COGNITIVE FLEXIBILITY GROWTH PATTERNS AND SPEECH AND LANGUAGE

SKILLS AMONG SCHOOL AGE CHILDREN

BY

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Abstract

This study investigated the cognitive flexibility trajectories of children in grades kindergarten through fifth grade. The study utilized the longitudinal data from the Early Childhood Longitudinal Study, Class of 2010-2011 (ECLS-K:2011) to conduct latent class growth analysis and growth mixture models to better understand cognitive flexibility changes over time.

A diverse sample of 14,173 children from 970 schools from the ECLS-K:2011 dataset was included. The findings suggested that cognitive flexibility (CF) development has multiple growth trajectories, depending on students' initial levels of CF (their intercept) and their rate of change (slope). Results indicated that a model with five trajectories, or classes, best fit the data, although most of the sample (81.2%) belonged to one class. Those with higher socioeconomic status typically performed better, especially for initial cognitive flexibility levels. Speech and language deficits were also found to increase the probability of being in both an *at-risk* trajectory class (54%) and *remediated* class (28%). Both of these classes contained individuals whose initial starting cognitive flexibility was well below expected levels. These findings support the idea that a single growth curve would not fully take into account all children's growth trajectories of where they began and their rate of change.   It also includes supporting evidence that a deficit of speech and language skills increases the probability that a student will struggle significantly with CF skills. Implications include points for building CF skills for elementary students, possible interventions, and educational policy regarding speech and language skills as well as socioeconomic status.

Chapter 1: Introduction

A second-grade student must listen to a teacher's directions while simultaneously inhibiting the sound of other students talking behind him or her. That child must keep the information in memory while moving about the classroom to prepare for the current assignment. The child may have to be able to take a deep breath or appropriately verbally express dislike as another student accidentally bumps into him or her. The child then needs to return back to the original task and remember the multiple steps needed to complete the assignment. The child must do these things while inhibiting inner thoughts of what the child may see, hear, smell, and feel. All of these skills, which involve executive functioning capacities, are needed to be a successful student in the classroom. Executive functions (EF) refer to an umbrella term of inter-related mental processes that are responsible for purposeful, goal-directed behavior (Best & Miller, 2010).

Recent research has proposed three dimensions that are frequently highlighted within the domain of executive functions: working memory, inhibitory control, and cognitive flexibility (Huizinga et al., 2006; Lehto et al., 2003; Miyake et al., 2000). Working memory is the capacity to hold and manipulate information in our minds over short periods of time (Baddeley & Hitch, 1994). For example, it allows children to remember and connect information from one paragraph to the next while reading. Inhibitory control is a skill that allows us to master and filter our thoughts and impulses so that we can resist temptations, distractions, and habits (Diamond & Taylor, 1996). This allows us to pause and think before we act, as well as use selective, focused, and sustained attention. A child may use this skill to play a game like *Simon Says* or to wait until he/she is called on to answer a question. Cognitive flexibility is the ability to easily switch gears and adjust to changed demands, priorities, or perspectives (Davidson et al., 2006; Garon et al., 2008). Cognitive flexibility can also be defined as the ability to cue a change of focus or the alteration of perceptions, emotions, thoughts, or actions in reaction to an internal or external stimulus. This may allow a child to understand the difference between *inside* and *outside* voices or to try a different strategy when working out a conflict with another child. An important aspect of executive function(s) is that these dimensions do not usually occur independently in real life situations. Instead, these three functions work together to produce competent executive functioning (Diamond & Taylor, 1996).

We are born with the potential to develop these capacities. Our genes provide the blueprint, but our experiences during infancy, early childhood, and into adolescence help to develop these abilities. These abilities develop through practice and are strengthened by experiences (Rothbart et al., 2006). A challenge to understanding executive functions in children is that these skills develop rapidly through childhood and that the progression is not always linear but occurs in spurts. To complicate it further, different components of executive functions appear to develop different trajectories. For example, inhibitory control grows rapidly through the preschool years but then slows as children age. This is in contrast to both working memory and cognitive flexibility which are thought to develop in a linear fashion from around the age of four until adolescence (Morgan et al., 2019). Since executive functions are dependent on the development of the frontal lobes, it has been proposed that executive functioning capabilities will demonstrate improvement that is aligned with neurophysiological developments within the prefrontal cortex (Anderson, 2002).

Neurocognitive Skills

The three skills that have been most commonly cited as executive functions (i.e., working memory, inhibition, and cognitive flexibility) depend on increasingly understood neural circuits involving components of the prefrontal cortex (PFC) and other areas of the brain. Due to this, these three skills can be identified as neurocognitive skills (Zelazo & Lee, 2010). Neurocognitive skills are then required to be able to engage in the goal-directed control of thought, action, and emotion. This goal-directed control in turn is then needed for various kinds of behavior. These behaviors imply the use of EF skills but are not that same as those skills. The behaviors may be more commonly displayed by individuals with a certain temperamental or personality characteristic. A figure of neurocognitive skills and associated temperaments, personalities, and goal directed behaviors is found in Appendix A.

EF can be further understood by separating it from other similar, partially overlapping constructs. EF skills can be related to but different from the term *intelligence.* For example, EF skills tend not to be as related to *crystallized intelligence,* which is based on facts or knowledgebase. This is in contrast to *fluid intelligence*, with which EF overlaps greatly due to the similar tasks needed of making predictions, identifying patterns, and drawing logical conclusions (Duncan et al., 1995).

EF skills can also overlap with the construct of self-regulation or social-emotional learning. Self-regulation is a broad term that can be defined in many ways but includes how people adjust their behavior. EF skills are only involved when self-regulation is deliberate and a conscious effort, where the individual is decisively changing their behavior in order to attain their goal (Blair & Raver, 2014).

Executive Functions and Achievement

Teachers are very aware of needed executive functioning abilities in the classroom. It is often on tasks in the classroom that include demands on executive functions where deficits are first noticed (Brouwers & Tomic, 2000). Teachers may note difficulties with paying attention, managing emotions, completing tasks, and communicating wants and needs verbally as important factors affecting whether or not a child may succeed in school (Zelazo, 2004). It is these important skills that allow for a student to be successful in education, and research has strongly shown a link between executive functioning and academic functioning. Executive functioning capabilities assessed in early childhood (either directly or indirectly through teacher ratings) have been found to predict school readiness for both math and reading (Espy et al., 2004; McClelland et al., 2007; Morrison et al., 2010; St. Clair-Thompson & Gathercole, 2006; Sung & Wickrama, 2018; Ursache et al., 2012), overall school achievement (Clark et al., 2010; Mazzocco & Kover, 2007), grades (Duckworth & Seligman, 2005), high school completion (Vitaro et al., 2005), and college graduation (McClelland et al., 2013). EF abilities appear to be even more important for school readiness than global cognitive scores or entry level reading or math (Blair & Razza, 2007; Brown & Landgraf, 2010; Davis et al., 2010; Morrison et al., 2010). Further, executive functioning abilities predict both reading and math competence throughout the school years (Borella et al., 2010, Duncan et al., 2017; Gathercole et al., 2004).

Clark et al. (2010) studied 104 children on measures of inhibition, working memory, and cognitive flexibility. They measured the children at 4 years of age on these executive functioning abilities to assess how much executive functioning predicted math achievement at the age of 6. The study showed EF abilities assessed in preschool accounted for a large percentage of the variance of the children's mathematical achievement at 6 years of age. EF abilities that were assessed at preschool have also predicted long term outcomes. For example, McClelland et al. (2013) found that children's attention persistence at age 4 significantly predicted reading and math outcomes at age 21 and college completion by age 25. Also, a recent study that utilized the Early Childhood Longitudinal Study - Kindergarten Cohort of 2011 (ECLS-K:2011) and included a large sample of children (*N*= 11,010), found that deficits in EF abilities at kindergarten did increase children's risk of experiencing academic difficulties from kindergarten through third grade. Specifically, these deficits increased their likelihood of being in the *at-risk* growth trajectory for reading, mathematics, and science (Morgan et al., 2019).

Research has also linked EF capabilities to a wide range of general outcomes (Baler & Volkow, 2006; Barch, 2005; Diamond, 2005; Fairchild et al., 2009; Lui & Tannock, 2007; Penades et al., 2007; Taylor-Tavares et al., 2007). Poor executive functioning abilities are associated with obesity, overeating, substance abuse, and poor treatment adherence (Crescioni et al., 2011; Miller et al., 2011; Riggs et al., 2010). Also, weak executive functioning has been linked to poor productivity, and difficulty finding and keeping a job (Bailey, 2007). Poor executive functions lead to social problems that include reckless behavior, violence, and emotional outbursts (Broidy et al., 2003; Denson et al., 2011). On the other side of the spectrum, people with strong executive functioning competence tend to have a better quality of life (Blair & Razza, 2007).

General EF abilities have been cited in numerous studies to have an impact on academic achievement, as well as in many other areas of life. However, cognitive flexibility specifically has also been noted to have a significant impact on a student's ability to be successful. Cognitive flexibility deficits are thought to reduce a student's abilities to shift their attention across learning tasks. For example, a student may struggle to switch their attention to a new topic being covered in a lecture or book the student is reading (Zelazo et al., 2016).

Cognitive Flexibility Interventions

Research suggests that EF is highly malleable during childhood (Diamond et al., 2007). The favorable effects of interventions targeting social and emotional learning have found to be largely mediated by experience-induced improvements in EF and particularly, cognitive flexibility (Riggs et al., 2006).

To demonstrate how malleable cognitive flexibility can be, studies have been completed to assess how effective interventions are when cognitive flexibility is targeted. Research on reflection training has shown that it can improve cognitive flexibility skills. In one study completed by Espinet et al. (2013), children who had failed the Dimensional Change Card Sort (DCCS), a measure of cognitive flexibility, were given reflection training, and showed marked improvements compared to the control groups (i.e., these included DCCS practice with no feedback at all, DCCS practice with only minimal yes/no corrective feedback). The children were taught during a 15-minute session to pause before responding, reflect on the hierarchical nature of the task, and formulate higher order rules for responding. Improvements on following assessments of the DCCS were significant for the reflection group, and larger than those seen with corrective feedback or practice. Moriguchi et al. (2015) also had children, 3 to 5 years old, practice on the DCCS but then also teach the rules to a puppet. The authors argued that teaching is a form of reflection training in that it requires review of what is being taught. Children who had received this training displayed significant improvement on the DCCS compared to the control group.

Speech and Language Skills and Their Impact on Cognitive Flexibility

Current research generally supports the fundamental ideas of Vygotsky (1986) and Luria (1959, 1961) regarding the importance of verbal processes in the utilization and development of self-regulation and executive functioning capabilities. For example, with age, children increasingly use verbalization as a strategy to maintain task information in mind (Karbach & Kray, 2007), and blocking the use of inner speech disrupts cognitive control in children and adults (Emerson & Miyake, 2003).

Flexibility is considered an important aspect of human cognition and behavior (Fausey et al., 2010) and has often been considered in earlier models of intelligence and creativity (Guilford, 1982). As we reflect on our own inner experience, most people report that it has a verbal quality (Baars et al., 2003). This can also be referred to as *verbal thinking, inner speaking,* or *inner speech*. Additionally, inner speech has been proposed to have an integral role in the self-regulation or cognition and behavior of both children and adults. The concept of inner speech is sometimes used interchangeably with *thinking*. However, this definition and past research in this area has been difficult due to methodological issues. Although it is an area difficult to study, inner speech dysfunction has been implicated in numerous psychiatric and developmental disorders (Emerson & Miyake, 2003).

There is mounting evidence that inner speech plays an increasingly prominent role in supporting cognitive operations during childhood. Much of the work in this area has come from the studies of cognitive flexibility and planning. The ability to represent linguistic rules to guide and support flexible behavior has been proposed to be an integral part of executive functioning development (Zelazo et al., 2004; Zelazo et al., 2003). Younger children (3-5 year olds) appear to benefit from the prompt to use verbal labels, both on switching tasks (cognitive flexibility) and in other contexts, suggesting a lack of spontaneous inner speech use at younger ages (Zelazo et al., 2003).

There is also research that has been completed with adults that support inner speech's role in task switching or cognitive flexibility (Baddeley et al., 2001). Emerson and Miyake (2003) completed a study to compare switching performance across a range of experiments using articulatory suppression (the process of inhibiting inner speech) and a foot-tapping control. Utilizing articulatory suppression consistently disrupted performance by increasing the switch cost (how long it takes to switch) between trials requiring different rules. This suggests that inner speech acted as a tool to prepare for transitions between trials. This effect was also impacted by the types of task cues used. Task conditions with explicit cues reduced the effect of articulatory suppression. This suggests that inner speech is not required when task materials adequately supported the required mode of response. However, task difficulty did not make a difference to the articulatory suppression effect. These results suggest that inner speech supported performance by acting as a mnemonic cue for how to respond, especially when cues were lacking in the task itself.

To further explore this, Miyake et al. (2004) completed a follow up study comparing the switch costs for color or shape judgment tasks with the explicit full word (e.g., SHAPE) or a less transparent, single letter (S…) cues. Articulatory suppression increased the switch costs for the single letter but not the full word. The results indicate that blocking inner speech only mattered when inner speech was needed to complete the cues of the task.

There is mounting evidence that children with speech and/or language impairment (SLI) display deficits beyond that of only the linguistic domain. Students with SLI typically have a delay in their oral language development that may present as either a receptive language (i.e., what they understand of language) deficit or expressive language (i.e., articulation, vocabulary) deficit (Crosbie et al., 2009). Students with a SLI often also have executive functioning and more specifically, cognitive flexibility deficits as well. A meta-analysis that included 46 studies found that there were reliable differences between children with and without SLI; children with a SLI consistently performed below that of their typical peers on measures of cognitive flexibility (Pauls & Archibald, 2016).

Cognitive flexibility deficits have also been cited in many disabilities and disorders that interfere with learning, for example, a specific learning disability (Geary, 2012, autism spectrum disorder (O'Hearn et al., 2008), conduct disorder (Zelazo et al., 2016) obsessive-compulsive disorder (Pietrefesa & Evans, 2007), and attention-deficit hyperactivity disorder (Castellanos et al., 2006). Related, these disabilities and disorders have also been connected to language difficulties in some way or another but especially inner speech dysfunction. For example, use of internalized speech has been shown to help children regulate their behavior and decrease outbursts. Also, children with behavioral problems often have difficulties with cognitive rigidity (lack of cognitive flexibility) leading to poor frustration tolerance and an ability to adapt to new situations.

Current Study

This was a study regarding the growth of cognitive flexibility skills in elementary aged children, with a particular focus on examining the influence of speech and language skills on cognitive flexibility. This study sought to understand the longitudinal trajectories or growth of students' cognitive flexibility skills over time. Longitudinal trajectories take into account both intercept (baseline or where the student started) and their specific rate of growth (slope) over time. Students may be placed into classes by their similar baseline and rate of growth scores. Specifically, this study examined the following hypotheses:

1a. Children's cognitive flexibility scores will increase over time; however, not all children will develop at the same pace. Based on previous research and theory, it was expected that there would be four classes. Previous research conducted utilizing the same database as this study detected 4 classes each for reading, mathematics, and science scores. For example, in the previous study, Class 1, the at risk or repeated academic difficulty class, contained about 6% of the sample, and typically scored two standard deviations below the mean in first grade and then further declined until third grade. This was in contrast with Class 4, which contained about 30% of the sample and maintained an above average trajectory or one standard deviation above the mean from first to third grade. Class 2 and Class 3 remained slightly below and slightly above average, respectively. Research has also connected EF skills and academic achievement over multiple studies discussed previously and due to this, it was expected that there would be the same number of classes for academic outcomes, as well as cognitive flexibility (Morgan et al., 2019).

1b. The at-risk class will have a lower baseline cognitive flexibility score (or intercept) as well as a slower rate of change (or slope) as compared to the other three classes that will either have a higher intercept and/or faster rate of change.

2. Children identified with a speech and language difficulty, as assessed by the *pre*LAS language screener, will be more likely to be in the at-risk class of cognitive flexibility. The at-risk class will be defined as the class with the lower baseline (or intercept) as well as slower rate of change (or slope).

Chapter 2: Literature Review

The following discussion reviews the literature on executive functions, as well as cognitive flexibility. First, the theoretical underpinnings of executive functions and cognitive flexibility research are presented, followed by a discussion of the neuroanatomy involved. Finally, the relationship of having a speech and language deficit with cognitive flexibility development is discussed.

