correlated with their rate of growth *after* the "knot" (slope 2) but not with the rate of growth *before* the "knot" (slope 1). In contrast, the initial status in the NT group was negatively correlated with both slopes. This implies that autistic children who started at a low standing at the starting point made more rapid gains after 2nd grade, which was when both the NT group and the Autism group as a whole started to slow down on their progress.

There is emerging evidence that autistic children demonstrate persistent impairment in working memory with little or no improvements regardless of age (e.g., Andersen et al. 2015; Chen et al. 2016; Vogan et al. 2018). However, these studies were either cross-sectional with children of varying age in the sample and compared their performances against their NT peers to conclude as having persistent impairment (Chen et al. 2016), or some longitudinal studies investigated only 2 years of development (Andersen et al. 2015; Vogan et al. 2018). These studies also included a small sample with age ranges from 8 to adolescent years, while significant gains are reported in younger age groups.

In contrast, longitudinal analyses that span across six years in this study revealed that some autistic children, especially those who started at a lower standing, started to make rapid gains after three years. As some of the aforementioned studies only included high-functioning autistic children (e.g., Andersen et al. 2015) with only a two-year window of development, the unique developmental trajectory of these “late-bloomers” may not have been captured appropriately in previous studies. As such, current findings suggest that there is a risk of making misleading conclusions about autistic children’s WM trajectories when their samples include a narrow range of age, when they examine a short window of time for longitudinal analyses, or when they define “persistent impairment” as performing poorer when compared in a parallel-manner with their NT group. Findings from this analysis further highlight the possibility that the

"Matthew effect[6]" may not apply when describing autistic children's unique developmental trajectories.

Relationship Between Initial Status and Rates of Growth: Cognitive Flexibility

On the contrary, in the cognitive flexibility domain, autistic children's initial status at Fall of kindergarten was found to be negatively correlated with both slopes: their rate of growth before the "knot" (slope 1) as well as their rate of growth after the "knot" (slope2). This implies that autistic children who started at a low standing at the starting point with their CF performances made more rapid gains throughout their elementary school years when compared to those who started at a high standing at Fall of kindergarten. The magnitudes of the correlations were moderate to high for both slopes. Such aspects of the cognitive flexibility trajectory for the Autism group were similar to those of the NT group. In other words, the CF trajectory of the Autism group was more predictable when compared to their WM trajectory. Such strong and negative relationships between the initial status and both slopes are promising indicators that autistic children who demonstrated difficulties with cognitive flexibility at a young age have the potential to make rapid gains as they move through their elementary school years, especially during the first three years.

Relationship Between the First and the Second Slope

For both WM and CF developmental trajectories, no relationships were found between the first and second slope in the Autism group. In other words, autistic children making rapid gains during the first three years of their elementary school years did not necessarily signify that they would make more or less gains during the second half of their elementary years. Similarly,

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[6] Stanovich (1986) termed the Matthew Effect, which states that those who have more academic ability show a greater ratio of growth compared to those who are at a disadvantage in academic ability.

autistic children making slow gains during their early elementary school years did not necessarily predict whether they would make slow or rapid gains during the second half of their elementary school years. Such a finding is another indication that drawing conclusions on autistic children's EF development based on cross-sectional studies or longitudinal studies with less than a few years under observation may not be providing an accurate representation of their developmental trajectories.

Relationship between Each Time Point

One side finding from the current study was that children's working memory or cognitive flexibility performances at a young age is a poor indicator for later WM or CF performances (Tables 7-10). In other words, children's performances farther from the "plateauing" point have weaker predictability of their stabilized level of EF. This was a meaningful finding as many researchers have used children's early EF performances as a predictor for their long term academic and school success (e.g., Bull et al. 2008; Clark et al. 2013; Prager et al. 2016). A closer examination is warranted when making such predictions as there may be other, third variables, or mediating or moderating factors that influence children's long-term performances besides their early EF performances.

Heterogeneity in Developmental Trajectories:

Broadly, both Autism and NT groups displayed greater heterogeneity in their EF performances during the first few years of their elementary school years, but their level of heterogeneity decreased as they got older. However, the Autism group as a whole displayed greater fluctuation throughout their elementary school years when compared to their NT peers.

Heterogeneity in Rates of Growth. Overall, the heterogeneity in both groups decreased from slope 1 to slope 2, demonstrating a greater diversity in rate of growth during the first few years of their elementary school years, then their rate of growth became similar to each other as their performances regress towards the mean and reach the "plateauing" points.

In the WM domain, the heterogeneity of slope 1 in the NT group was greater than the Autism group, reflecting greater diversity in their rates of growth. But with slope 2, the NT group showed a very small variance compared to the Autism group, implying that the performances of the NT group became similar to each other as they reach the "plateauing" point. However, the Autism group continued to show high variability in their rates of growth during the later years of their elementary school. Further, the decrease from slope 1 to slope 2 is not as drastic in the Autism group as it is in the NT group. These findings reflect a continued heterogeneity in the rates of growth of the Autism group.

In the CF domain, the heterogeneity of slope 1 was far greater in both Autism and NT groups. When both groups reached the later years of their elementary school (i.e., slope 2), their heterogeneity decreased drastically. However, the diversity in the rates of growth in the Autism group was still relatively high, indicating some degree of continued heterogeneity in their rates of growth during the later years of elementary school. Taken together, it can be inferred that autistic students' rates of growth do not converge into an "expected range" as their NT peers do. Instead, they continue to follow their own trajectories even when they are approaching the "plateauing" points.

Heterogeneity in the EF Performances at Each Time Point. Overall, the heterogeneity in both groups at each time point demonstrated a decreasing trend, indicating greater individual differences in their performances when they are younger, and such differences diminishing as they regress towards the mean and reach the "plateauing" points.

However, in the WM domain, the trend in heterogeneity in the Autism group was far less predictable – the variances fluctuated throughout the development while it was decreasing in the long run. In contrast, the NT group showed a more predictable trend, starting with high variability when they are younger, and the heterogeneity decreasing consistently as they get older.

In the CF domain, the trend in heterogeneity in both groups demonstrated a predictable and decreasing trend. However, the Autism group started with very high heterogeneity in the beginning, but the trend became similar between the two groups as they enter the second half of their elementary school years.

With both WM and CF domains, the two groups started with a wide gap in the level of heterogeneity at the starting point, but such differences in the level of heterogeneity at the end of trajectories were small, indicating that the diversity in their performances became minimal as they reach the "plateauing" points.

Limitations

A few limitations must be noted in this study. First, according to the Center for Disease Control (CDC), the prevalence of autism continues to increase, from 1 in 150 children in 2000 to 1 in 44 children (2.27%) in 2018 (Maenner et al. 2021). Considering this rate as accurate, children identified as having autism are underrepresented in the ECLS-K 2011 dataset. A total of over 18,000 children were sampled for the data collection, and only about 310 children (1.72%) were identified as having a professional diagnosis of autism as reported by parents or their teachers. This may be due to the nonresponse rate of the parent interview, underreporting by parents, or attrition. Another limitation is that the data collection starts in Fall of kindergarten year, while the growth spurt in EF skills is found to occur between the ages of 3 and 5.

Therefore, findings from this study do not include analyses from an important early developmental period of EF and will not capture the comprehensive trajectories of their growth. Further, standardized cognitive tests such as the IQ test could have been a meaningful covariate to examine the relationship between autistic children's cognitive ability and their growth trajectories of EF. However, this information is not included in the dataset. Though I attempted to create a matched sample with children's reading and math scores, it was not successful due to a significant portion of the autistic students not having these scores. This led to a NT comparison group that is distinctively larger than the Autism group. Moreover, the direct measures used to assess children's working memory and cognitive flexibility (Numbers Reversed, DCCS™) are only one type of measure for those skills. For instance, the Numbers Reversed assessment only assesses children's auditory working memory, but not visuospatial working memory. Lastly, due to the inhibition domain not being included in this study, the findings from this study do not provide the entire developmental trajectories of children's EF development. Regardless, this study provides unique perspectives and deeper understanding of the qualities of the developmental trajectories of WM and CF for autistic children during their elementary school years. Further studies that examine the entire developmental trajectories from toddler years to adulthood would be especially beneficial to gain a better understanding of the EF developmental trajectories for the autistic population.

Implications & Conclusion

All the findings from the current study converge into an important implication that autistic children's working memory and cognitive flexibility may be more malleable at a younger age with a great diversity in their performances, and they may have a wider window for growth than their NT peers. Moreover, the predictability of later EF skills in autistic children was found to decrease as time points get farther apart. This may be due to other external factors that may contribute to autistic children's developments as they get older. Taken together, it is critical that researchers examine possible contributing factors for autistic children's maximal growth in their EF development during their "sensitive periods" in order to maximize their potential.

It is also noteworthy that autistic children follow their own unique developmental paths with a greater diversity in the shape of their developmental trajectories instead of following the predictable growth paths that their NT peers were found to follow. Therefore, drawing conclusions on autistic children's EF development based on the expected development of their NT peers may not be appropriate. Instead, educators, parents and researchers' understanding of the heterogeneous and unique nature of autistic children's EF development is critical.

Table 1. Data collection schedule from T1 to T9

	Semester & Grade	School year
T1	Fall of kindergarten	2010-11
T2	Spring of kindergarten	
T3	Fall of first grade	2011-12
T4	Spring of first grade	
T5	Fall of second grade	2012-2013
T6	Spring of second grade	
T7	Spring of 3rd grade	2014
T8	Spring of 4th grade	2015
T9	Spring of 5th grade	2016

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 2. Percentage of Missingness in the Dataset at Each Time Point

Time Point	% of Missingness			
	Working Memory		Cognitive Flexibility	
	Autism Group	NT Group	Autism Group	NT Group
T1	30.19%	11.33%	29.87%	11.33%
T2	14.61%	1.67%	14.61%	1.67%
T3*	73.38%	63.43%	73.38%	63.43%
T4	21.43%	1.82%	21.10%	1.82%
T5*	73.70%	64.75%	73.38%	64.84%
T6	24.68%	2.52%	28.57%	2.76%
T7	29.22%	3.38%	33.44%	3.85%
T8	33.77%	4.40%	36.36%	4.93%
T9	38.64%	5.37%	39.61%	5.72%

* excluded from the analysis due to high percentage of missingness

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 3. Fit indices for Unconditional Latent Growth Models of Working Memory

Working Memory	Subgroup	Model Type	χ^2	df	p	CFI	RMSEA	SRMR
Model 1	Autism	Linear	134.779	23	0.000	0.896	0.132	0.114
Model 2	NT	Linear	2181.057	23	0.000	0.730	0.166	0.124
Model 3*	Autism	Piecewise; Knot at T6	36.618	19	0.009	0.984	0.058	0.040
Model 4	Autism	Piecewise; Knot at T7	54.652	19	0.000	0.967	0.082	0.065
Model 5*	NT	Piecewise; Knot at T4	268.236	19	0.000	0.969	0.062	0.033

* final models

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 4. Fit indices for Unconditional Latent Growth Models of Cognitive Flexibility

Working Memory	Subgroup	Model Type	χ^2	df	p	CFI	RMSEA	SRMR
Model 6	Autism	Linear	587.476	21	0.000	0.841	0.119	0.104
Model 7	NT	Linear	1410.591	23	0.000	0.831	0.074	0.055
Model 8*	Autism	Piecewise; Knot at T6	28.695	19	0.071	0.983	0.043	0.051
Model 9*	NT	Piecewise; Knot at T4	369.592	19	0.000	0.831	0.074	0.055
Model 10	NT	Piecewise; Knots at T4 & T7	188.896	14	0.000	0.916	0.061	0.039
Model 11	NT	Quadratic	236.404	19	0.000	0.895	0.058	0.044

* final models

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 5. Demographic characteristics of the Autism sample and the NT sample

Demographic Characteristics	Autism (N=310)	NT (N=3410)	Pearson Chi-square	p
Race				
White	170 (54%)	1930 (57%)		
Black / African-American	20 (8%)	220 (6%)		
Hispanic	70 (21%)	720(21%)	2.1	0.717
Asian-American / Pacific Islanders / Native American	40 (11%)	380 (11%)		
Other	20 (7%)	170 (5%)		
Sex Assigned at Birth				
Female	60 (18%)	1840 (54%)	147.221	<0.001*
Male	250 (82%)	1570 (46%)		
Income				
$20,000 or less	50 (19%)	430 (13%)		
$20,000 to $30,000	30 (13%)	310 (9%)		
$30,000 to $50,000	50 (20%)	510 (15%)		
$50,000 to $75,000	40 (14%)	610 (18%)	23.774	<0.001*
$75,000 to $100,000	30 (13%)	570 (17%)		
$100,000 to $200,000	40 (16%)	770 (23%)		
$200,000 or more	20 (6%)	210 (6%)		
Parents' Educational Level				
High School	50 (24%)	840 (25%)	4.759	0.093
2-4 year College	140 (62%)	1870 (55%)		
Postgraduate Degree	30 (15%)	690 (20%)		

Note: N rounded to the nearest 10 per confidentiality agreement

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 6. Summary of Parameter Estimates for WM and CF domains

	Working Memory		Cognitive Flexibility	
	Autism	NT	Autism	NT
Knot	Spring of 2nd Grade (T6)	Spring of 1st Grade (T4)	Spring of 2nd Grade (T6)	Spring of 1st Grade (T4)
Latent Intercept (Initial Status)	420.077	444.854	66.610	83.465
Latent Slope 1	7.806	11.132	3.389	3.193
Latent Slope 2	4.131	3.922	1.447	0.540
Correlation between Initial Status and Slope 1	-0.020 (p=0.852)	**-0.786** (p=0.000*)	**-0.738** (p=0.000*)	**-0.873** (p=0.000*)
Correlation between Initial Status and Slope 2	**-0.270** (p=0.013*)	**-0.119** (p=0.002*)	**-0.537** (p=0.000*)	**-0.633** (p=0.000*)
Correlation between Slope 1 and Slope 2	-0.215 (p=0.167)	-0.022 (p=0.693)	0.031 (p=0.828)	**0.272** (p=0.000*)

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 7. Model-Implied Correlations between Each Time Point: Working Memory (Autism Group)

	T1	T2	T4	T6	T7	T8	T9
T1	1						
T2	0.672	1					
T4	0.604	0.629	1				
T6	0.560	0.620	0.719	1			
T7	0.529	0.586	0.681	0.778	1		
T8	0.484	0.537	0.625	0.715	0.741	1	
T9	0.455	0.506	0.591	0.677	0.739	0.784	1

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 8. Model-Implied Correlations between Each Time Point: Working Memory (NT Group)

	T1	T2	T4	T6	T7	T8	T9
T1	1						
T2	0.525	1					
T4	0.345	0.370	1				
T6	0.357	0.382	0.466	1			
T7	0.352	0.375	0.456	0.510	1		
T8	0.340	0.361	0.436	0.511	0.568	1	
T9	0.312	0.331	0.396	0.487	0.564	0.632	1

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 9. Model-Implied Correlations between Each Time Point: Cognitive Flexibility (Autism Group)

	T1	T2	T4	T6	T7	T8	T9
T1	1						
T2	0.579	1					
T4	0.446	0.456	1				
T6	0.340	0.395	0.486	1			
T7	0.311	0.370	0.470	0.707	1		
T8	0.248	0.307	0.416	0.652	0.704	1	
T9	0.158	0.215	0.330	0.559	0.651	0.733	1

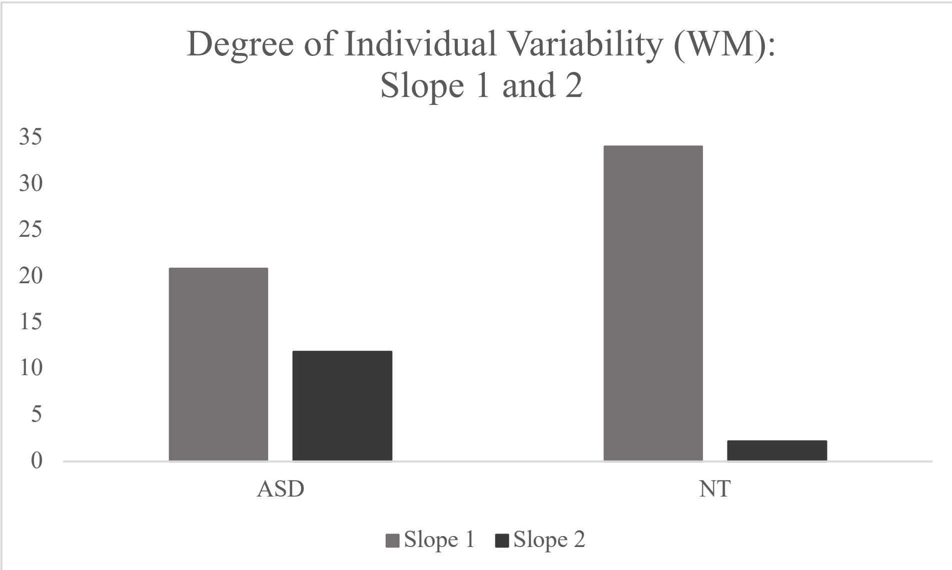
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 10. Model-Implied Correlations between Each Time Point: Cognitive Flexibility (NT Group)

	T1	T2	T4	T6	T7	T8	T9
T1	1						
T2	0.268	1					
T4	0.176	0.181	1				
T6	0.157	0.172	0.184	1			
T7	0.082	0.114	0.189	0.252	1		
T8	0.078	0.105	0.164	0.250	0.354	1	
T9	0.049	0.058	0.075	0.166	0.300	0.328	1

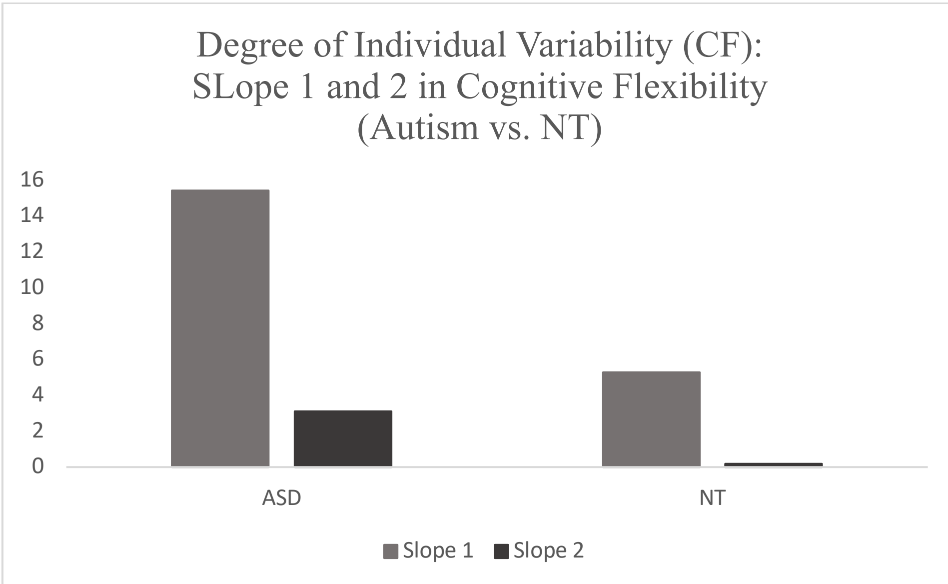
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Figure 1. Degree of individual variability of Slope 1 and 2 in Working Memory