Theory of Executive Functioning and Cognitive Flexibility

Multiple models have been proposed to account for EF. Existing models of EF that will be further elaborated below typically fall under two broad types: *representational models* focus on the kind of representations students can hold and the following executive control made possible by these abilities. *Componential models* consider EF as consisting of a group of correlated but separable cognitive processes that work together to create executive control. There is also the common distinction made in the research between unified and diverse models of EF. There can be overlap with representational/componential models, but it is not exact. Those who support unified models (similar to representational models) believe in a single unified EF process that underlies cognitive and response control, but proponents of diverse models (similar to componential models) claim that there are multiple dissociable EF processes (Jacques & Marcovitch, 2010).

In the past, EF has not been a well-defined construct. Related, EF has often been described as including a broad and diverse number of processes that direct thinking and behavior (Zelazo et al., 1997). Efforts to study executive functioning have increased in the past twenty years. These investigations into executive functioning have begun to clarify its precise nature. A few researchers, in the past, have considered it a single entity, similar on a conceptual level to general intelligence factor *g* (Duncan at al., 1995). However, many now look at executive functions as a unitary construct that includes relatively independent subfunctions (Baddeley, 1996; Miyake et al., 2000). Miyake et al.'s (2000) study proposed that the taxonomy of executive functioning consists of, at least, three basic functions: shifting (i.e., cognitive flexibility), updating (i.e., working memory), and inhibition. These three functions are required in different degrees in complex *frontal lobe* or executive functioning tasks. Miyake et al. used confirmatory factor analysis to indicate that these three skills are moderately correlated but also separable; this recognizes the importance of considering executive functions as both unified and diverse.

Unity and diversity (componential model)

Since the Miyake et al. (2000) study, many have looked to reproduce these results (e.g., Brydges et al., 2014; Duan et al., 2010; Friedman et al., 2006; Huizinga et al., 2006; Lee et al., 2013; Lehto et al., 2003; Miller et al., 2011; Rose et al., 2012; Usai et al., 2014). Many have found that at younger ages, executive functions remain *unitary* in nature (i.e., the three components of working memory, inhibition, and cognitive flexibility are not separated) and a two or three factor model does not fit. However, by the age of 9 to 10, executive functions begin to *diversify* and two or three factor models fit the data better than a unitary model. Brydges et al. (2014) looked at 135 children (ages 10 to 12 years) using measures that included working memory, cognitive flexibility, and inhibition. They assessed the children twice over a two-year period to determine if any changes in the structure of executive function occur in this age range. Longitudinal factor analyses showed that the structure of executive functions significantly differed between testing times, and that the factor structure of executive functions changed from a one-factor (i.e., unitary) model at age 10 to a two-factor model at age 12, where working memory was separable yet related to an inhibition/shifting factor. Another study (Lee et al., 2013) assessed 688 children (6 to 15 years old) annually on tasks that included updating and working memory, inhibition, and switch efficiency. Tests for longitudinal factorial invariance indicated that the data from the 6- to 13-year-olds conformed to a two-factor structure. For the 15-year-olds, a separated, three-factor structure was indicated. Also, in support of this theory, Lehto et al. (2003) assessed 108 children on similar tasks that measured working memory, inhibition, and CF. Both exploratory and confirmatory factor analysis presented three inter-related factors, which resembled those obtained by Miyake et al. (2000). These findings also support the view of executive functions being both unified and diverse. The three constructs of EF were chosen in the Miyake et al. (2000) study because they were common in the literature and could be utilized to examine the questions of unity and diversity. However, the model is not to be considered comprehensive and there are possibly more EF skills to be considered (Friedman & Miyake, 2017).

Friedman and Miyake (2017) followed up on their previous study to gain further insights into the *unity and diverse* theory. They reviewed multiple studies that included multiple age groups as well as populations and that included commonly studied EF skills. Their findings concluded that these commonly studied EFs continue to be correlated but separable when measured with latent variables and are not the same as general intelligence or *g.* A model of the *unity and diversity* theory is found in Appendix B.

Other Theories and Models

McCloskey (componential model).

The Miyake et al. (2000) study indicates three common EF skills; however, other researchers and practitioners have developed models that incorporate many more identified EF skills or abilities. McCloskey (2009) has proposed a model of executive functioning skills that has been built on the conceptual and empirical work of many across multiple areas, such as cognitive neuroscience and psychology, neuropsychology, developmental and clinical psychology, and educational psychology.

The model is structured using five tiers of executive capacity. The first two tiers are most commonly involved with daily self-control. The first tier is unitary and labeled *Self-activation*. This stage has to do with how our bodies wake up from sleep. However, cognitive flexibility (the area being focused on in the current study), is incorporated into McCloskey's (2009) second tier of his model, *Self-regulation*. Within the Self-regulation tier, there are a large number of executive functions that are responsible for cueing and directing functioning within the domains of sensation and perception, emotion, cognition, and action (McCloskey, 2009). The top three tiers are Self-control (i.e., Self-analysis), Self-generation, and Trans-self-integration. These tiers develop most commonly at the adolescent and older ages.

The model is meant to be clear that self-regulation functions cue and direct how we perceive, feel, think, and act (McCloskey, 2009). However, self-regulation related to these domains of functioning may not be cued or directed in perfect unison. The effectiveness of executive capacities might not be equivalent across the four domains. For example, a student may be good at cueing monitoring for thoughts and feelings, but poor at cueing monitoring for actions (McCloskey, 2009).

Goldstein and Naglieri (representational model)

There is also support for a model of EF that defines EF as a unitary structure. In other words, the term used would be Executive Function as opposed to Executive Functions. Goldstein, Naglieri, Princotta, and Otero (2014) found more than 30 definitions of the term executive functioning(s). This muddling of the definition makes both theory and assessment difficult and confusing. There is also considerable research (Chaytor & Schmitter-Edgecombe, 2003; Spooner & Pachana, 2006) that addresses how scales, like the Comprehensive Executive Functioning Inventory (CEFI), only have moderate correlations with direct assessments, such as the Dimensional Change Card Sort (DCCS), of EF skills. This identifies continued discrepancies within the research as to whether we are correctly assessing executive function(s). Naglieri and Goldstein (2013) utilized factor analysis from the CEFI to show support that one factor was the best solution. Their item groups included Attention, Emotion Regulation, Flexibility, Inhibitory Control, Initiation, Organization, Planning, Self-monitoring, and Working Memory scales. They concluded that when utilizing parent, teacher, and self-ratings based on observed behaviors, a one factor construct (Executive Function) best fit the data. This one *Executive Function* construct includes all of the item groups assessed on the CEFI. This change, of considering *Executive Function* and it being a unitary construct, then influenced theory and definition. Executive function then involves (per Goldstein & Naglieri, 2013), *how you decide what to do*. If you then look at this through a unitary construct, how you choose what to do requires that a person utilize initiation, planning, attending, memory, self-monitoring, flexibility, emotion-regulation, and inhibitory control. This model supports the notion of executive function being an ability that is represented or seen through student's behavior, social emotional competence, and academic/work. A model of Goldstein and Naglieri's theory is found in Appendix C.

Iterative reprocessing model (representational model).

Another comprehensive model of executive functions is the *Iterative Reprocessing* model proposed by Zelazo (2015). According to this model, reflection of information prior to responding yields a foundation for the control of attention. This use of executive functions or goal-directed modulation of attention is thought to be verbally mediated and involves the formulation and maintenance in working memory of explicit action-oriented rules. These rules vary in complexity and flexibility and are hierarchical in nature. Developmentally, research has found that 2.5 year old's successfully use a single rule to sort pictures (Zelazo & Reznick, 1991). 3 year old's can use a pair of rules, and 5 year old's can use a hierarchical set of rules, including a higher order rule for switching between rule pairs (Zelazo et al., 2013). A figure of the Iterative Reprocessing Model is found in Appendix D.

Summary of Theories

There are multiple theories and beliefs about the best perspective to utilize when viewing or understanding EF; this shows the need for further research in this area to better understand how EFs develop and are utilized by students. In particular, as this study hoped to do, investigations and comparisons of performance on EF measures across different age groups may help discover important information about the EF processes themselves.

Development of Cognitive Flexibility - Cross Sectional Studies

Several studies have looked at the development of executive functions, and specifically cognitive flexibility, over the span of childhood. Some have focused on the early childhood time frame of about 3 to 6 years of age due to the belief that a significant growth spurt occurs during this time period (Geradi-Caulton, 2000; Gerstadt et al., 1994; Jones, et al., 2003). Others have looked at the adolescent time period (usually beginning around 11 years) due to the same belief that a growth spurt occurs during this time. However, relatively fewer studies have looked at the development of executive functions and cognitive flexibility over a larger time frame or during other spans of ages (e.g., 7-10 years old)(Best et al., 2009).

Due to the developmental progression in cognitive flexibility skills over time in childhood, studies that have focused on early childhood often concentrated on the accuracy of the children's responses. They have found that by the age of five years, children can accurately switch between response sets (Zelazo, 2004). However, for school-age children, studies incorporate tasks that include both accuracy and reaction time. Including reaction time allows for assessing children over a wider range of ages using the same assessment instrument. This is important due to methodological challenges that arise from using multiple assessments. To avoid ceiling effects, researchers have often used more complex assessments that likely tap into multiple executive functions (Zelazo et al., 2016). When tasks have only been given to younger or older children and not both, it makes comparisons difficult.

Huizinga et al. (2006) completed a cross sectional study that looked at the differences in executive functions and cognitive flexibility in several age groups. The participants (n = 384) were in four ages groups (i.e., 7, 11, 15, and 21 years). Analyses indicated that executive functions, and especially cognitive flexibility, continued to develop into adolescence. Another study that also used a cross-sectional design included 3,500 participants, ages 8 to 21 years. Gur et al. (2012) administered a computerized neurocognitive battery that included an assessment of abstraction or mental flexibility. They found a moderate effect size for accuracy due to age, also indicating that cognitive flexibility development continued into adolescence.

Development of Cognitive Flexibility – Longitudinal Studies

A limited number of studies have examined children's performance on EF tasks across two assessment periods. One study of a large Dutch cohort of preadolescents (Boelema et al., 2014) indicated developmental changes in many different aspects of EF skills over an 8-year period (ages 11 through 19). They utilized the Amsterdam Neuropsychological Tasks (ANT), measuring Focused Attention, Inhibition, Sustained Attention, Speed of Processing, Working Memory, and Shift Attention. Results showed that significant growth takes place for all of the measured subcomponents of EF during adolescence. Girls showed better baseline performance and smaller maturational rates, suggesting they have more mature skills in early adolescence.

Studies that have used a longitudinal design and participants who were measured at three or more times using the same measure have been very limited at the school-age range. Most, if not all, of these studies were completed on relatively short intervals of time across the early childhood period (Clark et al., 2013; Hughes et al., 2010; Willoughby et al., 2012). The Clark et al. (2013) study looked at children at ages 3, 3.75, 4.5, and 5.25 years (N = 388) using the Shape School assessment. This assessment incorporated a graduated measure of executive control that included baseline, inhibitory control, and cognitive flexibility conditions. Clark et al. (2013) found that there were substantial gains at each of these ages in accuracy and speed for all conditions, but even more pronounced between ages 3 and 3.75.

Continued research in the area of measurement of cognitive flexibility skills and on the trajectory of cognitive flexibility skill development from early childhood through late childhood is needed so that benchmarks will be available against which to gauge the effect of specific interventions or educational approaches. Although there have been many studies completed at the preschool age, research has been lacking that focuses on the school-age child. A full picture of development from birth to adulthood would give us better guidance as to what developmental expectations are at a specific age level and help to begin to answer questions about how cognitive flexibility plays a part in an individual's successful outcomes.

Typical Assessments Utilized to Assess Cognitive Flexibility

The ways that cognitive flexibility and executive functions have been assessed have created difficulties and concerns. The following assessments take into account multiple different tasks when cognitive flexibility is assessed. Cognitive flexibility may not be the only component being measured when these assessments are utilized, but also inhibition or other needed skills to complete these tasks. Also, many of these assessments have not been developed to be utilized across the developmental span so that they can easily be compared and contrasted or represent development. Instead, it can be difficult to know what is due to developmental change or the difference in assessments that are given at different ages (Zelazo et al., 2013). The Dimensional Change Card Sort (DCCS) is a typical measurement of cognitive flexibility for early and late childhood that will be used in this study; therefore, it will be described more in depth within the next chapter (Doebel & Zelazo, 2015).

Wisconsin Card Sorting Test

On the Wisconsin Card Sorting Test (Grant & Berg, 1948), participants are shown four target cards consisting of different geometric shapes (i.e., triangles, circles, stars, and crosses) that also differ in terms of color (i.e., red, green, yellow, and blue) and number (i.e., 1, 2, 3, and 4). The participants are presented with test cards that they are required to match with one of the target cards, which can be difficult because the test cards can match multiple target cards on different dimensions. Participants are told on every trial only whether they matched correctly. Once they have sorted by one dimension correctly for 10 consecutive trials, the experimenter changes the dimension, and participants must then switch their response set. This continues until they have completed six categories or until they sort all test cards. Although this assessments is viewed as primarily an assessment of CF, the Wisconsin Card Sorting Test also has components of working memory and inhibition. Participants must not only keep relevant category information in mind and update that as the category changes (working memory), but they also must resist the temptation to sort cards as they did for previous categories (inhibition).

Flexible Item Selection Task

On the Flexible Item Selection Task, children are shown three items on each trial (e.g., small red boat, small blue boat, large blue boat) (Jacques & Zelazo, 2001). Two of the items match on a specific dimension (i.e., size) and two items match on another dimension (i.e., color). For all trials, one of the items is considered a *pivot* item or that one item can match with both other items (e.g., small blue boat). The child is asked to select a pair of matching items and then to immediately select another different pair. Research on this task has shown that 3 year old’s perform worse than both 4 and 5 year old’s on their first selection. In addition, 4 year old’s do well on their first selection but perform worse than 5 year old’s on the second selection., demonstrating that the 4 year old’s may have specific difficulties with the switching aspect of the task.

False Belief Tasks

The False Belief Tasks asks children to predict the behavior of a person who holds a mistaken belief about the whereabouts of an object or the contents of a container when they (the children) know the real location of the object or the container. To accomplish this task, children must reason from the viewpoint of the character and refrain from responding on the basis of their own reality perspective. Research on this task has also shown age-related changes between 3 and 5 years of age (Wellman et al., 2001).

Neuroanatomy

Research has long suggested that executive functioning skills develop based on the development of the pre-frontal cortex (Dujani & Uddin, 2015). Due to this, it is important to explore and understand the interplay between executive functioning skills and neuro-development. The frontal lobe has often been associated with executive functioning. The idea that executive functions exist came from the observations of people with brain damage, typically in their frontal lobes. In these cases, it was clear that a *higher* cognitive skill had been lost even when vision, audition, feeling, movement, speech, and long-term memory remained intact (Aron, 2008).

A five-circuit model of executive functioning has been proposed in the literature in the past (Zelazo & Lee, 2010), but more recently a seven-circuit model has been introduced (Middleton & Strick, 2001). The circuits have been divided into the following categories: skeletomotor, oculomotor, dorsolateral prefrontal, lateral orbitofrontal, ventromedial orbitofrontal, anterior cingulate, and inferotemporal/posterior parietal.

There are excitatory and inhibitory pathways that start in subcortical regions of the brain (i.e, basal ganglia and thalamus) and project to the frontal cortex and vice versa (Ardila, 2008). The skeletomotor (i.e., body movements) and oculomotor (i.e., eye movements) circuits appear to be related to controlling movement. There are three circuits that are suggested to be associated with executive functioning: the dorsolateral prefrontal circuit, orbitofrontal circuit, and the anterior cingulate circuit. The dorsolateral circuit regulates numerous executive functions including planning and maintaining, organizational strategies, implementing efficient memory search strategies, sustaining the instructional demands of a task, having the cognitive flexibility to shift sets, and regulating complex motor programming output. Specifically, this is a circuit implicated in the function of cognitive flexibility (Ardila, 2008). The orbitofrontal circuit is responsible for empathic, civil, and socially-appropriate behaviors (Zelazo & Lee, 2010). A personality change can be the distinct hallmark of orbitofrontal dysfunction. It can also be involved with regulating our abilities to inhibit, evaluate, and act on social and emotional decision making. The orbitofrontal circuit is also connected with cognitive and affective functions such as assessing emotional significance of events, anticipating rewards and punishments, adjusting behaviors to adapt to changes in rule contingencies, and inhibiting inappropriate behaviors (Zelazo & Lee, 2010). The anterior cingulate is responsible for regulating motivational mechanisms, so that apathy can be a common behavioral manifestation when damage to the anterior cingulate occurs.