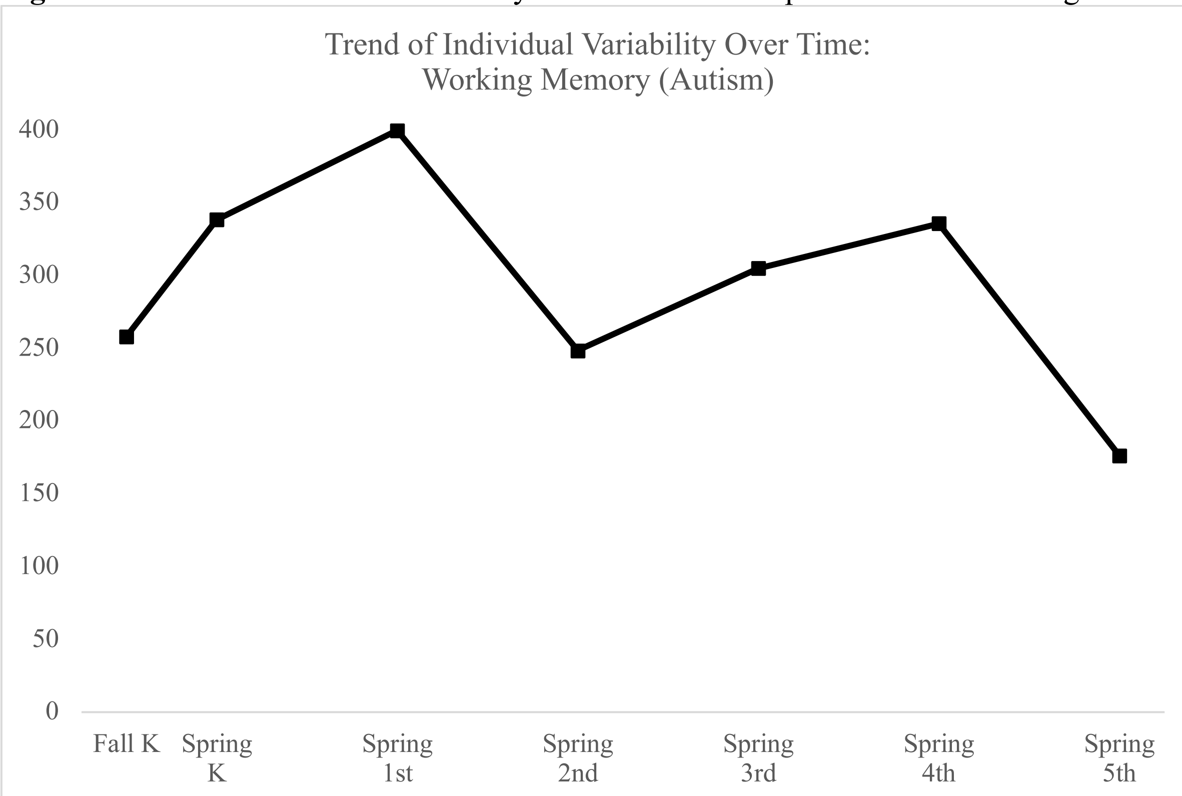
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Figure 2. Degree of individual variability of Slope 1 and 2 in Cognitive Flexibility



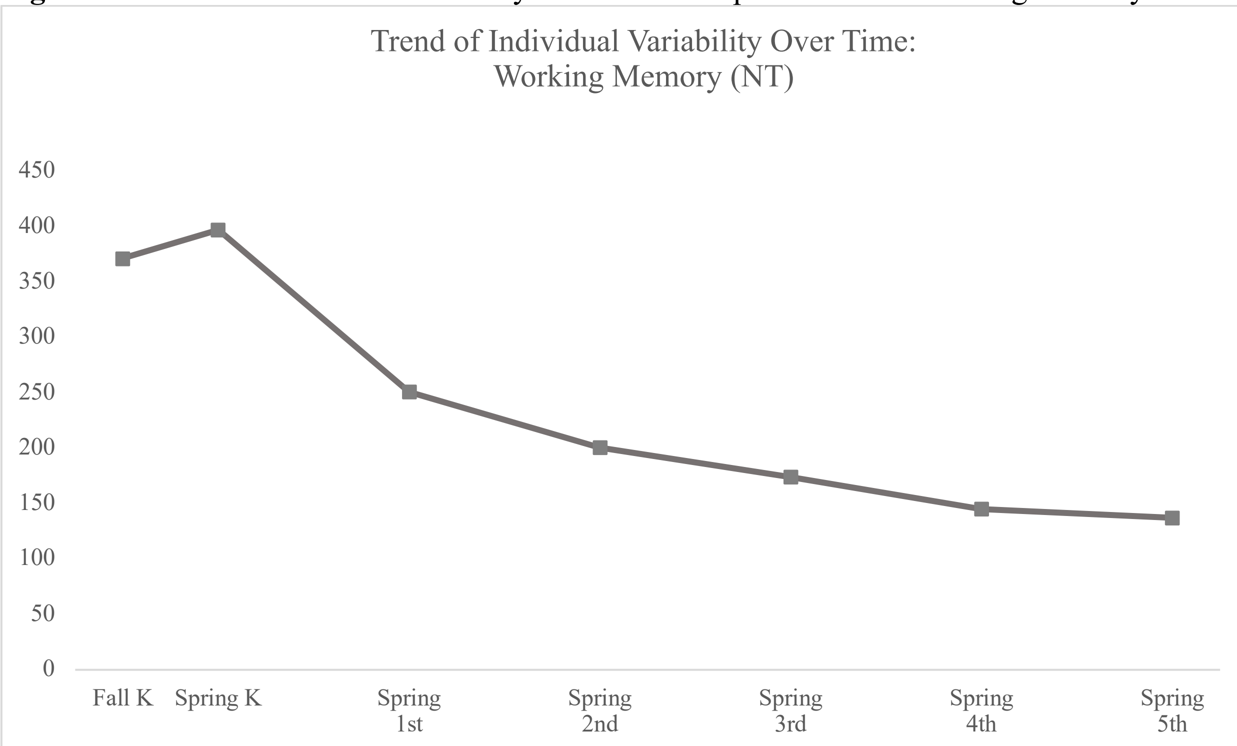
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Figure 3. Trend of Individual Variability in the Autism Group Over Time: Working Memory



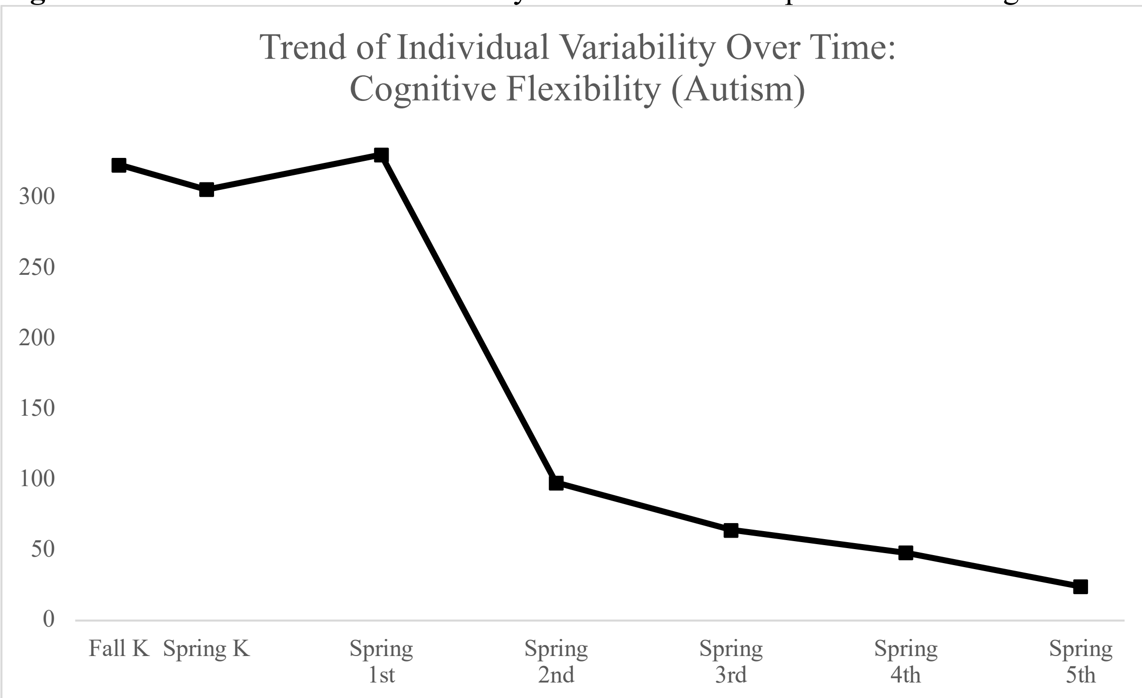
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Figure 4. Trend of Individual Variability in the NT Group Over Time: Working Memory



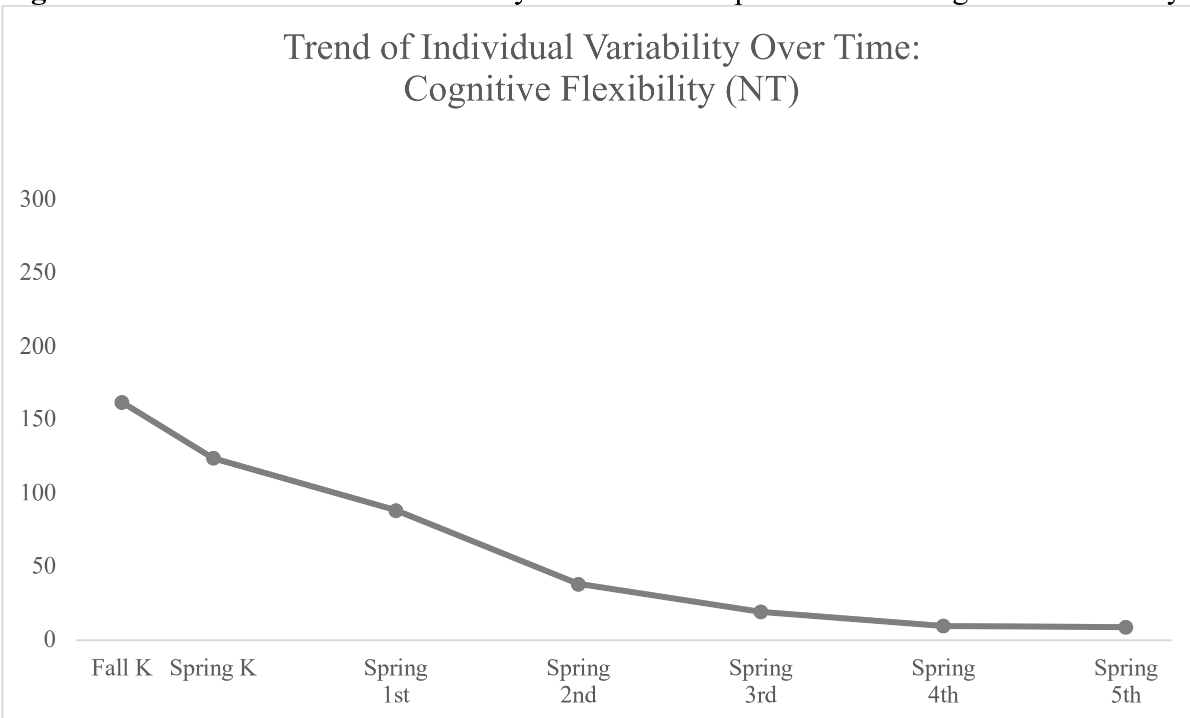
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Figure 5. Trend of Individual Variability in the Autism Group Over Time: Cognitive Flexibility



SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Figure 6. Trend of Individual Variability in the NT Group Over Time: Cognitive Flexibility



SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

CHAPTER III

Study Two: Predictors for Growth in Working Memory and Cognitive Flexibility in School-Aged Children with Autism

Abstract

Executive functioning (EF) in autistic children is highly malleable throughout their childhood, and various student-level and environmental factors play important roles in their development. This study used the Early Childhood Longitudinal Studies-Kindergarten Class of 2011 (ECLS-K: 2011). Conditional latent growth models were built to identify possible predictors for autistic children's working memory and cognitive flexibility performance upon entering kindergarten and their relative growth throughout their elementary school years. Findings indicate that socioeconomic status (SES) and students' approaches to learning (ATL) positively predicted autistic children's working memory performance upon entering kindergarten. Having ADHD, receipt of autism-related special education services at school, and students' ATL positively predicted autistic children's rate of growth in working memory during the first three years of their elementary school years, while student-teacher relationship (STR) predicted their rate of growth in working memory during the last three years of their elementary school. In addition, STR and ATL positively predicted autistic children's cognitive flexibility performance upon entering kindergarten, while living in a bilingual home environment positively predicted their rate of growth in cognitive flexibility during the first three years of autistic children's elementary school years. Implications and future directions are discussed.

Importance of Executive Functioning for School-Aged Children

During recent years, there has been a wealth of evidence that various components of EF in school-aged children have promising associations with positive school outcomes. For instance, EF is found to predict academic performance in children, especially in mathematics (e.g., Epsy et al. 2004; Kolkman et al. 2013) and literacy skills (e.g., Cantin et al. 2016; DeFranchis et al. 2017; Dilworth-Bart, 2012). Although there are some mixed findings in regards to the specific components of EF that may be responsible for children's academic skills, there is ample evidence that overall EF ability in children is positively associated with their academic skills in general (e.g., Bull et al. 2008; Clark et al. 2013; Prager et al. 2016). In addition to academic outcomes, EF skills are found to be associated with social, emotional and behavioral readiness which contribute to children's overall school success (Riggs et al., 2006; Schoemaker et al., 2013; Vogan et al., 2018; Zhou et al., 2007). Consequently, EF deficits in children can impose layers of challenges to building foundational skills for school success which can further lead to poor relationships with peers and teachers and poor overall adjustment to school.

Executive Functioning in School-Aged Children on the Autism Spectrum

Data indicate that autistic children often experience EF difficulties, which can manifest themselves through poor self-regulation, inability to focus and follow through with tasks, following directions, working cooperatively with others, and consequently poor academic outcomes (Hutchison et al., 2020; Otterman et al., 2019; Ros et al., 2018). Not surprisingly, autistic children are found to have greater challenges upon school entry when compared to their typically developing peers. Common challenges experienced specifically by autistic children, such as social skills, pragmatic communication, self-regulation, independence skills, as well as difficulty with generalization of acquired skills across settings make these children more vulnerable in their school setting. For instance, in Quintero and McIntyre's longitudinal study (2011), teachers reported greater concerns regarding school readiness for children with autism than for children with other developmental disabilities.

Studies find that EF deficits are correlated with the common characteristics of autism (Lopez et al. 2005). Difficulties across all EF subdomains at young ages were more prevalent in the autism sample when compared to their typically developing peers (Granader et al, 2014; Otterman et al. 2019). Furthermore, children's EF skills at early ages predicted their autism traits as measured by The Autism Diagnostic Observation Schedule – second edition (ADOS-2; Lord et al. 2012), and adaptive skills as measured by Vineland Adaptive Behavior Scales – second edition (Vineland-2; Sparrow et al. 2005) 12 years later when they reached adulthood (Kenny et al. 2018). Such findings demonstrate prognostic significance in EF skills at an early age and therefore place a greater emphasis on the urgency of addressing EF skills for young children with autism in order to foster positive long-term outcomes.

Development of Executive Functioning in Autistic Children Throughout Their Elementary School Years

As the findings from Study 1 indicate, autistic children continue to make significant progress with their EF performance throughout their elementary school years. These findings are consistent with previous studies on neurotypical children (e.g., Zelazo & Carlson, 2012). More importantly, Study 1 found that autistic children's "sensitive period" with high plasticity spans across a longer period of time when compared to their neurotypical peers. While there is a robust evidence base that children's inherent characteristics such as having autism or another developmental disability predicts greater challenges with their EF performance, many researchers demonstrate that environmental factors can also play an important role (see Hughes, 2011 for a review). Therefore, it is critical that researchers examine possible explanatory factors that are both internal (e.g., disability status) as well as external (e.g., family or school environments) that can contribute to autistic children's growth in EF during sensitive developmental periods. Taken together, the current study (Study 2) contributes to the existing research base by investigating the relationships between autistic children's EF developmental trajectories and possible explanatory factors contributing to growth in EF.

EF, Socioeconomic Status (SES) and Race

A family's high socioeconomic status (SES) is often linked to higher EF performances in children (e.g., Bernier et al., 2010; Hackman et al., 2015; Lengua et al., 2014). For example, St. John et al. (2019) found that SES was positively related with working memory, inhibitory control, and reaction time for working memory in kindergarten-age children. Research also found that the SES disparity in working memory was persistent from a very young age into middle childhood (Hackman et al., 2015), and even into early adulthood (Last et al., 2018). Moreover, a recent study indicates that EF skills in young children mediates the longitudinal relationship between their socioeconomic risk status and school readiness (Perry et al., 2018).

In addition to the SES disparity observed in children's EF performance, persistent racial disparities also appear to exist throughout children's EF development. More specifically, even after controlling for SES, racial gaps in children's EF performance persisted throughout their elementary school years, and such gap was most pronounced in Black and Hispanic children (Little, 2017).

While it is well-established that the SES and race are critical factors that can influence children's EF performance concurrently or at one point in time, less is known about whether SES and race have a longitudinal relationship with children's EF development or if they contribute to the rate of growth during sensitive periods of EF growth. Therefore, a closer examination of the relationships between SES, race, and the developmental trajectories of EF components in children with autism is indicated.

EF and Student Characteristics

Co-occurring Diagnoses. Many researchers agree that autism and ADHD share some phenotypic characteristics (e.g., Leitner, 2014) such as difficulties with pragmatic communication (Bishop & Baird, 2011) and perspective taking (Buitelaar et al., 1999). Not surprisingly, the data indicate that over 40% of children diagnosed with autism also meet criteria for a diagnosis of ADHD (Gnanavel et al., 2019). Another recent study found that about 23% of autistic children also had learning disabilities (Khachadourian et al., 2022).

EF deficits appear in children with ADHD (see Pennington & Ozonoff, 1996 for a review) as well as LD (Meltzer & Krishnan, 2007; Toll et al., 2011). Moreover, having co-occurring diagnoses of LD and ADHD appear to further impose difficulties in children's EF skills. More specifically, children with ADHD who also have LD were found to perform worse on EF tasks when compared to children with ADHD only (Mattison & Mayes, 2012). ADHD and LD appear to be closely related to autism in regards to EF skills; thus, the presence of co-occurring diagnoses must be taken into consideration when examining autistic children's EF development.

Sex Assigned at Birth. Gender differences are present in autism traits. Autistic males exhibit more externalizing behaviors and more stereotypic and repetitive behaviors than their female counterparts (Bargiela et al., 2016l Giarelli et al., 2010; May & Rinehart, 2013; Wijngaarden-Cremers et al., 2014). Autistic females were found to perform better on social-emotional reciprocity (Esler et al., 2022) and display higher motivation and capacity for maintaining friendships (Bargiela et al., 2016) when compared to their male counterparts. While many researchers have investigated gender differences in the behavioral profiles among autistic individuals, little is known whether such disparity exists in their neurobehavioral profiles as well. Emerging evidence suggests some gender differences in autistic children's EF profiles (Chouinard et al., 2019; Lemon et al., 2011), and such disparities in the autism characteristics among boys and girls warrant a closer examination on the effects of gender in autistic children's EF developmental trajectories.

EF and Approaches to Learning

Approaches to Learning (ATL) refers to a select set of positive learning behaviors such as keeping belongings organized, showing eagerness to learn new things, working independently, adapting to changes in routine easily, persisting in completing tasks, paying attention well, and following classroom rules (Torangeau et al. 2019). Evidence suggests that ATL is closely linked to children's school readiness (Lee, 2012; Vitiello & Greenfield, 2017). Further, children's early ATL is found to be associated with their long term school outcomes, especially in reading and math regardless of particular demographic characteristics (Li-Grining et al., 2010).

Skills related to ATL appear to be closely associated with EF skills (Vitiello & Greenfield, 2017). More specifically, poor working memory is found to contribute to inattentiveness and poor organizational and planning skills (Kofler et al., 2018), and cognitive flexibility is found to be linked to openness to learning new skills and to adapt to changes in routine (Steinmetz et al., 2011). Children's overall EF skills are often linked to their attentiveness, following rules in group settings and other behavioral and socioemotional skills that are necessary for their school readiness (Mann et al., 2017; Pellicano et al., 2017). Taken together, ATL is an important factor to be investigated when examining autistic children's developmental trajectories of EF skills.

EF and Student-Teacher Relationship

One of the factors that appears critical to children's positive school outcomes is the student-teacher relationship (STR). Quality of STR plays an important role in children's academic engagement (Pianta et al., 2012), especially for those children who are academically at risk (Roorda et al. 2011).

Not surprisingly, EF is found to be positively related to STR in young neurotypical children. More specifically, a recent meta-analysis revealed that quality of STR for school-aged children was linked to working memory and inhibition (Vandenbroucke et al., 2018). It was also found that children's EF skills prior to school entry positively predicted STR in kindergarten (McKinnon & Blair, 2018), and positive STR was found to be a consistent predictor for EF development in children (Cumming et al., 2020). Moreover, poorer EF was associated with lower teacher-rated kindergarten readiness for children with poor STR quality (Graziano et al., 2016).