One of the reasons executive functions have been referred to as the *conductor* of the brain is due to the prefrontal cortex (PFC) being highly connected with, and coordinating activity in, many areas throughout the brain. Connections of PFC to other areas of the brain occur mostly through white matter tracts. White matter includes the neurons that have developed the fatty, myeline sheath. The nerves become myelinated due to development and are experience-dependent. The myeline sheath allows for much quicker connections, like that of an insulated electrical cable. Neuro-imaging studies of children have shown that EF-related brain activity is generally more diffuse or more spread out and less isolated to specific pathways than seen in adults (Durston et al., 2006; Eslinger, 2009). As individuals grow in age and experiences, there is a change from more diffuse to more focal activity. This is due to the development of white matter (myeline) and synaptic pruning (Klingberg, 2006; Sheridan et al., 2014). This is thought to indicate an increase in the efficiency as well as the capacity of the brain as it processes information. As stated above, the PFC is highly connected to the basal ganglia (learning patterns and routines) and the thalamus (intersection highway of the brain), but it is also connected to the amygdala, which is an area important for emotion and stress. This is relevant due to the role that stress can play in turning EF skills off or heightening the response of EF skills when moderate levels of stress are induced.

Another important factor that has been studied, mostly with nonhuman primates, is the role of neurotransmitters in PFC functions (Wilson et al., 2010). Activity in individual neurons in the PFC is sensitive to a variation in levels of neurotransmitters present in the synapse-- especially catecholamines, dopamine, and norepinephrine (Cools & D'Esposito, 2011). Stress, as noted above, can play an important role in engagement with the environment or lack thereof. As levels of dopamine and norepinephrine increase moderately from baseline, the individual is most likely attentive and engaged. However, when exposed to high levels of stress and a large increase in the neurotransmitter catecholamines, they shut down neural activity in the PFC. Research on this area provides support for the well known Yerkes-Dodson inverted U-shape curve relating stress and performance (Yerkes & Dodson, 1908). The U-shape curve shows that when stress is low, performance is low, but as stress increases, performance increases also. This continues until a point where stress is too much and begins to negatively impact performance.

The inverted U-shape curve indicates the interactive *top-down, bottom-up* processing of this neural system. For example, the neurotransmitters dopamine and norepinephrine, neurotransmitters important in the PFC, originate in the limbic system and brainstem, which are areas that influence attention, emotional responses to stimulation, and the physiological response to stress. Experience can activate these areas, releasing dopamine, norepinephrine, and the glucocorticoid hormone cortisol. The chemicals increase neural activity in the PFC, which the PFC then feeds back on the limbic and brainstem areas to maintain an optimal or effective range depending on the context (Gunnar & Quevedo 2007). When stimulation is in an appropriate range and controllable, as seen in well-structured experiences in the classroom, neural activity is balanced and EF skills are possible. However, when stimulation is overwhelming, like that of a disorganized and chaotic classroom, activity in the system is weighted toward the subcortical structures and activity in the PFC is reduced. Activity in the brain is then associated with more reactive and automatic responses (Arnsten, 2009).

Hot and Cool Executive Functions

The interactions between executive functions and more basic influences such as emotion and stress are relevant to the distinction made between *hot* executive functions and *cool* executive functions (Zelazo & Muller, 2002). Hot executive functions involve the processes that operate in motivationally and emotionally significant situations, while cool executive functions involve the processes that operate in more affectively neutral contexts (Zelazo & Carlson, 2012). For example, most laboratory measures of executive functions assess cool EF, and do so using tasks that lack a significant affective or motivational component. One example of a measurement of cool EF is the Dimensional Change Card Sort (DCCS), which will be utilized for this study and thus will be further described below, whereas an example of a hot EF assessment is the delay of gratification, as measured by the *marshmallow test* (Mischel et al., 1989). The marshmallow test is an assessment of delayed gratification where a marshmallow is placed in front of a child who is told that they will get a second marshmallow if they do not eat the first one placed in front of them. The examiner then leaves for a set amount of time, assessing how long the child can wait to receive the treat. Poor hot EF skills are associated with inattentive or overactive problem behaviors and antisocial behavior disorders in children, whereas cool EF skills are associated with better academic outcomes, including math and reading (Brock et al., 2009; Willoughby et al., 2011).

Hot and cool EF skills show how integrated EF skills are to our everyday functioning and how they can be better explained and assessed depending on the circumstances (whether the task involves an emotionally driven piece or it is purely logical). EF skills are so important to our daily functioning and a better understanding of how they develop over time is needed. It has been proposed that our speech and language skills provide the basis for how we develop cognitive flexibility skills, an integral part of EF skills (Alderson-Day & Fernyhough, 2015). Our beginning use of flexible naming or labeling of objects (i.e., having multiple names for one object) requires us to shift perspectives on how a word is being used in each specific context.

Speech and Language

Speech Development

Speech and language have been cited as uniquely human capacities (Hauser et al., 2002). More than any other animal, human language allows for remarkable open-ended descriptions of all objects and activities. Language is very complex and full of detail. In some ways, much of language is rule-governed. One example of this is that we form plurals in English by adding the suffix, *s* or *es*, or we place the adjective before the noun. However, the English language can also be quirky and inconsistent. For example, the *ough* in *plough*, *tough*, and *slough* are pronounced in three completely different ways although they share the same orthography. The plurals like *oxen*, *sheep*, and *leaves* break the rule that governs plurals. The English language includes a vast array of irregularities, variations, and special cases that are set against a backdrop of partial regularities (MacWhinney, 1975).

With language being so complex, it is amazing that children are able to learn all of it. Noam Chomsky postulated the view that language is in our genetics and that it is not learned, but acquired (Chomsky, 1980). Compared to more basic systems, such as smell or balance, language processing is coordinated among many cortical regions. Linguistic theory typically analyzes language across six levels, including auditory phonology, articulatory phonology, lexicon, syntax, mental models, and pragmatics (MacWhinney, 2010). Auditory development involves learning how to distinguish the basic sounds of language and then using them to segment the flow of speech into words.

Auditory phonology involves the perceptual or receptive side of language use. Articulatory phonology involves learning to control the mouth, tongue, and larynx to produce sounds. This learning involves the expressive use of language. We cannot develop articulation (expressive) until we have an understanding (receptive) of the sounds in our language (MacWhinney, 2010). The next piece of language development is lexical or the learning of words. For humans to communicate with each other, words need to have a shared meaning. Due to this, the child then must be able to choose the correct meaning for each new word. However, children must not only be able to recognize words but also express them. To do this, children need to be able to recall the names for things on their own and then change these forms into articulation. Due to this, lexical development also shares both receptive and expressive parts. When children have acquired a collection of words, they can then place them into combinations. Syntax is the system of rules by which words and phrases are arranged to create meaningful statements. Learning mental models is relating those syntactic patterns to meaningful interpretations (MacWhinney, 2010). The last component, pragmatics, is the system of patterns that help a person to be able to determine how we can use language in a certain social setting (Ochs & Schieffelin, 1986).

Speech and Language Development and Cognitive Flexibility

Based on Vygotsky's (1986) theory of cognitive development, inner speech is a product of a developmental process. Due to a mechanism of internalization, linguistically-mediated social exchanges are transformed into an internal *conversation* with the self. The development of verbal mediation is seen as the process through which children become able to use language and other systems to regulate their behavior (Alarcon-Rubio et al., 2014; Day & Smith, 2013; Lidstone et al., 2010; Wallace et al., 2017).

Objects almost always have more than one name or label. This is seen frequently throughout our day; a fork is also silverware and a horse is also an animal. This competition between words is seen even more clearly for bilingual children who understand that everything in their world must have at least two names. A common laboratory experiment that assesses word learning demonstrates competition between words. A child is presented with a series of objects (some old and some new), given a word that is either old or new, and then asked to match up the word with an object. For example, they may be given a teacup, a glass, and a demitasse. The child already knows the words for cup and glass. The experimenter then states, "Give me the demitasse." The child, if accurate, will then infer that the demitasse refers to the object for which they do not have a well-established name. It makes sense to use the new name as the label for some new object. The child appears to be thinking in terms of competition between words, where each word is vying for a particular semantic niche. When the two words are in conflict, and no additional disambiguating clues are present, it makes sense for the child to assume the person is being reasonable and to use the new name for the new object (MacWhinney, 2010). Competition can force the child to move meanings around so that they occupy the correct semantic niche. One example is when a parent calls a toy horse a toy, the child may search for something to disambiguate the two words. For example, the parent may say, “Can you give me another toy?” Toy refers to not only the toy horse but also other toys. This can allow for the child to shift perspective and to understand the word toy in the framework of the shifted perspective. One example used by Clark (1997) is the case of the rocking horse. This object may be called a toy, horsey, or chair depending on how it is being used in the moment. This flexible use of labeling is an integral part of language learning. By learning how to shift perspectives, children develop how to cope with competition between words and thus, build on cognitive flexibility. This can be seen and is supportive of the idea that language is the beginning of training our minds to utilize cognitive flexibility.

Speech and Language Skills’ Impact on Cognitive Flexibility

There has been increasing evidence that suggests that children with specific language impairment have difficulties with executive functioning skills (Cragg & Nation, 2008; Crosbie et al., 2009; Farrant et al., 2015; Karasinski, 2015; Pauls & Archibald, 2016; Roello et al., 2015). An analysis of 46 studies (34 included inhibitory control tasks and 22 included cognitive flexibility tasks) concluded that children with a speech and language impairment consistently performed below same age peers on both inhibitory and cognitive flexibility tasks (Pauls & Archibald, 2016). Language use during daily interactions plays a key role in executive functioning. Language provides individuals with the capacity to, “think, learn, and behave through understanding and interacting through shared symbols” (Barkley, 1997, p. 72). While using language this way, individuals are communicating with themselves about how to solve a problem and to learn. Many believe that the development of language is necessary to other mental processes such as working memory and that some processes may not be possible until the development of internal language (i.e., self-talk) is complete. Many clinical approaches have shown how effective self-talk or language-driven executive control can be (Greene et al., 2001). When people are able to reflect upon their own inner experiences, they are most likely to report that it has a verbal quality (Baars et al., 2003).

Summary

As mentioned previously, cognitive flexibility is an important aspect of executive functioning that contributes to overall functioning. Although there are numerous studies which have outlined the development of cognitive flexibility throughout the pre-school years, there are limited resources that describe the continued development of cognitive flexibility throughout later childhood (Carlson, 2005; Garon et al., 2008). For example, major age-related changes in CF occur between 3 and 5 years of age. During the Dimensional Change Card Sort (DCCS), 3 year old's tend to perseverate (continuing to sort by pre-switch phase) on the post-switch phase, whereas 5 year old's (and some 4 year old's) can sort the cards correctly by both sets of rules. Due to limited longitudinal studies on this topic, we do not have an exact developmental account of cognitive flexibility across childhood (Best & Miller, 2010). Continued research is needed on the trajectories of cognitive flexibility development from early childhood through adulthood. Benchmarks are also needed to gauge typical development and to assess the usefulness of interventions. The current study explored the developmental trajectory of cognitive flexibility in children between the ages of five years old and ten years old. It was also hypothesized that a child who has a speech and language impairment will be more likely to have an at-risk trajectory of their cognitive flexibility development.

Chapter 3: Method

The current study modeled the longitudinal developmental trajectories of cognitive flexibility. In choosing an analytic approach, several observations about the dynamics of cognitive flexibility guided the decisions. To start, the meaning and determinants of cognitive flexibility development may vary depending on where the student starts. For example, a student who scores low on an assessment of cognitive flexibility in kindergarten may continue on a different trajectory than another student who scores higher. Furthermore, there may be underlying differences between students who score lower at the starting point than those who score higher, such that these students are exposed to different experiences that shape their trajectories. Therefore, any analytic model of cognitive flexibility over time should account for both initial starting point scores and subsequent changes conditional on that starting point. To account for both initial start points and change over time, latent class growth modeling (based on Muthen, 2004) was used to uncover common pathways for change in cognitive flexibility and then described the characteristics of students whose CF skills represent these pathways.

The methodology and research design are presented in this chapter. The first section includes the sampling design of the ECLS-K:2011 database. This is then followed by descriptions of the participants included in the ECLS-K:2011 sample and types of measures used. All information pertaining to the ECLS-K:2011 dataset in the following segments was found in the *ECLS-K:2011 User's Manual* (Tourangeau et al., 2019).

Database

This study relied on data collected as part of the Early Childhood Longitudinal Study, Kindergarten Class of 2010-2011 (ECLS-K:2011). This data collection was sponsored by the US Department of Education (USDE), within the Institute of Education Sciences (IES) and National Center for Education Statistics (NECS). The focus of this multi-source, multi-method study is on the school experiences and development of children, and includes interviews with parents, data collected from teachers and administrators, and direct child assessments. The base year data were collected from the children enrolled in the kindergarten class of 2011. A total of 18,170 kindergarten students from 970 schools throughout the U.S participated. The ECLS-K:2011 is a longitudinal study, with the same children followed from kindergarten through the fifth grade. Information was collected in the fall and the spring of kindergarten (2010-11), the fall and spring of first grade (2011-12), the fall and spring of second grade (2012-13), the spring of third grade (2014), the spring of fourth grade (2015), and the spring of fifth grade (2016).

The ECLS-K:2011 cohort was sampled using a multistage sampling design. In the first stage, 90 primary sampling units (PSUs) were selected from a national sample of PSUs. The PSUs were counties and county groups. In the second stage, public and private schools educating kindergartners (or ungraded schools educating children of kindergarten age) were selected within the PSUs. Finally, students were sampled from the selected schools. The schools were selected from a preliminary version of the frame developed for the 2010 National Assessment of Educational Progress (NAEP), which contained information about public schools that were included in the 2006-07 Common Core of Data Public Elementary/Secondary School Universe Survey and private schools that were included in the 2007-08 Private School Universe Survey. The NAEP frame had not yet been updated and, therefore, was not final at the time it was obtained for use in the ECLS-K:2011. For this reason, a supplemental frame of newly opened schools and kindergarten programs was developed in the spring of 2010, and a supplemental sample of schools selected from that frame was added to the main sample of study schools. In the third stage of sampling, approximately 23 kindergartners were selected from a list of all enrolled kindergartners in each of the sampled schools.

Trained field staff assessed children in their schools and collected information from parents. The majority of parent interviews were conducted by telephone, although interviews were conducted in person for parents who did not have telephones, who were difficult to contact by telephone, or who preferred an in-person interview. Teachers and school administrators were contacted at their schools and asked to complete hard-copy self-administered questionnaires. Before- and after-school care providers were asked to complete hard-copy self-administered questionnaires in the children's kindergarten year.

The ECLS-K:2011 oversampled Asian Pacific Islander and Indian/Alaskan children, twins, and children with low and very low birth weight (Tourangeau et al., 2014). In this current study, the ECLS-K sampling weights were utilized for all analyses.

Participants

The full sample consisted of 18,174 children total who participated in the Early Childhood Longitudinal Study, Kindergarten Class of 2010-11 (ECLS-K:2011). However, due to missing data on some of the variables, only 14,173 students' information was utilized in the current study when analyzing the cognitive flexibility scores. Gender characteristics of the sample included 51.2% male and 48.8% female participants. In terms of race, where parents were allowed to choose more than one category, 23.8% were Hispanic/Latino, 69.8% White, 15.6% Black/African American, 9.7% Asian, 2.4% American Indian/Alaska Native, and 1.4% Native Hawaiian/Pacific Islander. See Table 1 for further participant characteristic information.

Measures and Variables

Data were collected from children, their parents, and their schools. Direct child assessments were conducted using instruments from several copyrighted assessment batteries. The following sections describe the instruments that are relevant to this study.

The Dimensional Change Card Sort (DCCS)

The DCCS (Zelazo, 2006) is an easily- administered measure of executive functions. It is suitable for use across the lifespan, but the standard version of this task is usually used with healthy children between the ages of 3 and 5 years. Children are shown two target cards (e.g., blue rabbit and red boat) and asked to sort a series of bivalent test cards (e.g., red rabbits and a red boat) according to one dimension. They are then administered a post-switch phase where they are told to sort the same types of test cards according to another dimension (e.g., shape). In the kindergarten and first grade data collections, the DCCS was administered as a table-top card sort with the items administered by a trained assessor. Beginning with the second-grade data collections, a computerized version of the DCCS developed for the National Institutes of Health Toolbox for the Assessment of Neurological and Behavioral Function (NIH Toolbox) was administered. The change to a computerized version of the task was made so that the DCCS would remain age-appropriate through the end of the data collection. This version was utilized in the fall and spring of second grade, spring of third, spring of fourth, and spring of fifth grade. The computerized version can be used for ages 3-85 (Zelazo et al., 2013). The NIH Toolbox DCCS consists of 40 trials, including 5 pre-switch trials (sort by one dimension, e.g., color), 5 post-switch trials (sort by a different dimension, e.g., shape), and 30 mixed-block trials (sorting dimension varies by trial). Testing conducted in the development of the NIH Toolbox DCCS indicates that 8 year old's typically scored at ceiling on the pre-switch and post-switch trials. Due to this, children under the age of 8 begin with pre-switch trials, and children 8 and above begin with mixed block trials and are given credit in the scoring for completing the pre-switch and post-switch correctly. However, for the ECLS-K: 2011, children were administered the version of the NIH Toolbox DCCS for ages 8 years and older, regardless of their age at assessment. In second grade, approximately 90% of the EKLS:K 2011 children in the fall subsample for second grade and approximately 40% of children in the spring subsample of second grade who had a score on the DCCS were not yet 8 years old when the DCCS was administered. In third grade, nearly all were 8 years old (99.5 %), and for fourth and fifth grades, all were at least 8 years old. The decision to administer the same version of the DCCS from second grade forward, regardless of being age 8 or above, was made so that all study children would receive the same version of the DCCS task. Use of the same measure allows for longitudinal analysis of performance.

Scoring for the computerized version is based on a combination of accuracy and reaction time. For any given individual, accuracy is considered first. If accuracy levels for the participant are less than or equal to 80%, the final *total* computed score is equal to the accuracy score. If accuracy levels for the participant reach more than 80%, the reaction time score and accuracy score are combined.

Overall, the DCCS has shown excellent test-retest reliability and convergent validity (*ICCs* = .90–.94; Beck et al., 2011; *ICCs* = .92; Zelazo et al., 2013). In the past, it has been difficult to study developmental changes in cognitive flexibility due to a lack of consistent measures across childhood. Due to this, it has been difficult to tease out developmental changes from task demands. The DCCS was created to address this issue.

To interpret individual performance, this study utilized the computed (overall) score, where higher scores indicate higher levels of cognitive flexibility. In addition, the DCCS computed score provides a way of gauging raw improvement or decline from Time 1 to Time 2 (or subsequent assessments). This computed score ranges from 0-10, but if the score is between 0 and 5, it indicates that the participant did not score high enough in accuracy (80 percent correct or less) (Zelazo, 2006). A list of the scores of each wave, where the same children were administered the DCCS at different times (fall of kindergarten through spring of fifth grade) can be found in Table 2.

Data Preparation for DCCS

Using the ECLS:2011 data set and SPSS, I first addressed how to compare waves of DCCS scores during waves 1-4 and waves 5-9. In waves 1-4 (kindergarten through first grade), DCCS assessment is scored on a scale of 1-18, as opposed to the 1-10 scale of waves 5-9. This is due to only accuracy being taken into account for the scoring due to developmental progression of cognitive flexibility. Younger children were administered the DCCS as a tabletop activity as opposed to the computerized version that was also able to take into account and measure reaction time as well as accuracy. To address this concern and allow the results to be compared across waves, I multiplied waves 1-4 DCCS scores by .55 to place the scores on a 10-point scale.

Issues of non-normal distribution within waves 5-9 (second through fifth grade) were then addressed. The skewness is due to how the DCCS is scored at that age level by taking into account both accuracy and reaction time. If a child did not receive 80% accuracy on the assessment, their reaction time was not included in their score. This created a subset of children whose scores caused the data to skew negatively. For example, approximately 4% of children in the third-grade data collection failed to achieve greater than 80% accuracy. In fourth grade, this percentage was 2% and in fifth grade, 1%. To counteract this, the mean reaction time of the children's performance within that wave was added to those children's scores that did not include a reaction time. An adequate skewness is between -1 and 1. This created an adequate skewness statistic of: -.427 (wave 5), -.291 (wave 6), -.250 (wave 7), -.281 (wave 8), and -.223 (wave 9).

Parent and Teacher Interview

Parent interviews were conducted using a computer-assisted interview (CAI) process. Parent interviews took place during the fall and spring from kindergarten through fifth grade. Most interviews were conducted in English; provisions were made for parents who spoke other languages. The majority of interviews were conducted over the telephone but a small number of interviews were conducted in person. The average length of the interview varied and was dependent upon the number of questions included, and also what the focus was during that round. For example, fall interviews focused more on children's experiences during the previous summer and any enrichment or educational activities that may have been provided. The respondent to the parent interview was usually a parent or guardian in the household who identified himself or herself as the person who knew the most about the child's care, education, and health. For subsequent interviews after kindergarten, interviewers attempted to complete the parent interview with the same respondent who completed the parent interview from previous rounds. For purposes of this study, the interview information was used as a source of background information for the variables that contributed to socioeconomic status (SES).

Socioeconomic Status

The ECLS-K:2011 dataset constructed a composite variable that was utilized in this study as a control variable, from a series of questions from the parent interview. The variables used to create the SES composite were the following: father's education, mother's education, father's occupation, mother's occupation, and household income. It has been well established in the literature that lower SES is associated with lower EF skills, even after controlling for general cognitive ability (Farah et al., 2006; Farah et al. 2008; Masten et al., 2012; Mezzacappa, 2004; Noble et al., 2005; Obradovic, 2010; Ursache & Noble, 2016). Parent/guardian's education and occupation data were collected in the fall of 2010. Household income data was collected in spring 2011. In the current sample, the mean SES is -.054140, with a standard deviation of .8148789 and a range between -2.3300 to 2.5960. According to the ECLS-K:2011 data, 26% of students came from poor households or those with income below 100 percent of the federal poverty level, 23% came from near-poor or those with income between 100 and 199 percent of the federal poverty level, and 51 percent came from nonpoor households or income above 200 percent the federal poverty level. Related to parent's education, 31 percent of students had parents whose highest level of education was a high school diploma or below, 34 percent has parents with some postsecondary education, and 35 percent had parents with a bachelor's degree or higher (Little, 2017).

Speech/Language Skills

Children were administered a language screener that included two tasks from the Preschool Language Assessment Scale (*pre*LAS2000). The *pre*LAS2000 is a commercially available, norm referenced, language proficiency battery for children ages 4-6 years old. It was developed to measure expressive and receptive language skills. The full measure, used to develop a proficiency classification, is made up of five subtests. The purpose of the scores from the full assessment are to help determine whether there are delays in certain areas of language development (Rainelli et al., 2017). However, multiple large-scale studies have utilized and adapted the *pre*LAS2000 measure to be used for screening purposes. Beginning with the ECLS-K, 1998-99, the first three subscales were utilized, and then, subsequent studies (Head Start FACES, 2003, 2006, 2009) have used just the first two subtests of “Simon Says” and “Art Show”. The purpose of the “Simon Says” task queries children to follow simple, direct instructions given by the assessor in English. This task is assessing the children’s receptive language ability. The “Art Show” task is a picture vocabulary assessment that tests children’s expressive vocabulary. All children were administered the language screener as the first component of the direct cognitive assessment. For children whose home language was English, the screener mostly served as a warm-up. For those who home language was other than English, it determined whether the children understood English well enough to be given the full direct assessment in English. For the purpose of this study, the *pre*LAS2000 was utilized to determine whether or not children displayed deficits in their language skills as a dichotomous variable. The ECLS-K:2011 used a score of 16 as a cut off (based on previous use of the *pre*LAS) and so this continuous variable was computed into a dichotomous variable of students who scored 1-15 as “1” (those who did not pass) and students who scored 16-20 as “2” (those who passed). The mean of the *pre*LAS2000 scores for this sample is 18.38, with a potential range between 0-20 and a standard deviation of 3.279. Those children who did not pass the screener consisted of 10% of the sample. Please refer to Table 3 for further information on how the sample of children performed in the *pre*LAS2000.

Chapter 4: Results

This chapter provides the results of the univariate growth curve, as well as the latent class growth analyses and growth mixture models that were performed. For the first hypothesis of determining the appropriate number of classes, latent variable mixture modeling (LVMM) in the structural equation modeling (SEM) framework was utilized to explore the different developmental trajectories of cognitive flexibility for students in grades kindergarten through fifth grade. Based on previous research, four trajectories were expected (Morgan et al., 2019). LVMM is an emerging, very flexible statistical technique used to analyze and model longitudinal data. It is utilized when the data follows a pattern of change in which both the strength and the direction of the relationship between the independent and dependent variables differ across students or participants. The analysis identifies distinct subgroups of individuals following a distinct pattern of change over age or time on a specific variable (in this study, cognitive flexibility) (Andruff et al., 2009). This analysis allowed each child's initial levels and growth rates in cognitive flexibility to be estimated and to explore inter-individual differences (variance) in the initial levels and intra-individual change over time. Socioeconomic status was incorporated as a control variable within the model.

For the second hypothesis, multinomial logistic regression was applied to predict whether or not a difficulty with speech and language skills during the fall of kindergarten, as indicated by the dichotomous variable of whether or not the student passed the oral language screener (*pre*LAS2000), placed that student at greater risk of being in the *at-risk* class.

Latent Variable Mixture Modeling (LVMM)

Conventional growth modeling approaches assume individuals come from a single population and that a single growth trajectory can sufficiently approximate an entire population. Also, it is assumed that covariates that affect the growth factors influence each individual in the same way. However, there are theoretical frameworks and existing studies that categorize individuals into distinct subpopulations (e.g., SES, age groups) (Berlin et al., 2014 McArdle et al., 2002; Ram & Grimm, 2007) The results of these studies confirm theoretical beliefs that heterogeneity of growth trajectories exist within the larger population. Also, the findings from these studies suggest that describing an entire population using a single growth trajectory estimate is oversimplifying the possible complex growth patterns that describe continuity and change among members of different groups. Rather, a latent class growth analysis (LCGA) or growth mixture modeling (GMM) approach may be the most suitable method for fully understanding the information about interindividual differences in intraindividual change by taking into account unobserved heterogeneity (i.e., different groups) within a larger population (Jung & Wickrama, 2008).

There are typically two latent variables (sometimes called random coefficients). The first is an intercept, which represents the level of outcome or the first measure of cognitive flexibility when time is equal to zero (in this study, fall of kindergarten), and the second is slope, which represents the rate of change in the outcome over time. In LVMM, each participant has his/her own estimated intercept and slope. If the slope and intercept are believed to relate to one another, their covariance can be modeled to reflect how an individual’s start value relates to his/her rate of change. Latent variables also have means, reflecting the average of all individuals’ intercepts and slopes. Participants also have their own deviations from the means at each time period, called residual/error variance, as well as residuals, and/or random effects.

The specific interpretation of the intercept and slope depend on how the researcher fixes or estimates the relations between these latent variables and their indicators. By fixing the observed variable factor loadings, different hypothesized relations can be tested about the origin (zero point) and the rate or shape of change (assuming the individuals are assessed at the same intervals). For example, by looking at both intercept (i.e., origin) and slope (i.e., rate of change), we can explore the developmental trajectories of students' cognitive flexibility skills over time. The goal is focused on the relationships among individuals, and the intent is to classify individuals into specific groups or categories based on their individual response patterns, so that participants within a group are more similar than participants between groups (Jung & Wickrama, 2008).

Growth Mixture Modeling (GMM)

Conventional growth modeling approaches give a single average growth estimate, a single estimation of variance of the growth parameters, and assumes a uniform influence of covariates on the growth and variance parameters. However, it is possible that there exists a subset of individuals whose growth trajectories are significantly different from the overall estimate. For example, given a typical sample of individual growth trajectories for adolescent mental health symptomatology, you may have a single average growth estimate that is steadily increasing with a positive slope or increasing symptomology (worse mental health). However, there may also exist a trajectory that is decreasing in poor mental health symptomology or improving mental health. This *recovery* group may have a higher intercept and negative slope. These are characteristics that are significantly different from that of the whole sample (Jung & Wickrama, 2008).

Growth mixture modeling relaxes the assumption that all individuals are drawn from a single population with common parameters and allows for differences in growth parameters across unobserved subpopulations. This is completed by using latent trajectory classes, which allow for different groups of individual growth trajectories to vary around different means. The results are separate growth models for each latent class, each with its specific estimates of variances and covariate influences. This modeling flexibility is the basis of the GMM framework (Muthen & Asparaouhov, 2006).

Latent Class Growth Analysis (LCGA)

Latent class growth analysis is a specific type of GMM where the variance and covariance estimates for the growth factors within each class are assumed to be fixed at zero. By assuming this, all individual growth trajectories within a class are considered to be homogenous. This framework of growth modeling has been largely developed by Nagin and colleagues (Nagin & Land, 1993), and is represented in the SAS procedure Proc Traj (Jones et al., 2001). The advantage of this approach is the identification of distinct classes prior to conducting GMM. LGCA can be seen as a starting point to conducting GMM.

Sample Weights

Sampling weights were utilized for all analyses completed due to the multi-stage sampling design of the ECLS-K:2011. Main sampling weights designed for use with data from a complex sample survey serves two purposes. The main sampling weight weights the sample size up to the population total of interest. In the ECLS-K:2011, weighting produced national-level estimates. Also, the sampling weights adjusts for differential nonresponse patterns that can lead to bias in the estimates. For example, if people with certain characteristics are systematically less likely than others to respond to a survey, the collected data may not accurately reflect the characteristics of the nonrespondents, leading to bias. Replicate weights were only utilized when completing analyses for the univariate growth model. Replicate weights are utilized to inform more precise standard error estimates when using a complex survey design like the ECLS-K:2011. In Mplus, the option to use both replicate weights and the MLR estimator is unavailable. The MLR estimator was needed due to its applicability with non-normal distribution. When completing the analyses for the univariate growth curve, it was explored whether or not the replicate weights changed the standard errors or significance, and no difference was found. However, to address the sampling method and multilevel survey model data, school ID was utilized in the CLUSTER command. For example, students from the same school are more likely to be similar to each other than to those students from other schools and to address this; the CLUSTER command recognizes those students that may be more similar than different based on location.

Decisions on Factor Loadings

The observed outcome measures (time 1-time 9) are treated as the multiple indicators of these two latent growth factors (intercept and slope). When completing the growth models, the factor loadings on the intercept growth factor are all fixed to 1, and the factor loadings on the slope growth factor are called time scores. The time scores play three roles: they determine the form (linear or nonlinear) of the growth process. Time scores also define the centering point of the growth process. Setting the time score to 0 time 1 would define the first time point (baseline) to zero as the centering point of the growth process so that the latent intercept growth factor would represent the initial level of the outcome measure. Lastly, time scores define the scaling of the growth factors. Most times, including the current study, the scale of the time scores are matched with the observed time scale (e.g., fall of kindergarten to spring of fifth grade). Decisions on factor loadings are further discussed in step 1 below.

Decisions on Growth Parameters

As seen in Figure 1, growth parameters have to do with the latent factors of intercept and slope (the variances, covariances and residuals), as opposed to the factor loadings when modeling the time points. When conducting LCGAs, there is no individual variation around the mean growth curve allowed and so both intercept and slope growth factors are fixed to 0. However, when conducting GMMs, both intercept and slopes can be freely estimated. Freely estimating the variances for all growth factors adds a great deal of complexity and can lead to convergence problems, improper solutions, and overall model instability. Due to this, decisions around which factors to constrain are discussed further in step 3. However, a better understanding of which growth factors were constrained or allowed to be freely estimated can be found in Figure 1, or the final, conditioned growth mixture model path analysis.

Hypothesis 1a and 1b: Estimating Children's Cognitive Flexibility Growth Trajectories and Identification of At-Risk Class

Conceptual Description of Growth Modeling

Once the data was prepared in SPSS, I then transferred the data to the Mplus format. All models were estimated in MPlus version 8.0 (Muthen & Muthen, 1998-2019), under missing data theory, using all available data and robust (full information) maximum likelihood estimation (MLR). This strategy for handling missing data is an appropriate, modern method of modeling with missing data that makes use of all available data points (Little et al., 2013) and adjusts the standard errors and scales chi-square statistics to account for a non-normal distribution. In comparison to other techniques, MLR is more efficient and less biased than traditional approaches (Wang & Wang, 2012). Missing values were coded as "-9" in the data. Consistent with recommendations (Jung & Wickrama, 2008; Muthen, 2004), a five-step process was utilized to estimate LCGAs and GMM in this study.