Importantly, children with autism may be at greater risk for developing poor STR. Teachers report having a more difficult time building positive relationships with children with autism when compared to students with intellectual disability or typical development (Blacher et al. 2014). Based on the evidence that links children's EF skills and STR, EF may play an important role in autistic children's building of positive STR, and close examination of such relationships is essential in fostering school success in autistic children.

EF and Special Education Services & Interventions for Autism

While there are documented deficits in EF in autistic children, what remains unclear is the effectiveness of school-based intervention services in remediating autistic children's EF deficits. There is emerging evidence on the effectiveness of school-based EF interventions that directly target EF skills for autistic as well as for neurotypical children (Cavalli et al., 2022; Otero et al., 2014), but generalizability, availability and feasibility of these interventions remain as barriers for a wider population.

School-aged children with autism are entitled to various special education services as per the federal Individuals with Disabilities Education Act (IDEA). Seven-point-three million students in the United States, or 14% of all public school students receive special education services under the IDEA, and 11% of these students qualify for the special education services for their autism diagnosis (U.S. Department of Education, 2021). Common services that are identified in the IDEA include speech-language pathology and audiology services, physical and occupational therapies, early identification and assessment and counseling services (IDEA, 2004). These services are intended to assist children with disabilities so that they may benefit from their public education experience and to improve educational results by meeting their unique needs and providing necessary tools (IDEA, 2004). These autism-related special education services may directly or indirectly target EF skills as part of their educational interventions.

While little is known about the relationship between autism-related special education services and autistic children's EF performances, a school-based intervention that directly targets EF skills (Unstuck and On Target) was found to effect autistic children's EFS skills (Cannon et al., 2011). Therefore, it will be worthwhile to investigate if these services have any effect on their EF performances, as EF skills are an important predictor for overall school success for school-aged children.

EF and Health Outcomes

Children's healthy lifestyle factors such as diet, physical activity and sleeping habits are essential components in creating optimal learning outcomes (Jirout et al., 2019). There is emerging evidence that EF is positively linked to health-related behaviors (Allom & Mullan, 2014; Gray-Burrows et al., 2019). More specifically, EF was found to be related to healthy diet (Hall & Fong, 2013; Hall et al., 2008), intention to engage in physical activities (Hall et al., 2008), and health-related quality of life (Brown & Landgraf, 2010). Further, physical activity was often linked to improved working memory performance (Mora-Gonzalez et al., 2019; Mora-Gonzalez et al., 2021; Zach & Shalom, 2016), and poor working memory was found to be related to child obesity (Wu et al., 2017; Yang et al., 2018) and poor quality of sleep (Wilckens et al., 2014).

While the current literature base supports the relationship between EF, specifically working memory and health-related behaviors in the general population, less is known about these relationships among school-aged children. Moreover, while autistic children are often found to experience health-related challenges such as sleep difficulties (see Carmassi et al., 2019 for a review), poor diet (see Kral et al., 2013 for a review), and obesity (Broder-Fingert et al., 2014), little is known about the relationship between autistic children's health outcomes and their EF developmental trajectories. Therefore, it is important to examine such relationships in school-aged autistic children in order to support optimal learning and health outcomes.

EF and Bilingualism

Evidence suggests that bilingualism has a positive effect on children's EF development (Tran et al., 2019). Such benefits appear to be particularly pronounced in the cognitive flexibility domain (see Fox et al., 2019 for a review). Specifically, the positive effects of bilingualism on cognitive flexibility were apparent from a very young age at 24-months (Poulin-Dubois et al., 2011), and such a relationship persisted in school-aged children (Adi-Japha et al., 2010; Farrant et al., 2012; Gonzalez-Barrero & Nadig, 2019) as well as high school and college students (Christoffels et al., 2015; Kharkhurin, 2017).

While many researchers agree on the benefits of bilingualism on typically developing children's cognitive flexibility and overall learning outcomes, less is known about whether such benefits extend to autistic children in a similar way. One recent study (Gonzalez-Barrero & Nadig, 2019) found that bilingual children with autism outperformed their monolingual counterparts on the Dimensional Change Card Sort (DCCS™) tasks that measured their cognitive flexibility. Nevertheless, issues around recommendations for bilingualism on autistic children are an ongoing topic of debate. Consequently, many bilingual parents of autistic children have a difficult time deciding whether to maintain their primary language in their homes and whether to teach their children to speak their heritage languages (Howard et al., 2021). They often receive mixed recommendations from professionals in regard to retaining their heritage language in the home (Kay-Raining Bird et al., 2012). As a result, some parents give up their heritage language and use only English in the home in accordance with the advice they received from professionals (Yu, 2013), whereas others put in their best effort to maintain bilingualism for their child (Jegatheesan, 2011).

Such scarcity of evidence and lack of consensus around this topic may be due to many autistic children experiencing communication delays, with 25% to 35% of them being identified as minimally verbal (Rose et al., 2016). Many parents of autistic children report that they decided to give up teaching their child their heritage language due to the concern that their child would acquire limited language in their lifetime (Hampton et al., 2017). Therefore, instead of examining the relationship between autistic children's fluency in multiple languages and their cognitive flexibility, examining external factors such as being immersed in a bilingual environment can have more utility and greater practical implications. Taken together, it is critical that researchers examine the relationship between autistic children's bilingual home environment and their EF development in order to better understand the impact of bilingualism on autistic children's learning outcomes.

Gap in Literature

While EF development in autistic children has been an area of interest for many researchers in the past few decades, little is known about child-level and environmental factors that may contribute to their longitudinal growth in EF domains. More specifically, while many studies examined predictors for children's EF performances at one point in time, far less is known about contributing factors for the rate of growth during sensitive developmental periods in school-aged autistic children. Therefore, the current study aims to address the following research questions:

Research Questions

1. What are the predictors for autistic children's working memory performance upon entering kindergarten, and for the relative growth over time during their elementary school years?

2. What are the predictors for autistic children's cognitive flexibility performance upon entering kindergarten, and for the relative growth over time during their elementary school years?

Method

Dataset

The present study used the restricted version of the Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K: 2011) dataset, sponsored by the National Center for Education Statistics (NCES) within the Institute of Education Sciences (IES) of the U.S. Department of Education. ECLS-K:2011 followed approximately 18,170 children from kindergarten through 5th grade. Parents, teachers, school administrators and before- and after-school care providers of these children also participated in the data collection. There were nine waves of data collection from Fall of 2010 to Spring of 2016.

Participants

The Autism sample (N= approximately 310) from Study 1 was used for the current study. The Participants section in Study 1 describes how students were included in this sample.

Measures

Demographic Characteristics

Demographic characteristics of the sample included: 1) Race/ethnicity (White, Black, Hispanic, Asian-American / Pacific Islanders / Native Americans (AAPINA), other), 2) sex assigned at birth (male, female), 3) income range (under $20,000, $20,000 to $30,000, $30,000 to $50,000, $50,000 to $75,000, $75,000 to $100,000, $100,000 to $200,000, $200,000 or more), and 4) parent's educational level.

Variables

Working Memory. The Number Reversed subset of the Woodcock-Johnson III (WJ III: Woodcock 2001) was administered to measure working memory from kindergarten through 5th grade, across nine time points. Students were asked to repeat strings of numbers presented backwards, starting with two-number sequences. Five two-number sequences were presented before progressing to three-number sequences. The length of sequence increased after five trials, up to a maximum of eight numbers. If the child responded incorrectly for three consecutive trials, the task ended instead of progressing to a longer number sequence. Each item was scored as "correct," "incorrect" or "not administered" (Tourangeau et al. 2019).

Cognitive Flexibility. The Dimensional Change Card Sort (DCCS™) (Zelazo 2006; Zelazo et al. 2013) was used in ECLS-K: 2011 to measure cognitive flexibility from kindergarten through 5th grade, across nine time points. Students were asked to sort cards by either color or shape across 30 trials. DCCS™ is designed to measure children's ability to switch between tasks accurately and rapidly rather than to test their ability to sort by shape or color (Tourangeau et al. 2019). Study 1 further describes the two versions of the test (i.e., computerized and tabletop) that were used at different time points and how the equivalency of the scores from these two types of tests were established (p. 19). In summary, percentage scores were created from the DCCS™ scores to reflect students' accuracy at each time point.

Sex Assigned at Birth. A composite variable for students' sex was drawn from parent-reported information about the child's sex or the Field-Management System (FMS). FMS includes data about the participating schools, staff, and students from administrative records or other existing data sources. Information about student's sex was collected from their school at the time of sampling and was stored in the FMS. Parents were asked about the child's sex in the fall of kindergarten, then confirmed in the spring of kindergarten. Parents were asked in the subsequent rounds of data collection only if this information was missing.

Race. A composite variable for students' race was drawn from either the parent-reported information about the child's race or the FMS. FMS data were used only if parent responses about the child's race were missing.

Socioeconomic Status (SES). SES was computed three times during the data collection period, at Fall of kindergarten (T1), Spring of 1st grade (T4), and Spring of 5th grade (T9). It was computed using responses from the parent interview. The five components used to create the SES variable are 1) parent 1's education, 2) parent 2's education, 3) parent 1's occupational prestige score, 4) parent 2's occupational prestige score, and 5) household income. The mean composite score from these three time points was then computed for each child.

Attention Deficit Hyperactive Disorder (ADHD). In Spring 2011 (T2), Spring 2012 (T4), Spring 2013 (T6), Spring 2014 (T7), Spring 2015 (T8) and Spring 2016 (T9), parents were asked during the parent interview, "Did you obtain a diagnosis of a problem from a professional?" If the response was yes, they were asked a follow up question to specify what the diagnosis was. One of the options was *Attention Deficit Hyperactive Disorder (ADHD).* The ADHD variable was assigned a value of 1 if parents responded at least once during the six rounds of interview that the child had a diagnosis of ADHD. If not, 0 was assigned.

Learning Disability (LD). In T2, T4, T6, T7, T8, and T9, parents were asked during the parent interview, "Did you obtain a diagnosis of a problem from a professional?" If the response was yes, they were asked a follow up question to specify what the diagnosis was. One of the options was *specific learning disabilities.* The Learning Disability variable was assigned a value of 1 if parents responded at least once during the six rounds of interview that the child had a diagnosis of specific learning disability. If not, 0 was assigned.