1. Specify a Single-class Latent Growth Curve Model

The first step in estimating a GMM is identifying a single group model that best represents change over time (i.e., straight line, one curve, two curves, or two or more separate trajectories). Theory and prior research should be used to guide selection and suggests that multiple patterns of cognitive flexibility will exist. In addition, review of individual-level raw data and mean level performance over time can provide clues as to how best to model change (Berlin et al., 2014). Located in Figure 2 is a graph of the whole samples' individual observed values and growth lines from wave 1 to wave 9. If several single-group models seem reasonable, a separate latent growth curve analysis should be conducted for each pattern of change. In this study, this single-group model is used as the base model for the mixture analyses (identifying classes). The statistical fit can then be utilized to evaluate each of the models and establish the best way to model change over time.

The data was collected at the following assessment points: fall of kindergarten, spring of kindergarten, fall of first grade, spring of first grade, fall of second grade, spring of second grade, spring of third grade, spring of fourth grade, and spring of fifth grade. Time (for the slope factor loading) is then coded as 0, .05, .10, .15, .20, .25, .35, .45, and .55.

In the current study, the following models were estimated to identify the best single-group model (model that best represents change over time for the whole sample) that was utilized as the base model for the mixture analyses (identifying classes): linear, quadratic, cubic, and piecewise quadratic. For the linear model, two latent factors were defined: one representing initial levels of DCCS scores and one representing linear change in DCCS scores (slope). Factor loadings for the intercepts for the nine observed measures of DCCS scores were fixed to 1. Factor loadings for the slope were set to the above time coding. For the quadratic model, an additional latent variable was added to the linear model. It represented a quadratic pattern of change for DCCS scores (factor loadings fixed to 0, .0025, .01, .0225, .04, .0625, .1225, .2025., .3025). For the cubic model, an additional latent variable was added to the quadratic model, representing a cubic pattern of change (factor loadings fixed to 0, .000125, .001, .003375, .008, .015625, .042875, .091125 .166375). When estimating the cubic growth model, I received a message about a negative residual variance for the fourth wave of DCCS scores. As residuals cannot be negative, I addressed this problem by fixing the residual variance for the fourth wave to 0. The solution fixed the problem and no additional warnings were generated. I also estimated a piecewise growth model, which is utilized when the expected growth process is not linear and likely to consist of phasic developments connected by turning points. It includes a linear slope for waves 1 through 4, a separate slope for wave 5, and a quadratic function for waves 6 through 9. A piecewise model was hypothesized due to the nature of the DCCS scores and because waves 1-4 were assessed by table-top and only included accuracy, whereas waves 5-9 included a computer activity and encompassed reaction time.

The fit statistics are provided in Table 4. Based on review of the fit statistics, the linear, quadratic, and cubic models provide a poor fit of the data. To evaluate the goodness of fit of single-group models, excellent models generally have the following values: Comparative Fit Index (CFI)/Tucker-Lewis Index (TLI) >= .95, Root Mean Square Error of Approximation (RMSEA) < .05, Standardized Root Mean Square Residual (SRMR) < .05, and the lowest Bayesian Information Criterion (BIC). The piecewise quadratic model has a CFI value of .976, TLI of .965, RMSEA of .017, SRMR of .028, and the lowest BIC value of 319,483.868. These results indicate that the piecewise quadratic model has adequate goodness of fit statistics and the best fit overall.

Additionally, Figure 3 includes four graphs that upon visual inspection, reveal that the model with better fit statistics has the higher proportion of overlapping lines. It is possible to see what is tested statistically, specifically, the discrepancy between the observed sample and estimated values or how well the modeled data “fit” with the actual data. Based on both fit statistics and visual inspection of these findings, the piecewise quadratic model serves as the best base model or single-group model for the growth mixture analyses. The piecewise quadratic model then guided the following next steps of conducting LCGAs and GMMs.

2. Specify an Unconditional Latent Class Model without Covariates

Jung and Wickrama (2008) recommend that the next step in the process is to specify an unconditional latent class growth model (LCGA) without covariates. Covariates may have a significant direct effect on the growth factors (intercept and slope) and can distort results. This is important to keep in mind and to follow up the unconditional model with the appropriate conditional model (with covariates, e.g., SES) to compare to the results (Muthen, 2004). Specifying a LCGA model with no within-class variance is recommended. As noted earlier, LCGA is a useful initial modeling step prior to completing a GMM model. This is due to LCGA assuming no within-class variance on the growth factors, whereas GMM freely estimates the within-class variances. The benefits of fixing within-class variances to zero are the clearer identification of classes and a less computational burden. These are both important factors in the beginning stages of model building.

When conducting LCGAs, I took an exploratory approach and estimated as many classes as possible that yielded proper solutions or an identified model. The fit statistics did show better fit results as more classes were added. However, this can be typical of LCGAs, since within class variance is fixed to 0 (homogenous classes). Due to this, the model fit statistics can typically result in better fit statistics as more classes are added. A table with the specific results of the LCGAs with 3 classes, 4 classes, and 5 classes can be found in Table 5.

I followed up these models with a conditioned model that included the covariate of socioeconomic status. The result can be found in Table 6. The results did not appear clear, as both a 4-class model and a 5-class model had positive indicators. The 4-class model had the lowest BIC value of 299,288.595, as compared to 299,418.994 for the 5-

class model; however, the 5-class model indicated a significant LMR *p* value of .0004 compared to a non-significant *p value* of .1624 of the 4-class. Due to this, when moving on to the next step of conducting GMMs, a 4 through 5-class model was considered.

3. Determine the Number of Classes

Studies have been ongoing regarding the best fit indices or method to find the best model for the number of classes. Nylund et al. (2007) determined that of all the fit indices and tests available in Mplus, the Bootstrap Likelihood Ratio Test (BLRT) performed best, followed by the Bayesian Information Criterion (BIC), and then the Akaike's Information Criterion (AIC). However, due to the computational burden of the BLRT, it may not be best to utilize in the model exploration stages, but when a few plausible models have been identified. Also, the BLRT was unable to be utilized in these analyses due to the use of sample weights and CLUSTER (not available with COMPLEX MIXTURE command). Mplus does not allow for both to be utilized. Due to this, the model with a low BIC value and a significant Lo-Mendell-Rubin Test *p* value (LMR) comparing the *k* and *k*-1 class model guided the analysis. In other words, comparing the current model against the model with one less class than the current model guided the analysis. Other considerations include successful convergence, high entropy value (near 1.0), no less than 1% of a total count in a class, and high posterior probabilities (near 1.0). One's research question, parsimony, theoretical justification, and interpretability should all be kept in mind. It is also possible to take an exploratory approach and estimate as many classes as possible that yield solutions (Berlin et al., 2014).

I first started conducting GMMs, after conducting LCGAs for 3 to 6 classes, by freely estimating all available options including means, variances, and covariances.

However, multiple warnings were generated, indicating convergence problems, improper solutions, and overall model instability. One issue that emerged was a strong association between intercepts and change functions for some classes. I also often encountered negative variance in at least one or more classes. Both a 4-class and 5-class model yielded these warnings, as well as a lack of convergence, and indicated that some growth parameters would need to be constrained. It is not unusual to decide to only estimate intercept and not slope, or only estimate for certain classes rather than across all classes. When looking at the graphs to determine if any class needed its own class-specific variance, it was observed that a there was a lot of variability across slope one and often, a negative variance. The warnings often included, "PROBLEMS WITH SLOPE 1." Due to this, slope one was restricted to be equal to 0. This was decided to be allowable due to the non-significance of slope 1's residual variance. This resolved the concerns of slope 1 and the model terminated normally. Slope 2 was set to have the variances equal across all classes (equal to 1). Slope 3 and the intercept were allowed to be freely estimated variances for each class.

Results of goodness of fit statistics were then reviewed to determine the appropriate number of classes. These results can be found in Table 7. Class 5 obtained the lowest BIC value of 283,739.283, as compared to a model with 4 classes. Also, when looking at the LMR *p* value of comparing 5 classes minus one (4-class), the 5-class model has a significant *p* value of .0385. A 6-class model was also estimated; however, issues with a negative variance, a class that contained less than 1% of the sample, and a poor LMR *p* value indicated it was not an appropriate choice. Due to these results, it was determined that a 5-class model best fits the data. In other words, 5 classes were identified that best represent initial starting performance (intercept) and change over time (slope).

4. Address Convergence Issues

Jung and Wickrama (2008) identified the importance of addressing convergence issues and see this as a previous step to model selection. This was done with the STARTS syntax in Mplus. This step was done in conjunction with previous steps, as successful convergence was needed to ensure models were correct and terminated normally. For all models estimated, successful convergence was obtained. This was also checked by using the OPTSEED command in Mplus to ensure the model estimation did not have local solutions.

5. Specify a Conditional Latent Class Model with Covariates (SES)

The 5-class conditional model (with covariate of SES) was selected due to the goodness of fit statistics. In addition to the above fit statistics, the 5-class model also demonstrated good posterior probabilities of class membership from .888 to .993 (closest to 1.0). This indicates a high degree of classification precision in the model. The 5-class model also had high entropy, .970 (1.0), and all proportions of latent classes are above 1%. The following describes the beginning levels and rate of change for each of the 5 classes.

Individuals in the sample were classified into 5 classes, each with its own different beginning level and growth trajectory of cognitive flexibility over time. Of the total 14,173 participants, 1.5% were classified in Class 1 (N = 213), 7.8% in Class 2 (N= 1124), 3.2% (N = 453) in Class 3, 5.3% in Class 4 (N = 708), and 82.1% in Class 5 (N = 11,676). The observed and estimated growth trajectories of cognitive flexibility are shown by class in Figure 4 (Sample and Estimated Growth Means). The lines with squares represent observed growth trajectories, and the lines with triangles represent the model predicted trajectories. Included in Figure 5 are the observed individual values and mean growth line for each class. Overall for all classes, the variances (or how much each individual varied from the mean growth line or intercept) for waves 1-9 were significant, indicating a great deal of variability, especially for times 2 and 3. That can also be seen in the graph of observed individual values. The variance for slope 1 is 1.064 ($p < 0.0001$), the variance for slope 2 is 0.148 ($p < 0.0001$), the variance for slope 3 is 0.062 ($p < 0.05$), and the variance for the quadratic slope is .001 ($p < 0.05$). Although all are significant, there is a progression of greater variability with the younger grades (especially for time 2 and 3) compared to slope 3. Figure 6hows both the 4-class and 5 class GMM and the following describes each class.

Class 1 constituted 1.5% of the sample and can be defined as the “at risk” group. This group averaged an intercept or beginning level of cognitive flexibility of 3.682 ($p <$ .0001) which is more than 2 standard deviations below the mean and is significant. Class 1’s rate of change or slopes (S1 =3.750, p = .001; S2 = 3.355, p = .0001; S3 = 3.327, $p <$ 0.05) remained consistent over time, did not show large growth, and the class continued to remain significantly lower than the rest of the classes or sample through wave 9. A significant mean slope indicates that the trajectory is not flat. The quadratic slope 3 indicated a mean of 0.122 and was not significant, indicating that the quadratic slope 3 for class 1 remained flat. The covariance between intercept and slope indicates whether or not there is a relationship between where a student in the class started and how fast they grew (slope). For class 1, where they started influenced their rate of growth. The covariance between intercept and slope 1 (.027, $p < .05$), intercept and slope 2 (.206, $p < .0001$), and intercept and slope 3 (-0.121, $p < 0.0001$) are all significant.

R^2 values indicate whether or not the outcome measures (wave 1 through wave 9) are well explained by the intercept and slope growth factors. The R^2 values for class 1 for the observed outcome measures (wave 1 through wave 9) are varied but consistently higher values than the other classes. For slope 1, time point 1 and 4 demonstrated strong values of .618 and .599, indicating that variation of the outcome measures are well explained by the intercept and slope growth factors; however, time points 2 and 3 (consistent across all classes) are not as strong (.251 and .338). For time points 5 through 9, the R^2 values are all over .60 (range from .733 to .821), indicating that the variation of the observed measures are well explained by the growth factors of intercept and slopes (including the impact of SES since it is included in the model).

Class 2 consisted of 7.8% of the sample and also averaged a low intercept at 3.671 or more than 2 standard deviations below the mean. However, class 2 demonstrated a significant increase in slope 1 (S1 = 35.324, $p < .001$), where they finished slope 1 very close to the mean of time point 4 (end of first grade) at 8.958. Class 2 then remained close to the average (within one standard deviation) for the continuing time points through 5th grade. Class 2 appears to be a “remediated class” or a group of individuals who entered kindergarten with significantly below average cognitive flexibility, but who made significant gains in their cognitive flexibility. Class 2’s covariances between intercept and slopes are also all significant, indicating where they started impacted their growth (0.11, $p < .05$; .053, $p < 0.0001$; .020, $p < 0.0001$).

The R^2 values for class 2 for the observed outcome measures (wave 1 through wave 9) are varied. For time points involved with slope 1, R^2 values range from .057 to .221, indicating that the variation of the observed outcome measures are not well explained by the growth factors (intercept and slope) or the covariate of SES. However, the R^2 values of time 5 to time 9 range from .460 to .566, indicating an increase in how well the outcome measures are explained by the growth factors of intercept and slope.

Class 3 contained 3.2% of the sample and had an average intercept of 8.673, which is slightly above the mean. However, class 3 or the “decreasing class” contained a negative slope 1 (S1 = -23.828, *p* <. 001) and contained a significant decrease between the mean of intercept (initial) and their performance at time point 4 or the end of first grade. Then, Class 3 appeared to recover (S2 = 5.202, *p* <. 001) and remained within one standard deviation from the mean for the continuing time points. Their slope 3 was also significant (2.995, $p < 0.0001$) but their quadratic slope 3 was not significant, indicating a flat quadratic growth (0.685, $p = .515$).

The R^2 values for class 3 for the observed outcome measures (wave 1 through wave 9) are also varied. For time points involved with slope 1, R^2 values range from .097 to .339, indicating that the variation of the observed outcome measures are not well explained by the growth factors (intercept and slope) or the covariate of SES. However, the R^2 values of time 5 to time 9 range from .555 to .680, indicating an increase in how well the outcome measures are explained by the growth factors of intercept and slopes.

Class 4 consisted of 5.3% of the sample and had an average initial start of 5.66, which is about 1.5 standard deviations below the mean of CF. The starting point of Class 4, or the “midrange class,” is below the mean; however, class 4 demonstrated a positive slope 1 of 23.704 ($p < .0001$), demonstrating their improved CF over time. Class 4 contained a significant negative slope 2, like the others (-14.152, $p < .0001$), but a non-significant slope 3 (1.184, $p = .064$).

The R^2 values for class 4 for the observed outcome measures (wave 1 through wave 9) are also varied. For time points involved with slope 1, R^2 values range from .066 to .251, indicating that the variation of the observed outcome measures are not well explained by the growth factors (intercept and slope) or the covariate of SES. However, the R^2 values of time 5 to time 9 range from .467 to .578, indicating an increase in how well the outcome measures are explained by the growth factors for time points involved with slope 2 and 3.

Class 5 constituted 82.1% of the sample and has an average intercept of 8.605. Class 5's slope remained fairly consistent, with the exception of slope 2 (S2 = -12.681, $p < .001$), which accounts for the change from only assessing accuracy to including both accuracy and reaction time. This change at slope 2 affected all classes except for those that did not gain mastery of accuracy on the DCCS assessment (classes 1 and 3). Class 5 also accounts for the majority of the sample and included 11,576 individuals. Due to this, class 5 is considered the *average* development growth, or in reference to the multinominal logistic regression, the reference class. The covariances of class 5 are also all significant, indicating that their intercept impacted their future rate of growth on all slopes. Intercept with slope 1 (0.035, $p < .05$), intercept with slope 2 (0.202, $p < 0.0001$), and intercept with slope 3 (-0.124, $p < 0.0001$).

The R^2 values for class 5 for the observed outcome measures (wave 1 through wave 9) are varied. For time points involved with slope 1, R^2 values range from .041 to

.170, indicating that the variation of the observed outcome measures are not well explained by the growth factors (intercept and slope) or the covariate of SES. However, the R^2 values of time 5 to time 9 range from .422 to .543, indicating an increase in how well the outcome measures are explained by the growth factors.

Socioeconomic Status (SES) Covariate

The continuous variable of socioeconomic status (SES) was included as a covariate factor. Within the overall model, the intercept and slope 1 were positively related to parent SES. A one unit increase in SES was associated with a .169 ($p < 0.000$) gain for a student's initial start point (intercept). Also, an increase in SES was associated with a .347 gain on a student's slope 1 ($p < .05$). Slope 2 was not significant (-.186, $p =$ .096). These results indicate that higher SES is associated with better performance at the initial assessment of the DCCS and over the first slope (waves 1-4).

Hypothesis 2: Speech and Language Deficits in Kindergarten will Predict Membership in the At-Risk Class of Cognitive Flexibility

Multinomial logistic regression was then used to assess whether deficits in speech and language in the fall of kindergarten, as indicated by being in the lowest 10% on the *pre*LAS 2000 assessment, predicted membership in the *at-risk* class for cognitive flexibility. With five latent classes, there are four logits in the multinomial logit model where the last class is treated as the reference group. These estimated logits were then transformed into probabilities to better understand the likelihood of those having not passed the screener, being in the *at-risk* trajectory class. When taking both intercept and slope into account, it was found that the probability of those who did not pass the speech screener, or odds of being in the *at-risk* trajectory group, was 54%. This was in comparison to 28% for class 2, 1% for class for class 3, 2% for class 4, and 15% for class 5. These findings suggest that speech and language deficits by kindergarten increase the risk for membership in the *at-risk* and *remediated* trajectory class of cognitive flexibility. The equations that represent the probability of each class can be found in Table 9.

When only taking the intercept factor into account when completing the transformation of the estimated logits to probabilities, the likelihood of those who did not pass the screener being in the *at-risk* trajectory group increased. When taking only the intercept into account, as opposed to above where intercept and rate of change was taken into account, it was found that the probability of those who did not pass the speech screener being in the *at-risk* trajectory group was 79%. This is in comparison to 5% for class 2, 1% for class 3, 1% for class 4 and 14% for class 5. When only taking into account the intercept or beginning CF score, it is even more likely that a student struggling with speech and language deficits will also struggle with CF. The equations that represent the probability of each class can be found in Table 10.

Chapter 5: Discussion

This chapter includes a discussion and interpretation of the results of the present study. The findings of multiple growth patterns are explored and assimilated with past research. The roles of SES and speech skills in relation to CF is then considered. This is then followed by the current study's limitations, ideas for future directions and implications.

Summary of Important Findings

Cognitive Flexibility Growth Patterns

Growth mixture modeling (GMM) was used to examine the cognitive flexibility trajectories of a large, nationally representative sample of kindergarten children who were followed until the 5th grade. It was hypothesized that a 4-class model would best fit the data; however, the goodness of fit statistics did not indicate that. A 5-class model best fit the data. Although the number of classes hypothesized was not supported, the main idea of multiple classes held true in that not all children started or grew at the same rate. Class 1 started low and remained low, class 2 started low but made significant gains, class 3 started high but decreased significantly and then returned, class 4 started slightly below average but made significant gains and class 5 started around the mean and remained consistent across time. However, all classes, except the at-risk class, caught up by the end timepoint (5th grade). Also, interesting to note is that when a 4-class model was conducted, it appears that the mid-range class and remediated class were one class but the goodness of fit statistics implies that due to their difference regarding where each class started (intercept), was best to separate out to two classes. This shows that one single growth model does not adequately represent all students CF skills from kindergarten to fifth grade. If we were to traditionally only take a single growth line, the initial start points and rate of change of these specific classes would be lost to the general whole group. By using GMM, it is instead possible to see the separate growth patterns of each class. This is essential so that we can better understand development and growth over time for those who don't fit the single growth line.

CF and Learning

A couple of factors may have played a role in why the hypothesis of 4 classes was not supported. When hypothesizing regarding number of classes, previous research on the specific ECLS-K:2011 dataset was utilized. However, that research focused predominantly on achievement in reading, mathematics, and science (Morgan et al., 2019). The Morgan et al. study found 4 classes or group trajectories in each subject. Each group trajectory remained fairly consistent across time. For example, individuals who started below average remained below average, or there was a consistency across initial start point (intercept) being linked to rate of change (slope).

There were also differences in analytic method between the Morgan et al. (2019) study and the current one. Those authors utilized PROJ TRAJ in SAS and chose to use a 5% threshold for the size of the smallest trajectory group, thus rejecting models that contained more classes. These factors may have influenced the difference of results and they may have found more classes as well.

Instead of looking at studies that focused predominantly on achievement results, it may have been more prudent to look at past research on cognitive assessment results or more specifically, fluid reasoning assessments. This study found that 82.1% of the sample fit into one class, which would be an approximate percentage of those 1.5

standard deviations above and below the mean. This class includes the largest section of the sample. This suggests that it may be possible that CF, as assessed by the DCCS, also falls along a normal curve similar to intellectual functioning. There is support for this idea from a study completed to validate the DCCS. Zelazo et al. (2013) utilized the Block Design subtest for the WPPSI-II to demonstrate its convergent validity. There has also been a significant amount of research demonstrating that EF overlaps considerably with reasoning ability, or *fluid intelligence* (Ackerman, Beier, & Boyle, 2005; Kane, Hambrick, & Conway, 2005). Some believe that EF is identical with fluid intelligence (Kyllonen & Christal, 1990). Fluid intelligence can be defined as cognitive processing that is not associated with any specific content domain and as involving novel problem solving (Blair, 2006). It is important to consider how cognitive flexibility, as assed by the DCCS, and fluid intelligence may be similar or interact with each other. This information (that this study found most of the sample to fall into 1 class that looks similar to a normal curve) helps us to understand the nature of CF and the possibility that CF and fluid intelligence are identical or that they are highly correlated due to needing CF to complete fluid intelligence activities like the Block Design subtest.

CF skills are necessary when problem solving, due to the need for flexibility when figuring out the best way to approach the problem. When we learn new skills, in the beginning, children and adults may be inconsistent. Some days we may be more successful than others on this new skill. The time points 1-4 have a great deal of variability. So much that the growth parameter of slope 1 had to be constrained, indicating that kindergarten and first grade students are not consistent across time. Also, the R^2 values indicated that little of the variance was due to the growth factors of intercept and slope 1. This means that there are other possible covariates that may help explain more of the growth between kindergarten and first grade. However, for slope 3, all classes had significantly higher variance and it could be considered that the growth factors were responsible for a large portion of the variance.

Previous research has often utilized cross sectional data and few studies have utilized longitudinal data. The current study makes significant contribution to the research in that it utilized data that has followed individuals from kindergarten to fifth grade and how their CF has grown over time. This is especially important because as noted in previous sections, most research has centered on pre-school children and has not extended through elementary school age children.

SES and CF

Consistent with past research (Blair & Raver, 2016; Farah et al., 2006; Farah et al. 2008; Masten et al., 2012; Mezzacappa, 2004; Noble, Norman,, & Farah, 2005; Obradovic, 2010), SES played a significant role in the development of CF. Children with lower SES tended to have weaker CF. However, its impact was strongest at the beginning time point or fall of kindergarten, when children may have had little or no previous exposure to school, as well between kindergarten to first grade. As time went on, SES remained significant but to a lesser degree. This indicates how important early development of CF skills are and how early childhood experiences can impact CF skills development.

Speech and CF

It was then investigated whether and to what extent speech and language deficits increased the risk of experiencing each type of class trajectory, including the *at-risk* trajectory. It was found that the probability of those who did not pass the speech screener or odds of being in the *at-risk* trajectory group was 54%. These findings suggest that speech and language deficits by kindergarten increase the risk for membership in the *at-risk* and *remediated* trajectory class of cognitive flexibility and that hypothesis 2 was supported. This supports previous literature in that speech and language skills are an important aspect of CF (Cragg & Nation, 2008; Crosbie et al., 2009; Karasinski, 2015; Pauls & Archibald, 2016; Roello et al., 2015). When we begin using language and naming objects, we utilize CF skills. For example, when we learn the name of a specific object is *chair*, we then have to be flexible to multiple different types of chairs and include them under the label as *chair*. Due to this, it is expected that there would be a relationship between CF and speech and language skills.

Limitations

Measurement Impurity and Ecological Validity

Despite the useful findings, there are some limitations to this study. The most frequently mentioned challenge of assessing EF and CF is the concern of measurement impurity (Miyake et al., 2000). Measurement impurity is thought to occur because there are often multiple processes that contribute to individual differences in performance on any EF or CF task. For example, many tasks require a combination of executive and non-executive cognitive processes to be completed successfully. The DCCS is an example where there is an impurity problem due to recruiting multiple executive tasks. To complete the DCCS successfully, the student may utilize all three EFs. For example, they have to inhibit their first response when switching, utilize working memory to keep in mind the correct switch, and then successfully switch (cognitive flexibility). If a student performs low on the DCCS, it becomes a question of which part or parts with which they struggled (Zelazo et al., 2016). Although the ECLS-K:201l contained a very large sample size and a multi-year time frame with extensive measures, it did not contain multiple measures of cognitive flexibility. Using multiple measures of CF would decrease concerns with measurement impurity problems and allow us to be more confident in that we are truly assessing CF skills.

There has also been a concern regarding ecological validity or that these highly structured tasks that are completed in a quiet and emotionally neutral setting are not adequately assessing CF skills in “everyday life”. In response to this concern, some have utilized questionnaire-based assessments that try to capture everyday EF skills by rating students based on observations from parents, teachers, or self. These assessments have had consistently weak associations with performance-based assessments and have raised questions about what is being measured. However, some believe that the questionnaire-based assessments do a better job of assessing real life EF skills. Barkley and Murphey (2010) found that questionnaire-based assessments did a better job of relating to real-life performance and predicting later life outcomes. This study questions how useful EF performance-based assessments may be to real life circumstances and how much they can help guide recommendations. One solution was to create an assessment that better approximated real-world contexts. Due to this, the *Multiple Errands Task* (MET) assessment was created (Burgess et al., 2006). Only one similar real-life assessment has been created for use with children called the *Kitchen Task* (Berg, Edwards & King, 2012). This task has the child create play dough from a recipe and the examiner provides cues as needed and observes the child’s behavior and skills with this real-life task.

Although these assessments are relatively new, more possibilities are opening based on technological advances (Alderman et al., 2003). The DCCS has shown excellent validity, but having multiple measures of different types, like questionnaires or real-life assessments, that include structured observations, may address the ecological validity concern.

Other Limitations

There were multiple covariates that were not included in this study, but that may have an impact on cognitive flexibility development, such as gender, race, disability status, and academic or behavioral interventions. Adding in more covariates would likely help the model to be more appropriately identified (per Muthen & Muthen, 2000). More covariates would help explain more of the variance and influences of CF skills over time, especially for slope 1 where the R^2 values indicated that the latent factors of intercept and slope did not explain a good portion of the variance. The other covariates would also help us to know more about the individuals within the classes. The students who started low and caught up by time point 5 may have been due to possible interventions or just their individual natural progression of CF skills over time. However, one class, class 1, started low and did not close the gap between the other students. This may have been due to a lack of a specific intervention others received or their own individual natural progression. Although these other factors (e.g.,interventions, individual characteristics) were not assessed in this current study, SES did impact CF skills, especially upon entry to kindergarten.

Another limitation is that the study's estimates are not causal. Instead, the estimates indicate that speech and language deficits upon entry to kindergarten increase the risk or probability of cognitive flexibility deficits from kindergarten to fifth grade while controlling for SES. Based on the results, it is not possible to say that speech and language deficits caused deficits in CF skills or vice versa.

Also, another limitation is that the *pre*LAS2000 is often utilized as a screener and does not give an in-depth assessment of speech and language skills. The preLAS2000 did provide adequate assessment to distinguish amongst those with speech difficulties in classes but it would most likely identify the most severe cases of expressive and receptive language skills and may not be sensitive enough to identify those with moderate to mild speech and language skill deficits. Also, this study utilized the total score and did not differentiate between receptive and expressive language skills.

Data from the ECLS-K:2011 are available only through the fifth grade. Due to this, the study was unable to investigate whether the observed predictive relations between speech and language skills and children's cognitive flexibility trajectories were present during middle or high school. Deficits in speech and language skills may become less of a risk factor for cognitive flexibility over time, possibly due to exposure to the school environment. When assessing for a longer period of time, it may be possible to see whether or not the exposure to the school environment eventually helps to remediate CF skills. For example, it is possible that middle school curriculum or experiences are likely to help build these skills.

Future Directions

It is vital to continue to examine EF, and more specifically CF, due to their known association with children's achievement and success in school (Clark, Pritchard, & Woodward, 2010; Mazzocco & Kover, 2007). Limited research, and especially, limited agreement on both theory and vocabulary of EFs and CF, limit the understanding of these constructs and make it difficult for clinicians to apply understanding and implement interventions that may be beneficial to children. Further investigating factors that may have influenced class 2 (remediated) and class 4 (mid-range) (both had low initial start points and higher rate of change) would further the understanding of what specific factors can be beneficial for children who initially struggle with CF. Important questions to ask would be: what type of programming did these students receive, what type of schools did these students attend, what type of individual characteristics do these individuals have, and what type of family and community factors are involved? Understanding these questions could help in both a systems approach (what programming may help build CF skills) to the family level (what parents can do to help build CF skills).

The ECLS:2011 dataset also assessed for working memory, another component of EFs. Further study that included this data would be beneficial to understand if working memory, another similar component of EF, also indicates multiple classes and how working memory develops over time. This would be beneficial due to the inter-related nature of EF skills and lead to better understanding of how they develop and/or work together.

There were distinct differences between waves 1-4 and waves 5-9 in this study. It may be more beneficial to look at each set of waves/slopes individually. There appears to be more variability within slope 1 or waves 1-4 as opposed to waves 5-9. This may also be due to CF's similarity to fluid intelligence and how cognitive constructs establish themselves as children grow older. It is often difficult to assess individual components of intellectual functioning until children grow older and these skills differentiate themselves from a more general intelligence. This is important for clinicians to establish to better understand learning and development within children. Prior research has supported different growth patterns for both fluid reasoning and crystalized intelligence over a broader life span (2-92 years of age) but have not focused on specific age ranges or with varied assessments (McArdle et al., 2002).

The multinomial logistic regression, looking at whether or not a speech and language deficit predicts class membership, indicated significant results for both the at-risk and remedial classes. This suggests that future research should investigate this further by utilizing a study with a more comprehensive speech and language assessment. It also would be important for future studies to look at either only receptive or expressive language to understand if one or both are connected to CF so that specific interventions can be tailored to the need. Another important future direction is to look at the *remedial* class and whether or not having been provided interventions around speech and language skills played a role in their remediation.

Implications

The findings of the current study have important implications for education and efforts to improve CF. Deficits in EF and CF have been reported to increase elementary school children's risk for academic difficulties (Clark et al., 2010; Mazzocco & Kover, 2007). If we think again about that 2^{nd}-grade student mentioned in the very beginning who must utilize CF skills to be successful in the classroom, like switching between tasks or recognizing the appropriate level of their voice when inside, it is evident how important these skills are in the classroom environment. When children struggle with these skills, it may appear that they have behavioral issues as opposed to a skill deficit.

This might prompt a teacher or parent to respond in a negative way, as opposed to coaching that child though building CF skills, especially if that child struggles consistently with CF skills. If schools consistently assessed for these skills within their student population, it may be more likely that teachers would be aware of the skill deficits and more likely to implement appropriate interventions.

Recognizing the growth patterns found in this study help develop important suggestions for teachers and parents. This study identifies that some children will enter kindergarten with below age expectation CF skills and will either need support to build those skills or time to grow these skills on their own. However, most will reach their peers by the end of 5th grade. Those that do not (at-risk class) will need support and intervention.

Also, the amount of variability identified between kindergarten and second grade indicates that parents and teachers should expect variability or fluctuations of their children's CF skills. For example, on any given day, all students might need support with CF skills and that this is not atypical for children of this age group.

The current study also showed the impact of speech and language deficits on CF and that children who failed the language screener are more likely to be in the at-risk class. This is important for the education system and parents to recognize so they are aware of the possible implications from these deficits and/or the need for interventions in the area of speech and language skills. This finding also supports the association between these two areas of speech and CF skills. This is important to recognize because it gives teachers and parents suggestions for interventions or to recognize that if students are already identified as having speech and language concerns, they also may need to be assessed for CF skills and provided additional interventions.

SES was also a significant factor in influencing CF. This supports that lower SES children enter kindergarten not as ready for the classroom environment compared to their peers of higher SES. This has implications for specific policy in education and government. Ameliorating poverty and the inconsistency in environment that comes with impoverishment will support children to develop age appropriate CF skills upon entry to kindergarten. For example, screening children and initiating CF interventions in programs like Head start may help to facilitate these children's CF skills.