Special Education Services for Autism. In T2, T4, T6, T7, T8, and T9, special education teachers were asked, "For which of the following disabilities has this child received special education or related services this school year, whether for the child's primary disability or another of his/her disabilities?" Special Education Services for Autism variable was assigned a value of 1 if teachers chose *'Autism'* to this question at least once during the six rounds of interview. If not, 0 was assigned.

Student-Teacher Relationship. In T2, T4, T6, and T7, the child-level teacher questionnaire included questions about closeness with teachers. The *Student-Teacher Relationship Scale (STRS)* (Pianta & Stuhman 2004) was used to assess teacher-reported measure of closeness and conflict between teacher and child. The STRS contains two scales, Closeness and Conflict. The Closeness scale contained 7 items and measured the affection, warmth, and open communication that the teacher experiences with the child. Each item was scored on a 5-point scale ranging from "definitely does not apply" (1) to "definitely applies" (5). The Closeness scale score was computed at each time point that STRS was administered, which was the average rating on the seven items in the Closeness scale. The average score was computed when the teacher provided a rating on at least five of the seven items included in the scale (Najarian et al. 2019).

A composite score for the Closeness scale score at each time point (T2, T4, T6, T7) was computed for each child by averaging the scale score from each time point. The average score was computed when the child had at least 2 or more scale scores from the 4 time points.

Approaches to Learning. The child-level questionnaire was administered at T1, T2, T4, T5, T7, T8, and T9 by the child's teacher. Teachers were asked to rate the frequency of the following behaviors of the child: 1) keeps belongings organized, 2) shows eagerness to learn new things, 3) works independently, 4) easily adapts to changes in routine, 5) persists in completing tasks, 6) pays attention well, and 7) follows classroom rules. Response options included: 1 – "Never," 2- "Sometimes," 3 – "Often," and 4 – "Very Often." The Approaches to Learning scale score was then created for each time point by computing the mean of the seven items for each time point. A score was computed when the teachers provided a rating on at least 4 of the 7 questions above. The mean composite score was created from the Approaches to Learning scale scores from those seven time points. The mean composite score was computed if the child had an Approaches to Learning scale score in at least 4 of the 7 time points.

Health Scale. In T1, T2, T4, T7, T8, and T9, parents were asked during the parent interview, "Would you say your child's health is...' 1) excellent; 2) very good; 3) good; 4) fair; or 5) poor?" These scores were reverse-coded for higher rating to signify better health. A mean composite score was computed for each child from those six time points. The mean composite score was computed if the child had the Health Scale score in at least 4 of the 7 time points.

Bilingual Home. In T1, T4, and T9, parents were asked during the parent interview, "Is any language other than English regularly spoken in your home?" If the response is '*Yes,*' then parents were asked a follow up question, "Is English also spoken in your home?" If the response is '*Yes*' again, then a score of 1 was given to the child for each time point. A child received a value of 1 for the Bilingual Home variable if they had a score of 1 at all three time points (T1, T4, and T9). If a child had a score of 0 at any of the three time points, they received a zero for the Bilingual Home variable.

Analyses

Missing Data

Missingness in the WM and CF scores within the Autism sample is reported in Study 1 (p.39). In addition, due to such high levels of missingness in Fall of 1st grade and Fall of 2nd grade as reported in Study 1, these two time points (i.e., T3 & T5) were excluded from the current analyses. Table 11 displays the percentage of missingness for the covariates used in the current study.

Little's test of missing completely at random (Little, 1998) was conducted for the covariates using SPSS version 28. The covariates that entered the final conditional models for the WM and the CF domains passed Little's MCAR test with χ^2=52.830 (p=0.365). Therefore, missing data when estimating the conditional latent growth models were handled by Full Information Maximum Likelihood (FIML) as this method is shown to be robust with structural equation models (SEMs) under the assumption of MAR or MCAR (Allison, 2003).

Multivariate Normality

Mardia's skewness and kurtosis test was conducted to test the assumption of multivariate normality (Kres, 1983; Mardia, 1980). The set of variables included in the final model for the Working Memory domain met the assumption of multivariate normality ($p > 0.05$). However, the set of variables included in the final model for the Cognitive Flexibility domain did not meet the assumption of multivariate normality ($p<0.05$). Therefore, the "MLF" estimator (maximum likelihood estimation with standard errors based on the first-order derivatives) was used for the CF model when building the latent growth model.

Latent Growth Modeling: Conditional Model with Time-Invariant Covariates

To address the aims of this study, conditional latent growth models were created using the Lavaan package (Rosseel, 2012) in R statistical environment for the WM and CF domains separately. Conditional latent growth model allows us to test potential influences of the covariates on the trajectory parameters (Bollen & Curran 2006). In other words, conditional models permit us to include variables that predict the latent intercept and latent slopes of the model.

Time-Invariant Covariates vs. Time-Variant Covariates. Two types of covariates can be added to an unconditional latent growth model: Time-invariant covariates and time-variant covariates. Time-invariant covariates are the ones that assume one value throughout the data collection time period, whereas time-variant covariates are ones that can change their values over time (Beaujean, 2014).

Time-invariant covariates allow us to test the influence of the covariate on the trajectory parameters, while time-variant covariates permit us to incorporate repeated measures of the covariates to test the time-specific influence of the variables on the individual trajectory (Bollen & Currant 2006). While some covariates used in the current analysis (e.g., Student-Teacher Relationship, Approaches to Learning) can vary over time, a decision was made to treat them as time-invariant covariates by creating a mean composite score. The rationales for such a decision were as follows: 1) the purpose of the analyses in the study is not to examine whether the selected variables have time-specific influence on the parameter estimates, but to examine how they contribute to the overall trajectory, and 2) having both time-variant and time-invariant covariates in the model would complicate the interpretability of the findings while there is little utility in knowing how changes in covariates influence children's performances at each time point. Taken together, it was concluded that treating all variables as time-invariant covariates would generate more parsimonious analyses and interpretations.

Model Evaluation Criteria. The analyses in the current study adopted the "cut-off" criteria for the maximum likelihood (ML) method in structural equation modeling proposed by Hu & Bentler (1999) (i.e., CFI ≥ 0.95; SRMR ≥ 0.08; RMSEA ≥ 0.06).

Conditional Model: Working Memory. The final unconditional model built for the Working Memory domain with the Autism group (Model 3, Table 3) was used as the basis in building the conditional model. For working memory, the following covariates entered the model as time-invariant covariates: *Sex Assigned at Birth, Race, Socioeconomic Status, ADHD status, LD status, Autism-Related Services, Student-Teacher Relationship, Approaches to Learning,* and *Health Scale*. These variables were selected to enter the working memory LGM model based on their hypothesized relationship with children's working memory development. This conditional model fit the data well. The fit indices were χ^2=84.567, df = 55, CFI = 0.971, RMSEA = 0.052, SRMR = 0.031 (Table 12). This model was chosen as the final conditional LGM model for working memory.

Conditional Model: Cognitive Flexibility. The final unconditional model built for the Cognitive Flexibility domain with the Autism group (Model 8, Table 4) was used as the basis in building the conditional model. For cognitive flexibility, the following covariates entered the model as time-invariant covariates: *Sex Assigned at Birth, Race, Socioeconomic Status, ADHD status, LD status, Autism-Related Services, Student-Teacher Relationship, Approaches to Learning,* and *Bilingual Home*. Similar to the WM domain, these variables were selected to enter the cognitive flexibility LGM model based on their hypothesized relationship with children's cognitive flexibility development. This conditional model fit the data well. The fit indices were

χ^2=67.296, df = 55, CFI = 0.977, RMSEA = 0.033, SRMR = 0.034 (Table 13). This model was chosen as the final conditional LGM model for cognitive flexibility. The Lavaan package (Rosseel, 2012) in R was used to estimate these LGM models (RStudio Team, 2020).

Results

Demographic Characteristics

Approximately 18,170 students participated in the ECLS-K: 2011 data collection from years 2010 to 2016. Of those, about 310 students were reported to have a diagnosis of autism. Approximately 54% of the children with autism were identified as White, and approximately 82% of the children were identified as male, which reflects the estimated gender profile of the autism population. Modal categories for the household income were $20,000 or less and $30,000 to $50,000. Further, a majority of the parents (62%) reported to have attended 2–4-year colleges. Demographic characteristics of these students are illustrated in Table 14.

Explanatory Factors: Working Memory

Sex Assigned at Birth. Children's sex assigned at birth was found to predict their initial status of WM performance such that the initial status of girls at Fall of kindergarten was lower than boys. Such difference was statistically significant ($\beta = -0.176$, $p = 0.021$). However, statistically significant sex differences were not found in either Slope 1 or Slope 2 ($p > 0.05$).

Socioeconomic Status (SES). Family's SES was found to predict autistic children's initial status of WM performances such that the higher the family's SES, the higher the children's initial status at Fall of kindergarten was. Such relationship was statistically significant ($\beta = 0.213$, $p = 0.007$). However, the relationship between family's SES and either Slope 1 or Slope 2 was not statistically significant ($p > 0.05$).

ADHD Status. Having a diagnosis of ADHD in addition to autism was not found to predict the initial status of WM performances at Fall of kindergarten ($p > 0.05$). However, autistic children's ADHD diagnosis was found to predict their Slope 1 such that having a diagnosis of ADHD predicted a higher rate of growth from Fall of kindergarten to Spring of 2^{nd} grade ($\beta = 0.312$, $p = 0.003$). In contrast, having a diagnosis of ADHD predicted a lower rate of growth from Spring of 2^{nd} grade to Spring of 5^{th} grade ($\beta = -0.240$, $p = 0.028$). Both relationships were statistically significant.

Special Education Services for Autism. Having received special education services for autism at school at least at one time point was found to be negatively related to autistic children's initial status with WM performances at Fall of kindergarten ($\beta = -0.312$, $p = 0.000$). In contrast, having received such services at school was found to be positively related to autistic children's rate of growth from Fall of kindergarten to Spring of second grade (Slope 1) ($\beta = 0.209$, $p = 0.042$). Having received autism-related services at least at one time point at school was not found to have a statistically significant relationship with autistic children's rate of growth beyond Spring of 2^{nd} grade ($p > 0.05$).

Student-Teacher Relationship. Teacher-reported rating of autistic children's Student-Teacher Relationship (STR) was not found to predict their initial status at Fall of kindergarten or rate of growth from Fall of kindergarten to Spring of 2^{nd} grade (Slope 1) ($p > 0.05$). However, autistic children's rating on STR was found to predict a higher rate of growth from Spring of 2^{nd} grade to Spring of 5^{th} grade ($\beta = 0.243$, $p = 0.034$).