Summary

This study investigated the cognitive flexibility trajectories of children in grades kindergarten through fifth grade and made significant contribution to the research by utilizing data that has followed individuals across nine time points or waves. Results found that 5 patterns existed. These findings suggest that cognitive flexibility (CF) development has multiple growth trajectories or that children started and grew at different rates, although most of the sample (81.2%) belonged to one class. There were multiple classes depending on where some students started (their intercept) and their rate of change (slope). Socioeconomic status (SES) was significant, especially for initial cognitive flexibility levels. Those with higher SES levels performed better on the fall of kindergarten assessment. Those with speech and language deficits were also found to have increased probability of being in both the *at-risk* trajectory class (54%) and *remediated* class (28%). Both of these classes contained individuals whose initial starting cognitive flexibility was well below expected levels. This demonstrates the importance of building speech and language skills in early childhood and that those skills can have an impact on other areas of development.

References

Ackerman, P., Beier, M., & Boyle, M. (2005). Working Memory and Intelligence: The Same or Different Constructs? *Psychological Bulletin, 131(1),* 30–60. https://doi.org/10.1037/0033-2909.131.1.30

Alarcón-Rubio, D., Sánchez-Medina, J. A., & Prieto-García, J. R. (2014). Executive function and verbal self-regulation in childhood: Developmental linkages between partially internalized private speech and cognitive flexibility. *Early Childhood Research Quarterly, 29*, 95–105 https://doi.org/10.1016/j.ecresq.2013.11.002

Alderman, N., Burgess, P. W., Knight, C., & Herman, C. (2003) Ecological validity of a simplified version of the Multiple Errands Shopping Test. *Journal of the International Neuropsychological Society, 9,* 31-44.

Alderson-Day, B., & Fernyhough, C. (2012). Inner Speech: Development, Cognitive Functions, Phenomenology, and Neurobiology. *Psychological Bulletin, 90(9*), 545–547. https://doi.org/10.1016/j.ciresp.2012.05.015

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8,* 71-82. https://doi: 10.1076/chin.8.2.71.8724

Andruff, H., Carraro, N., Thompson, A., Gaudreau, P., & Louvet, B. (2009). Latent Class Growth Modelling: A Tutorial. *Tutorials in Quantitative Methods for Psychology*, *5*(1), 11–24. https://doi.org/10.20982/tqmp.05.1.p011

Ardila, A. (2008). On the evolutionary origins of executive functions. *Brain and Cognition, 68(1),* 92–99. https://doi.org/10.1016/j.bandc.2008.03.003

Arnsten, A. F. T. (2009). Ameliorating prefrontal cortical dysfunction in mental illness: Inhibition of phosphotidyl inositol-protein kinase C signaling. *Psychopharmacology, 202(1–3),* 445–455. https://doi.org/10.1007/s00213-008-1274-9

Aron, A. R. (2008). Progress in executive-function research: From tasks to functions to regions to networks. *Current Directions in Psychological Science, 17(2),* 124–129. https://doi.org/10.1111/j.1467-8721.2008.00561.x

Baars, B. J., Ramsøy, T. Z., & Laureys, S. (2003). Brain, conscious experience and the observing self. *Trends in Neurosciences, 26(12),* 671–675. https://doi.org/10.1016/j.tins.2003.09.015

Baddeley, A. D., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology, 8,* 485–93. https://doi.org/10.1016/S0021-9924(03)00019-4

Baddeley, A. (1996). The Fractionation of Working Memory. *Proceedings of the National Academy of Sciences of the United States of America, 93,* 13468-13472. https://www.jstor.org/stable/40924

Baddeley, A., Chincotta, D., & Adlam, A. (2001). Working memory and the control of action: Evidence from task switching. *Journal of Experimental Psychology: General, 130(4),* 641–657. https://doi.org/10.1037/0096-3445.130.4.641

Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication Disorders, 36(3),* 189–208. https://doi.org/10.1016/S0021-9924(03)00019-4

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Ann. N. Y. Acad. Science,1118,* 122–141. https://doi.org: 10.1196/annals.1412.011; PMID: 17717092

Baler, R. D, & Volkow, N.D. (2006). Drug addiction: the neurobiology of disrupted self-control. *Trends Mol. Med. 12,* 559–66. https://doi.org/ 10.1016/j.molmed.2006.10.005

Barch, D. M. (2005). The cognitive neuroscience of schizophrenia. *Annuals Rev. Psychology, 1,* 321–53. https://doi.org/10.1146/annurev.clinpsy.1.102803.143959

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121(1*), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Barkley R., & Murphy, K. (2010). Impairment in Occupational Functioning and Adult ADHD: The Predictive Utility of Executive Function (EF) Ratings Versus EF Tests. *Archives of Clinical Neuropsychology, 25(3),* 157–173. https://doi.org/10.1093/arclin/acq014

Beck, D. M., Schaefer, C., Pang, K., & Carlson, S. M. (2011). Executive function in preschool children: Test-retest reliability. *Journal of Cognition and Development, 12(2),* 169–193. https://doi.org/10.1080/15248372.2011.563485

Berlin, K. S., Williams, N. A., & Parra, G. R. (2014). An introduction to latent variable mixture modeling (Part 2): Overview and cross-sectional latent class and latent profile analyses. *Journal of Pediatric Psychology, 39(2),* 174–187. https://doi.org/10.1093/jpepsy/jst084

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. Developmental Review, 29(3), 180–200. https://doi.org/10.1016/j.dr2009.05.002

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81,* 1641-1660. https:// doi.org/10.1111/j.1467-8624.2010.01499.x

Blair, C. (2006). How similar are fluid cognition and general intelligence? A developmental neuroscience perspective on fluid cognition as an aspect of human cognitive ability. *The Behavioral and Brain Sciences*, *29(2*), 109–125. https://doi.org/10.1017/S0140525X060

Blair, C., & Razza, R. P. (2007). Relating Effortful Control, Executive Function, and False Belief Understanding to Emerging Math and Literacy Ability in Kindergarten. *Wiley on behalf of the Society for Research in Child Development, 78(2),* 647–663. https://doi.org/10.1111/j.1467-8624.2007.01019.x

Blair, C., & Raver, C. C. (2014). Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PLoS ONE, 9(11).* https://doi.org/10.1371/journal.pone.0112393

Blair, C., & Raver, C. C. (2016). Poverty, stress, and brain development: New directions for prevention and intervention. *Academic Pediatrics*, *16*(3), S30-S36. doi:10.1016/j.acap.2016.01.010

Boelema, S. R., Harakeh, Z., Ormel, J., Hartman, C. A., Vollebergh, W. A. M., & Van Zandvoort, M. J. E. (2014). Executive functioning shows differential maturation from early to late adolescence: Longitudinal findings from a TRAILS study. *Neuropsychology, 28(2),* 177–187. https://doi.org/10.1037/neu0000049

Borella, E., Carretti, B., Riboldi, F., & De Beni, R. (2010). Working Memory Training in Older Adults: Evidence of Transfer and Maintenance Effects. Psychology and Aging, 25(4), 767–778. https://doi.org/10.1037/a0020683

Brock, L. L., Rimm-Kaufman, S. E., Nathanson, L., & Grimm, K. J. (2009). The contributions of "hot" and "cool" executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly, 24(3),* 337–349. https://doi.org/10.1016/j.ecresq.2009.06.001

Broidy, L. M., Nagin, D. S., Tremblay, R. E., Brame, B., Dodge, K. A., Fergusson, D. E. (2003). Developmental trajectories of childhood disruptive behaviors and adolescent delinquency: a six-site cross-national study. *Developmental Psychology, 30,* 222–45. https://doi.org/ 10.1037/0012-1649.39.2.222

Brown, T.E., & Landgraf, J.M. (2010). Improvements in executive function correlate with enhanced performance and functioning and health-related quality of life: evidence from 2 large, double-blind, randomized, placebo-controlled trials in ADHD. *Postgraduate Medicine,122,* 42–51. https://doi.org/10.3810/pgm.2010.09.2200

Brouwers, A., & Tomic, W. (2000). A longitudinal study of teacher burnout and perceived self-efficacy in classroom management. *Teaching and Teacher Education, 16,* 239-253. https://doi.org 10.1016/S0742-051X(99)00057-8

Brydges, C. R., Fox, A. M., Reid, C. L., & Anderson, M. (2014). The differentiation of executive functions in middle and late childhood: A longitudinal latent-variable analysis. *Intelligence, 47,* 34–43. https://doi.org/10.1016/j.intell.2014.08.010

Burgess, P. W., Alderman, N., Forbes, C., Costello, A., Coates, L. M. A., Dawson, D. R., Anderson, N. D., Gilbert, S. J., Dumontheil, I., & Channon, S. (2006). The case for the development and use of "ecologically valid" measures of executive function in experimental and clinical neuropsychology. *Journal of International Neuropsychological Society, 12 (2),* 194-209. https://doi.org/10.1017/S135561770606310

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in Preschool children. *Developmental Neuropsychology, 28(2),* 595–616. https://doi.org/10.1207/s15326942dn2802_3

Castellanos, F. X., Sonuga-Barke, E. J. S., Milham, M. P., & Tannock, R. (2006). Characterizing cognition in ADHD: Beyond executive dysfunction. *Trends in Cognitive Sciences, 10(3),* 117–123. https://doi.org/10.1016/j.tics.2006.01.011

Chaytor, N., & Schmitter-Edgecombe, M. (2003). The ecological validity of neuropsychological tests: A review of the literature on everyday cognitive skills. *Neuropsychology Review, 13(4),* 181–197. https://doi.org/10.1023/B:NERV.0000009483.91468.fb

Chomsky, N. (1980). *Rules and representations*. New York: Columbia University Press.

Clark, C. A. C., Pritchard, V. E., & Woodward, L. J. (2010). Preschool Executive Functioning Abilities Predict Early Mathematics Achievement. *Developmental Psychology, 46(5),* 1176–1191. https://doi.org/10.1037/a0019672

Clark, C. A. C., Sheffield, T. D., Chevalier, N., Nelson, J. M., Wiebe, S. A., & Espy, K. A. (2013). Charting early trajectories of executive control with the shape school. *Developmental Psychology, 49(8),* 1481–1493. https://doi.org/10.1037/a0030578

Clark, E. V. (1997). Conceptual perspective and lexical choice in acquisition. *Cognition, 64(1),* 1–37. https://doi.org/10.1016/S0010-0277(97)00010-3

Cools, R., & D'Esposito, M. (2011). Inverted-U-shaped dopamine actions on human working memory and cognitive control. *Biological Psychiatry, 69(12),* e113–e125. https://doi.org/10.1016/j.biopsych.2011.03.028

Cragg, L., & Nation, K. (2008). Go or no-go? Developmental improvements in the efficiency of response inhibition in mid-childhood. *Developmental Science, 11(6),* 819–827. https://doi.org/10.1111/j.1467-7687.2008.00730.x

Crescioni, A.W., Ehrlinger, J., Alquist, J. L., Conlon, K. E., Baumeister, R. F., et al. (2011). High trait self-control predicts positive health behaviors and success in weight loss. *Journal of Health Psychology, 16,* 750–59.

Crosbie, S., Holm, A., & Dodd, B. (2009). Cognitive flexibility in children with and without speech disorder. *Child Language Teaching and Therapy, 2*, 250–270. https://doi.org/10.1177/0265659009102990

Dajani, D. R., & Uddin, L. Q. (2015). Demystifying cognitive flexibility: Implications for clinical and developmental neuroscience. *Trends in Neurosciences,38 (9*), 571–578. https://doi.org/10.1016/j.tins.2015.07.003

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44(11)*, 2037–2078. https://doi.org/10.1016/j.neuropsychologia.2006.02.006

Davis, J. C., Marra, C. A., Najafzadeh, M., Lui-Ambrose, T. (2010). The independent contribution of executive functions to health-related quality of life in older women. *BMC Geriatric, 10,* 16–23. https://doi.org/ 10.1186/1471-2318-10-16

Day, K. L., & Smith, C. L. (2013). Early Childhood Research Quarterly Understanding the role of private speech in children's emotion regulation. 28, 405–414. https://doi.org/ 10.1016/j.ecresq.2012.10.003

Denson, T. F, Pederson, W. C, Friese, M., Hahm, A., Roberts, L. (2011). Understanding impulsive aggression: Angry rumination and reduced self-control capacity are mechanisms underlying the provocation-aggression relationship. *Pers. Soc. Psychol. Bull. 37,* 850–62. https://doi.org/ 10.1177/0146167211401420

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do." *Developmental Psychobiology, 29,* 315-334. https://doi.org/ 10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Diamond A. (2005). Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). *Developmental Psychopathology, 17,* 807–825. https://doi.org/10.1017/S0954579405050388

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool Program Improves Cognitive Control. *Science, New Series, 318*, 1387–1388. https://doi.org/ 10.1126/science.1151148

Doebel, S., & Zelazo, P. D. (2015). A meta-analysis of the Dimensional Change Card Sort: Implications for developmental theories and the measurement of executive function in children. *Developmental Review, 38*, 241–268. https://doi.org/10.1016/j.dr.2015.09.001

Duan, X., Wei, S., Wang, G., & Shi, J. (2010). The relationship between executive functions and intelligence on 11- to 12-year- old children. *Psychological Test and Assessment Modeling, 52(4),* 419–431.

Duckworth, A. L., & Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science, 16(12)*, 939–944. https://doi.org/10.1111/j.1467-9280.2005.01641.x

Duncan, J., Burgess, P., & Emslie, H. (1995). Fluid intelligence after frontal lobe lesions. *Neuropsychologia, 33(3)*, 261–268. https://doi.org/10.1016/0028-3932(94)00124-8

Duncan, R. J., McClelland, M. M., & Acock, A. C. (2017). Relations between executive function, behavioral regulation, and achievement: Moderation by family income. *Journal of Applied Developmental Psychology, 49*, 21–30. https://doi.org/10.1016/j.appdev.2017.01.004

Durston, S., Mulder, M., Casey, B. J., Ziermans, T., & van Engeland, H. (2006). Activation in Ventral Prefrontal Cortex is Sensitive to Genetic Vulnerability for Attention-Deficit Hyperactivity Disorder. *Biological Psychiatry, 60(10),* 1062–1070. https://doi.org/10.1016/j.biopsych.2005.12.020

Emerson, M. J., & Miyake, A. (2003). Memory and Language The role of inner speech in task switching: A dual-task investigation. 48, 148–168. https://doi.org/10.1016/S0749-596X(02)00511-9

Eslinger, P. J., Blair, C., Wang, J. L., Lipovsky, B., Realmuto, J., Baker, D., Thorne, S., Gamson, D., Zimmerman, E., Rohrer, L., & Yang, Q. X. (2009). Developmental shifts in fMRI activations during visuospatial relational reasoning. *Brain and Cognition, 69(1),* 1–10. https://doi.org/10.1016/j.bandc.2008.04.010

Espinet, S. D., Anderson, J. E., & Zelazo, P. D. (2013). Reflection training improves executive function in preschool-age children: Behavioral and neural effects. *Developmental Cognitive Neuroscience, 4,* 3–15. https://doi.org/10.1016/j.dcn.2012.11.009

Espy, K. A, McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., Senn, T. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology, 26(1),* 465–486. https://doi.org/ 10.1207/s15326942dn2601_6

Fairchild, G., van Goozen, S. H., Stollery, S. J., Aitken, M. R., Savage, J., et al. (2009). Decision making and executive function in male adolescents with early-onset or adolescence-onset conduct disorder and control subjects. *Biology Psychiatry, 66,* 162–68. https://doi.org/ 10.1016/j.biopsych.2009.02.024

Farah, M. J., Shera, D. M., Savage, J. H., Betancourt, L., Giannetta, J. M., Brodsky, N. L., Malmud, E. K., & Hurt, H. (2006). Childhood poverty: Specific associations with neurocognitive development. *Brain Research, 1110(1*), 166–174. https://doi.org/10.1016/j.brainres.2006.06.072

Farah, M. J., Betancourt, L., Shera, D. M., Savage, J. H., Giannetta, J. M., Brodsky, N. L., Malmud, E. K., & Hurt, H. (2008). Environmental stimulation, parental nurturance and cognitive development in humans. *Developmental Science, 11(5),* 793–801. https://doi.org/10.1111/j.1467-7687.2008.00688.x