Approaches to Learning. Teacher-reported rating of autistic children's Approaches to Learning was found to predict a higher initial status at Fall of kindergarten ($\beta = 0.354$, $p = 0.000$) as well as Slope 1 ($\beta = 0.324$, $p = 0.003$). However, autistic children's rating on Approaches to

Learning was found to predict a slower rate of growth beyond Spring of 2nd grade (Slope 2) (β = -0.232, p = 0.047).

Race, Learning Disability, and Health Scale. These three covariates were found to have no statistically significant relationships with either the initial status, Slope 1, or Slope 2 of autistic children's working memory trajectory ($p > 0.05$).

Relationships between the aforementioned explanatory factors and autistic children's initial status, Slope 1, and Slope 2 of the working memory trajectory are summarized in Table 15.

Explanatory Factors: Cognitive Flexibility

ADHD Status. Having a diagnosis of ADHD in addition to autism was not found to predict the initial status of CF performances at Fall of kindergarten ($p > 0.05$) or the rate of growth from Fall of kindergarten to Spring of 2nd grade (Slope 1) ($p > 0.05$). However, autistic children's ADHD status was found to predict a lower rate of growth from Spring of 2nd grade to Spring of 5th grade (β = -0.246, p = 0.049).

Student-Teacher Relationship. Teacher-reported rating of autistic children's Student-Teacher Relationship (STR) was found to predict a higher initial status at Fall of kindergarten (β = 0.258, p = 0.028). However, their rating on STR was not found to predict either the rate of growth from Fall of kindergarten to Spring of 2nd grade (Slope 1) or the rate of growth from Spring of 2nd grade to Spring of 5th grade (Slope 2) ($p > 0.05$).

Approaches to Learning. Teacher-reported rating of autistic children's Approaches to Learning was found to predict a higher initial status at Fall of kindergarten (β = 0.234, p = 0.036). However, their rating on Approaches to Learning was not found to predict either the rate of growth from Fall of kindergarten to Spring of 2^{nd} grade (Slope 1) or the rate of growth from Spring of 2^{nd} grade to Spring of 5^{th} grade (Slope 2) ($p > 0.05$).

Bilingual Home. Living in a bilingual home environment was found to predict a lower initial status at Fall of kindergarten ($\beta = -0.196$, $p = 0.040$). However, it was found to predict a higher rate of growth from Fall of kindergarten to Spring of 2^{nd} grade (Slope 1) ($\beta = 0.391$, $p = 0.009$). In contrast, a bilingual home environment was not found to predict their rate of growth from Spring of 2^{nd} grade to Spring of 5^{th} grade (Slope 2) ($p > 0.05$).

Sex, Race, SES, Learning Disability, and Autism Services. These five covariates were found to have no statistically significant relationships with either the initial status, Slope 1, or Slope 2 of autistic children's cognitive flexibility trajectory ($p > 0.05$).

Relationships between the aforementioned explanatory factors and autistic children's initial status, Slope 1, and Slope 2 of the cognitive flexibility trajectory are summarized in Table 16.

Discussion

The current study explored possible contributing factors for school-aged autistic children's EF performances upon entering kindergarten, and for their relative growth over time during their elementary school years. Broadly, across both working memory and cognitive flexibility domains, several student characteristics and environmental factors were found to be predictive of autistic students' EF performances upon entering kindergarten as well as their rates of growth across their elementary school years.

Working Memory

Socioeconomic Status (SES)

SES was found to be positively related to autistic students' working memory performance upon school entry in Fall of kindergarten. This finding is in line with the existing literature base that supports SES disparities on children's EF performances from young ages (Bernier et al., 2010; Hackman et al., 2015; Lengua et al., 2014; St. John et al. 2019).

However, SES was not found to influence the rates of growth throughout their elementary school years. This implies that SES disparity exists when autistic children enter kindergarten, and the gap persists without narrowing or widening significantly. The persistent SES disparity throughout their childhood tells us that school or other external factors do not compensate for the EF gap that existed upon entering school. This phenomenon is in line with previous studies that demonstrated that family SES did not predict the rate of growth of children's working memory across their childhood (Hackman et al., 2015) and the gap persists throughout children's development (Last et al., 2018). In other words, autistic children from low SES backgrounds and high SES backgrounds both made progress in WM at a similar rate from kindergarten to 5th grade, which implies that there may be some external factors prior to entering kindergarten that are attributable to the SES disparity upon entering school. Importantly, Hackman et al. (2015) found that early childhood home environment (i.e., degree of enrichment in the home, including toys and books) partially mediated the SES disparity in working memory. As it is well-established that EF plays an important role in children's school success and that autistic children demonstrate persistent challenges in EF skills, this finding has an important policy implication for autistic children from a low SES background. Enriching home environments at an early age should be an important target for prevention or intervention programs in order to address such persistent SES disparities in autistic children's working memory.

Co-occurring Diagnoses

While having learning disability (LD) did not influence autistic children's WM trajectory, having ADHD in addition to autism displayed an interesting influence on their rate of growth in WM. More specifically, autistic children who also had ADHD demonstrated significantly more rapid growth from Fall of kindergarten to Spring of 2nd grade, then they showed significantly slower growth from Spring of 2nd grade to Spring of 5th grade.

Research indicates that children with ADHD display EF deficits (see Pennington & Ozonoff, 1996 for a review), and there is an overlap in phenotypic characteristics between children with autism and children with ADHD (Leitner, 2014). While ADHD is the most frequently co-occurring condition in children with autism (Gnanavel et al., 2019; Salazar et al., 2015), children who have both autism and ADHD are understudied compared to children with autism or children with ADHD only. Further studies must untangle this seemingly interesting relationship between having dual diagnoses and their EF trajectories. The current finding implies that those with dual diagnoses may have a more rapid but narrower window for growth in WM when compared to children with autism only. Therefore, there is an urgent need for educators to understand this unique WM development trajectory for children with dual diagnoses, and pay particular attention during this short window of high plasticity for WM development.

Sex Assigned at Birth

The current study found that the initial status of working memory in Fall of kindergarten was lower for autistic girls than boys. While it is well-established in research that there are gender differences in behavioral presentations of autism, little is known about gender differences in EF performances among autistic children. One recent study found that the relationship between working memory and social communication was stronger in males with autism than without, while such a relationship was not found in females (Chouinard et al., 2019). Another study found that the relationship between children's EF and reading comprehension was stronger for girls than boys (Spencer & Cutting, 2021). While these researchers found gender differences in EF as a moderator, other researchers argue that there are no direct gender differences in children's EF development (Grissom & Reyes, 2019; Memisevic & Sinanovic, 2014).

While there is little support for significant gender differences in WM in the current literature base, gender as a moderator appears to work differently in various contexts. It is also important to note that the current study had an unbalanced group by sex, with 82% of the sample being boys and 18% being girls. Therefore, further investigation is warranted to examine possible gender differences in autistic children's WM developmental trajectories.

Approaches to Learning (ATL)

Approaches to Learning (ATL) was found to have a positive association with autistic children's initial status in WM at Fall of kindergarten as well as their rate of growth during the first three years of schooling. However, ATL was found to be negatively associated with autistic children's rate of growth in WM during the last three years of schooling. In other words, autistic students who enter kindergarten with high ATL appear to outperform on WM tasks than those with lower ATL, continue to make rapid progress during the first three years of schooling, and their rate of growth slows down as they reach the maturity point. Therefore, autistic children with strong ATL demonstrate a short period of window with high plasticity, and reach their maturity point earlier than other autistic children.

Research shows that ATL is closely related to children's school readiness (Lee, 2012; Vitiello & Greenfield, 2017) and long term school success (Li-Grining et al., 2010). Taken together, it is critical that autistic children receive early exposure to learning environments that reinforce behaviors relating to ATL from preschool years and throughout their schooling. This finding has an important practical implication for parents, early childhood educators, and early interventionists in that providing learning opportunities for behaviors relating to ATL may have a long-term positive impact on autistic children's WM as well as overall school readiness and adjustment.

Student-Teacher Relationship (STR)

Teacher-reported student-teacher relationship (STR) was found to predict autistic children's rate of growth in working memory after the "knot" (i.e., Spring of 2^{nd} grade to Spring of 5^{th} grade). Findings from Study 1 indicated that autistic children who started at a low standing with WM upon entering kindergarten made rapid growth after the "knot" as well.

Taken together, we can infer that these "late-bloomers" have their period of malleability during the last three years of their elementary school years, and this period is also when STR shows a positive association with their rate of growth in WM. Such an association is in line with a recent meta-analysis that demonstrated a positive association between quality of STR and school-aged children's working memory (Vandenbroucke et al., 2018). Therefore, positive STR can be particularly protective for autistic children who start at a lower standing initially but go through a "sensitive period" with high plasticity during the second half of their elementary school years. Therefore, it is critical for teachers to understand autistic children's unique developmental trajectories of WM and foster positive relationships especially with the "late-bloomers" to help them reach their full potential.

Special Education Services for Autism

The current study found a negative association between autistic children's initial status with WM at Fall of kindergarten and their receipt of autism-related special education services during their elementary school years. Based on the temporal ordering, we can infer that those who started at a lower standing with WM upon entering kindergarten ended up receiving autism-related services during their school years. Since WM is closely related with various aspects of school success, including academic, behavioral, social and emotional competencies, it is understandable that those who exhibited greater deficits in WM were more likely to receive services in order to support their learning.

A more notable finding was in the positive relationship between the receipt of autism-related services at school and the rate of growth from Fall of kindergarten to Spring of 2nd grade. In other words, autistic children who received autism-related services at school during their elementary school years made more rapid gains during the first three years of their schooling than those who didn't. In Study 1, the relationship between the initial status of WM upon entering kindergarten and their rate of growth during the first three years of schooling was not significant. However, while those who received autism-related services started at a lower standing at Fall of kindergarten, they made significantly more rapid gains during the first three years of schooling. Comparing these two findings, we can make an inference that, while autistic children as a whole who displayed greater WM deficits upon entering kindergarten continued to make slower gains during the first three years of schooling, specifically those who received autism-related services indeed made more rapid gains during the same time.

There is emerging evidence that school-based interventions that directly target EF domains can have positive effects (Cavalli et al., 2022; Otero et al., 2014). For instance, Kenworthy et al. (2014) examined the effectiveness of a cognitive-behavioral intervention named Unstuck and On Target (UOT) (Cannon et al., 2011) with school-aged autistic children. It was found that the UOT intervention was effective in increasing autistic children's various EF skills that were generalizable in their daily school settings. However, other school-based EF interventions did not demonstrate improved EF skills in children with autism and generalizability of the learned skills in real-life situations was unclear (de Vries et al., 2015; Fisher & Happe, 2005). More importantly, none of these interventions that specifically and directly target EF skills are readily available in school settings. However, all children with autism diagnosis are entitled to autism-related special education services as per the federal Individuals with Disabilities Education Act (IDEA). Although it is unclear whether autism-related services have a direct or indirect relationship with the rate of growth during the first three years of autistic children's schooling, findings from the current study suggest that such services can have a positive impact on their WM development during early years of schooling. This finding underscores the importance of timely and appropriate identification of eligibilities for various autism-related special education services that autistic students can benefit from in order to foster greater WM development and school success.

Cognitive Flexibility

Bilingual Home

The most notable finding within the cognitive flexibility domain appears to be the relationship between autistic children's bilingual home environment and their CF performance. More specifically, autistic children whose family members speak more than one language at home started their kindergarten year with lower standing in the CF domain, but they made more rapid growth than those from a monolingual home environment during the first three years of their elementary school years. In fact, bilingual home environment was the only predictor found in the CF domain from Fall of kindergarten to Spring of 2nd grade, which is the window identified as the "sensitive period" with high plasticity in Study 1. Such a finding was in line with a recent study that demonstrated an advantage for bilingual children with autism in the CF domain but not in the WM domain (Gonzalez-Barrero & Nadig, 2019).

There has been a growing interest in bilingualism for children with autism in the past decade. A few recent studies agreed that autistic children in bilingual families did not display further language delays or had any other detrimental effects (Beauchamp & MacLeod, 2017; Drysdale et al., 2015; Kay-Raining Bird et al., 2012; Petersen et al., 2012). While these studies concluded that there are no negative effects of bilingualism for autistic children (i.e., neutral effect), far less is known about specific advantages bilingualism has on autistic children's development and learning. Evidence on bilingual advantages on EF for autistic children are emerging yet rudimentary at this point. Future studies should investigate whether being immersed in a bilingual home has specific advantages for autistic children in their learning, including EF, academic outcomes, and social, emotional and behavioral outcomes.

Co-occurring Diagnoses

Similar to the working memory domain, LD was not found to have a significant relationship with autistic children's CF development. However, having co-occurring ADHD predicted autistic children's slower growth of CF during the last three years of elementary school years. This is the period of time when autistic children as a whole slow down in their growth in CF, and having ADHD in addition to autism appears to exacerbate the phenomenon. This supports the previous inference that children with dual diagnoses may have a narrower window for growth in EF when compared to children with autism only. This finding confirms the importance of better understanding the unique EF development trajectory for children with dual diagnoses.

Student-Teacher Relationship (STR) and Approaches to Learning (ATL)

While both STR and ATL were found to have positive associations with the rates of growth in the working memory domain, they were found to be positively linked to autistic children's CF performance only cross-sectionally at Fall of kindergarten. This implies that autistic children whose teacher rated highly on STR or ATL during their elementary school years had a higher standing with CF upon entering kindergarten. Such findings confirm the importance of behaviors relating to STR and ATL on EF performances overall, and implies that these behaviors are likely to contribute to overall school outcomes.

Limitations

While some covariates (e.g., SES, STR, ATL) can vary over time and can therefore exert a time-specific effect on autistic children's WM and CF trajectories, composite scores were created and they were treated as time-invariant covariates. Although this decision was made for better interpretability and parsimony of the statistical models, time-specific effects were not captured in the study. Therefore, it will be worthwhile to investigate the effects of one covariate at a time while treating the covariate as time-variant. That way, we can acquire a deeper understanding of how each covariate influences children's WM and CF trajectories over time. In addition, the current study only examined a sample of autistic children, and comparisons to their neurotypical (NT) peers were not made. Therefore, the significant relationships found cannot be claimed as being specific to autistic children only. Future studies should examine if such relationships also exist in NT children, children with other developmental disabilities such as ADHD, or children with both autism and ADHD, in order to better understand the uniqueness of children's EF development for each group. Moreover, it is important to note that medication status is unknown for autistic children with co-occurring ADHD. As ADHD-related medications can influence children's EF performance, findings regarding this specific group must be interpreted with caution.

Conclusion and Future Directions

This current study found several important internal and external factors that predicted autistic students' WM and CF development. Overall, among the predictors chosen in the study, more predictors for rate of growth were found in the WM domain than the CF domain. This implies that there may be a greater possibility of improving autistic children's WM developmental trajectory than CF trajectory through environmental factors. This may also mean that persistent disparities generated by demographic factors such as SES can be narrowed or widened by other student-level or environmental factors such as receipt of autism-related special education services.

While there can be a greater number of ways to influence autistic children's WM development, far fewer predictors were found in their CF development. However, the only contributing factor that was found to predict autistic children's rapid growth in the CF domain was an important one with many practical implications: a bilingual home environment. More specifically, as being raised in a bilingual home environment was found to be advantageous for CF development in children with autism, there can be great utility in investigating whether being immersed in multiple languages at school can also have a similar effect for autistic children from monolingual families. It would also be beneficial to examine how the frequency of verbal interactions in multiple languages influences CF development in a similar way.

Overall, findings from this study contribute to the current literature base by directing our attention to various student-level and environmental-level factors that could be arranged or manipulated. Results suggest that student demographic characteristics, learning behaviors and school or home environment collectively play an important role in autistic children's EF development. Future studies should examine ways to maximize exposure to factors that were found to predict greater growth in EF during developmentally sensitive periods of times for autistic children during elementary school.

Table 11. Percentage of missingness in the time-invariant covariates

Variables	% Missing
Sex	0%
Race	0%
SES	16.2%
ADHD	0%
LD	0%
Autism Svc	0%
Closeness w/ Teachers	15.3%
Approaches to Learning	24.0%
Health Scale	22.1%
Bilingual Home	13.6%

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 12. Fit indices for the conditional latent growth model in working memory of Autism group

	(N=310)
Model Type	Piecewise Linear
Knot	T6 (Spring of 2nd Gr.)
Test Statistics (Chi-square)	84.567 (p=0.006)
Degrees of Freedom	55
Comparative Fit Index (CFI)	0.971
RMSEA	0.052
SRMR	0.031

Note: N rounded to the nearest 10 per confidentiality agreement

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 13. Fit indices for the conditional latent growth model in cognitive flexibility of Autism group

	(N=310)
Model Type	Piecewise Linear
Knot	T6 (Spring of 2^{nd} Gr.)
Test Statistics (Chi-square)	67.296 (p=0.124)
Degrees of Freedom	55
Comparative Fit Index (CFI)	0.977
RMSEA	0.033
SRMR	0.034

Note: N rounded to the nearest 10 per confidentiality agreement

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 14. Demographic characteristics of the Autism sample

Demographic Characteristics		Autism (N=310)
Race		
	White	170 (54%)
	Black / African-American	20 (8%)
	Hispanic	70 (21%)
	Asian-American / Pacific Islanders / Native American	40 (11%)
	Other	20 (7%)
Sex Assigned at Birth		
	Female	60 (18%)
	Male	250 (82%)
Income		
	$20,000 or less	50 (20%)
	$20,000 to $30,000	30 (13%)
	$30,000 to $50,000	50 (20%)
	$50,000 to $75,000	40 (14%)
	$75,000 to $100,000	30 (13%)
	$100,000 to $200,000	40 (16%)
	$200,000 or more	20 (6%)
Parents' Educational Level		
	High School	50 (24%)
	2-4 year College	140 (62%)
	Postgraduate Degree	30 (15%)

Note: N rounded to the nearest 10 per confidentiality agreement
Percentages rounded to the nearest whole number

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 15. Relationships between covariates and autistic children's developmental trajectory of working memory

	Initial Status (Fall K)		Slope 1 (Fall K-Sp 2nd)		Slope 2 (Fall 3rd- Sp 5th)	
Covariates	Std. Beta	p	Std. Beta	p	Std. Beta	p
Sex (female=1)	**-0.176**	**0.021***	0.045	0.648	-0.009	0.930
Race (White=1)	0.022	0.776	-0.044	0.657	-0.016	0.877
SES	**0.213**	**0.007***	-0.112	0.275	0.000	0.998
ADHD (ADHD=1)	0.071	0.376	**0.312**	**0.003***	**-0.240**	**0.028 ***
LD (LD=1)	-0.118	0.111	-0.001	0.994	0.126	0.215
Autism Related Services	**-0.312**	**0.000***	**0.209**	**0.042***	0.045	0.681
Student-Teacher Relationship	-0.061	0.473	0.026	0.811	**0.243**	**0.034 ***
Approaches to Learning	**0.354**	**0.000***	**0.324**	**0.003 ***	**-0.232**	**0.047 ***
Health Scale	0.006	0.940	0.136	0.168	-0.045	0.683

* $p < 0.05$
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

Table 16. Relationships between covariates and autistic children's developmental trajectory of cognitive flexibility

	Initial Status (Fall K)		Slope 1 (Fall K-Sp 2nd)		Slope 2 (Fall 3rd- Sp 5th)	
Covariates	Std. Beta	p	Std. Beta	p	Std. Beta	p
Sex (female=1)	-0.063	0.629	-0.004	0.973	0.184	0.141
Race (White=1)	-0.002	0.982	0.130	0.324	-0.201	0.109
SES	0.036	0.684	0.003	0.979	-0.059	0.630
ADHD (ADHD=1)	0.166	0.114	0.078	0.591	**-0.246**	**0.049***
LD (LD=1)	-0.085	0.417	0.090	0.498	0.040	0.753
Autism Related Services	-0.200	0.095	0.203	0.154	0.123	0.372
Student-Teacher Relationship	**0.258**	**0.028***	-0.057	0.746	-0.164	0.177
Approaches to Learning	**0.234**	**0.036***	-0.042	0.770	-0.231	0.110
Bilingual Home	**-0.196**	**0.040***	**0.391**	**0.009***	-0.207	0.221

* $p < 0.05$
SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), The Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). Restricted-use data files.

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