Farrant, B. M., Maybery, M. T., & Fletcher, J. (2012). Language, cognitive flexibility, and explicit false belief understanding: Longitudinal analysis in typical development and specific language impairment. *Child Development, 83(1),* 223–235. https://doi.org/10.1111 /j.1467-8624.201 1.01

Fausey, C. M., Long, B. L., Inamori, A., & Boroditsky, L. (2010). Constructing agency: The role of language. *Frontiers in Psychology*, *1,* 1–11. https://doi.org/10.3389/fpsyg.2010.00162

Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., DeFries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science, 17*(2), 172-179. https://doi.org/10.1111/j.1467-9280.2006.01681.x

Friedman, N. P., Miyake, A., Robinson, J. A. L., & Hewitt, J. K. (2011). Developmental trajectories in toddlers' self-restraint predict individual differences in executive functions 14 years later: A behavioral genetic analysis. *Developmental Psychology, 47(5),* 1410–1430. https://doi.org/10.1037/a0023750

Friedman, N. P., & Miyake, A. (2017). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex 86,* 186–204. https://doi.org/10.1016/j.cortex.2016.04.023

Garon, N., Bryson, S.E., & Smith, I.M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134,* 31-60. https://doi.org/ 10.1037/0033-2909.134.1.31

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology, 40(2),* 177–190. https://doi.org/10.1037/0012-1649.40.2.177

Geary, D. C. (2012). Cognitive predictors of achievement growth in mathematics: A five Year Longitudinal Study. *Developmental Psychology, 47(6),* 1539–1552. https://doi.org/10.1037/a0025510

Gerardi-Caulton, G. (2000). Sensitivity to spatial conflict and the development of self-regulation in children 24-36 months of age. *Developmental Science, 3(4)*, 397–404. https://doi.org/10.1111/1467-7687.00134

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3 1/2-7 years old on a Stroop-like day-night test. *Cognition, 53),* 129–153. https://doi.org/10.1111/j.1751-9020.2011.00397.x

Goldstein, S., & Naglieri, J. (2011). Neurocognitive and Behavioral Characteristics of Children with ADHD and Autism: New Data and New Strategies. The ADHD Report, 19(4), 10–12. https://doi.org/10.1521/adhd.2011.19.4

Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *Journal of Experimental Psychology, 38(4),* 404–411. https://doi.org/10.1037/h0059831

Greene, J. D., Sommerville, B. R., Nystrom, L. E., Darley, J. M. & Cohen, J. D. (2001). An fMRI Investigation of Emotional Engagement in Moral Judgment. *Science, 293*, 2105–2108. https://doi.org/ 10.1126/science.1062872

Guilford, J. P. (1982). Cognitive psychology's ambiguities: Some suggested remedies. *Psychological Review, 89(1*), 48–59. https://doi.org/10.1037//0033-295x.89.1.48

Gunnar, M., & Quevedo, K. (2007). The Neurobiology of Stress and Development. *Annual Review of Psychology, 58(1)*, 145–173. https://doi.org/10.1146/annurev.psych.58.110405.085605

Gur, R. C., Richard, J., Calkins, M. E., Chiavacci, R., Hansen, J. A., Bilker, W. B., Gur, R. E. (2012). Age group and sex differences in performance on a computerized neurocognitive battery in children age 8-21. *Neuropsychology, 26*(2), 251-265. https://doi.org/10.1037/a0026712

Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: What is it, who has it, and how did it evolve? The Evolution of Human Language. *Biolinguistic Perspectives, 14–42.* https://doi.org/10.1017/CBO9780511817755.002

Hayford, S. R. (2009). The Evolution of fertility expectations over the life course. *Demography, 46*, 765-783. https://doi.org/ 10.1353/dem.0.0073

Hughes, C., Ensor, R., Wilson, A., & Graham, A. (2010). Tracking executive function across the transition to school: A latent variable approach. *Developmental Neuropsychology, 35(1),* 20–36. https://doi.org/10.1080/87565640903325691

Huizinga, M., Dolan, C. V., & Van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis.

Neuropsychologia, 44, 2017-2036. https://doi.org/10.1016/j.neuropsychologia.2006.01.010

Ionescu, T. (2012). Exploring the nature of cognitive flexibility. *New Ideas in Psychology, 30(2),* 190–200. https://doi.org/10.1016/j.newideapsych.2011.11.001

Jacques, S., & Zelazo, P. D. (2001). The Flexible Item Selection Task (FIST): a measure of executive function in preschoolers. *Developmental Neuropsychology, 20(3),* 573. https://doi.org/10.1207/S15326942DN2003_2

Jacques, S., & Marcovitch, S. (2010). Development of executive functions across the life span. (ed. Overton, W.F. & Lerner, R.M). *The Handbook of Lifespan Development, 1*. John Wiley & Sons, 431-466.

Jones, B. L., Nagin, D. S., & Roeder, K. (2001). A SAS procedure based on mixture models for estimating developmental trajectories. *Sociological Methods and Research, 29(3),* 374–393. https://doi.org/10.1177/0049124101029003005

Jones, L. B., Rothbart, M. K., & Posner, M. I. (2003). Development of executive attention in preschool children. *Developmental Science, 6(5),* 498–504. https://doi.org/10.1111/1467-7687.00307

Jung, T., & Wickrama, K. A. S. (2008). An introduction to latent class growth analysis and growth mixture modeling. *Social and Personality Psychology Compass, 2(1),* 302–317. https://doi.org/10.1111/j.1751-9004.2007.00054.x

Kane, M., Hambrick, D., & Conway, A. (2005). Working Memory Capacity and Fluid Intelligence Are Strongly Related Constructs: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin, 131(1),* 66–71. https://doi.org/10.1037/0033-2909.131.1.66

Karasinski, C. (2015). Language ability, executive functioning and behaviour in school-age children. *International Journal of Language and Communication Disorders, 50(2),* 144–150. https://doi.org/10.1111/1460-6984.12104

Karbach, J., & Kray, J. (2007). Developmental changes in switching between mental task sets: The influence of verbal labeling in childhood. *Journal of Cognition and Development, 8(2)*, 205–236. https://doi.org/10.1080/15248370701202430

Klingberg, T. (2006). Development of a superior frontal-intraparietal network for visuo-spatial working memory. *Neuropsychologia, 44(11)*, 2171–2177. https://doi.org/10.1016/j.neuropsychologia.2005.11.019

Lee, K., Bull, R., & Ho, R. M. H. (2013). Developmental changes in executive functioning. *Child Development, 84*(6), 1933-1953. https:// doi.org/10.1111/cdev.12096

Lehto, J. E., Juujarvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21,* 59-80. https://doi.org/ 10.1348/026151003321164627

Lidstone, J. S. M., Meins, E., & Fernyhough, C. (2010). The roles of private speech and inner speech in planning during middle childhood: Evidence from a dual task paradigm. *Journal of Experimental Child, 107,* 438–451. https://doi.org/10.1016/j.jecp.2010.06.002

Little, M. (2017). Racial and socioeconomic gaps in executive function skills in early elementary school: Nationally representative evidence from the ECLS-K:2011. *Educational Researcher, 46(2),* 103–109. https://doi.org/10.3102/0013189X17698700

Lui, M., & Tannock, R. (2007). Working memory and inattentive behavior in a community sample of children. *Behavior and Brain Function, 3,* 12. https://doi.org/ 10.1186/1744-9081-3-12

MacWhinney, B. (1975). Rules, rote, and analogy in morphological formations by Hungarian children. *Journal of Child Language, 2(1),* 65–77. https://doi.org/10.1017/S0305000900000891

MacWhinney, B. (2010). Language development (ed. Overton, W.F. & Lerner, R.M). *The Handbook of Lifespan Development*, *1*. John Wiley & Sons, 467-508.

Masten, A. S., Herbers, J. E., Desjardins, C. D., Cutuli, J. J., McCormick, C. M., Sapienza, J. K., Long, J. D., & Zelazo, P. D. (2012). Executive Function Skills and School Success in Young Children Experiencing Homelessness. *Educational Researcher, 41(9),* 375–384. https://doi.org/10.3102/0013189X12459883

Mazzocco, M. M. M., & Kover, S. T. (2007). A longitudinal assessment of executive function skills and their association with math performance. *Child Neuropsychology, 13(1),* 18–45. https://doi.org/10.1080/09297040600611346

McArdle, J.J., Ferrer-Caja, E., Hamagami, F., & Woodcock, R.W. (2002). Comparative Longitudinal Structural Analyses of the Growth and Decline of Multiple Intellectual Abilities Over the Life Span. *Developmental Psychology, 38,* 115-142. https://doi.org/10.1037//0012-1649.38.1.115

McClelland, M. M., Cameron, C. E., Connor, C. M. D., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43(4),* 947–959. https://doi.org/10.1037/0012-1649.43.4.947

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly, 28(2),* 314–324. https://doi.org/10.1016/j.ecresq.2012.07.008

McCloskey, G. (2009). Assessment and intervention for executive function difficulties (Eds. Perkins, L.A. & Van Divner, B.).New York, NY: Routledge.

Mezzacappa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Development, 75(5),* 1373–1386. https://doi.org/10.1117/12.572040

Middleton, F. A., & Strick, P. L. (2001). Cerebellar projections to the prefrontal cortex of the primate. *Journal of Neuroscience, 21(2),* 700–712. https://doi.org/10.1523/jneurosci.21-02-00700.2001

Miller, H. V., Barnes, J. C., & Beaver, K. M. (2011). Self-control and health outcomes in a nationally representative sample. *American Journal of Health Behavior, 35,* 15–27. https://doi.org/ 10.5993/AJHB.35.1.2

Mischel, W., Shoda, Y., & Rodriguez, M. I. (1989). Delay of gratification in children. *Science, 244(4907),* 933. https://doi.org/10.1126/science.2658056

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49-100. https://doi.org/ 10.1006/cogp.1999.0734

Miyake, A., Emerson, M. J., Padilla, F., & Ahn, J. C. (2004). Inner speech as a retrieval aid for task goals: The effects of cue type and articulatory suppression in the random task cuing paradigm. *Acta Psychologica, 115(2–3),* 123–142. https://doi.org/10.1016/j.actpsy.2003.12.004

Miyake, A., & Friedman, N. P. (2012). The Nature and Organization of Individual Differences in Executive Functions: Four General Conclusions. *Current Directions in Psychological Science, 21,* 8-14. https://doi.org/IO.II77/0963721411429458

Morgan, P. L., Farkas, G., Wang, Y., Hillemeier, M. M., Oh, Y., & Maczuga, S. (2019). Executive function deficits in kindergarten predict repeated academic difficulties across elementary school. *Early Childhood Research Quarterly, 46*, 20–32. https://doi.org/10.1016/j.ecresq.2018.06.009

Moriguchi, Y., Sakata, Y., Ishibashi, M., & Ishikawa, Y. (2015). Teaching others rule-use improves executive function and prefrontal activations in young children. *Frontiers in Psychology, 6(June),* 1–9. https://doi.org/10.3389/fpsyg.2015.00894

Morrison, F. J., Ponitz, C. C., & McClelland, M. M. (2010). Self-regulation and academic achievement in the transition to school. *Child Development at the Intersection of Emotion and Cognition,* 203–204. https://doi.org/ 10.1037/12059-011

Muthén, L.K. & Muthén, B.O. (1998-2019). Mplus User’s Guide. Seventh Edition. Los Angeles, CA: Muthén & Muthén

Muthén, B., & Muthén, L. K. (2000). Integrating person-centered and variable-centered analyses: growth mixture modeling with latent trajectory classes. *Alcoholism:*

Clinical and Experimental Research, 24(6), 882–891. https://doi.org/10.1111/j.1530-0277.2000.tb02070.x

Muthén, B. (2004). Latent Variable Analysis: Growth Mixture Modeling and Related Techniques for Longitudinal Data. In D. Kaplan (Ed.), Handbook of Quantitative Methodology for the Social Sciences (pp. 345-368). Newbury Park, CA: Sage. https://doi.org/10.4135/9781412986311.n19

Muthen, B., & Asparouhov, T. (2006). Item response mixture modeling: Application to tobacco dependence criteria. *Addictive Behaviors, 31(6),* 1050–1066. https://doi.org/10.1016/j.addbeh.2006.03.026

Nagin, D. S., & Land, K. C. (1993). Age, criminal careers, and population heterogeneity: Specification and estimation of a nonparametric, mixed poisson model. *Criminology, 31(3),* 327–362. https://doi.org/10.1111/j.1745-9125.1993.tb01133.x

Naglieri, J. A., Princiotta, D., & Otero, T. M. (2014). Introduction: A history of executive functioning as a theoretical and clinical construct. In Handbook of Executive Functioning (pp. 3–12). Springer New York. https://doi.org/10.1007/978-1-4614-8106-5_1

Nguyen, T., & Duncan, G. J. (2019). Kindergarten components of executive function and third grade achievement: A national study. *Early Childhood Research Quarterly, 46,* 49–61. https://doi.org/10.1016/j.ecresq.2018.05.006

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. Developmental Science, 8(1), 74–87. https://doi.org/10.1111/j.1467-7687.2005.00394.x

Nylund, K., Bellmore, A., Nishina, A., & Graham, S. (2007). Subtypes, severity, and structural stability of peer victimization: What does latent class analysis say? *Child Development, 78(6),* 1706–1722. https://doi.org/10.1111/j.1467-8624.2007.01097.x

Obradović, J. (2010). Effortful control and adaptive functioning of homeless children: Variable-focused and person-focused analyses. *Journal of Applied Developmental Psychology, 31(2),* 109–117. https://doi.org/10.1016/j.appdev.2009.09.004

Ochs, E., & Schieffelin, B. (1986). Language Socialization. *Annual Review of Anthropology, 15,* 163-191: https://www.jstor.org/stable/2155759.

O'Hearn, K., Asato, M., Ordaz, S., & Luna, B. (2008). Neurodevelopment and executive function in autism. *Development and Psychopathology, 20(4),* 1103–1132. https://doi.org/10.1017/S0954579408000527

Pauls, L. J., & Archibald, L. M. D. (2016). Executive functions in children with specific language impairment: A meta-analysis. *Journal of Speech, Language, and Hearing Research, 59,* 1074–1087. https://doi.org/10.1044/2016

Penadés, R., Catalán, R., Rubia, K., Andrés, S., Salamero, M., & Gastó, C. (2007). Impaired response inhibition in obsessive compulsive disorder. *European Psychiatry, 22,* 404–410. https://doi.org/ 10.1016/j.eurpsy.2006.05.001

Pietrefesa, A. S., & Evans, D. W. (2007). Affective and neuropsychological correlates of children's rituals and compulsive-like behaviors: Continuities and discontinuities with obsessive-compulsive disorder. *Brain and Cognition, 65(1),* 36–46. https://doi.org/10.1016/j.bandc.2006.02.007

Rainelli, S., Bulotsky-Shearer, R., Fernandez, V., Greenfield, D., & López, M. (2017). Validity of the first two subtests of the preschool language assessment scale as a language screener for Spanish-speaking preschool children. *Early Childhood Research Quarterly, 38,* 10–22. https://doi.org/10.1016/j.ecresq.2016.08.001

Ram, N., & Grimm, K. (2007). Using simple and complex growth models to articulate developmental change: Matching theory to method. International Journal of *Behavioral Development, 31(4),* 303-316. https://doi.org/10.1177/0165025407077751

Riggs, N. R., Jahromi, L. B., Razza, R. P., Dillworth-Bart, J. E., & Mueller, U. (2006). Executive function and the promotion of social-emotional competence. Journal of Applied Developmental Psychology, 27(4), 300–309. https://doi.org/10.1016/j.appdev.2006.04.002

Riggs, N. R., Spruijt-Metz, D., Sakuma, K. K., Chou, C. P, & Pentz, M. A. (2010). Executive cognitive function and food intake in children. *Journal of Nutrition Education and Behavior, 42,* 398–403. https://doi.org/ 10.1016/j.jneb.2009.11.003

Roello, M., Ferretti, M. L., Colonnello, V., & Levi, G. (2015). When words lead to solutions: Executive function deficits in preschool children with specific language impairment. *Research in Developmental Disabilities, 37,* 216–222. https://doi.org/10.1016/j.ridd.2014.11.017

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2012). Implications of Infant Cognition for Executive Functions at Age 11. *Psychological Science, 23(11)*, 1345–1355. https://doi.org/10.1177/0956797612444902

Rothbart, M.K., Posener, M.I., & Kieras, J. (2006). Temperament, attention and the development of self-regulation. In K. McCartney & D. Phillips (Eds.), *The Blackwell handbook of early child development* (pp. 328-357). Malden, MA: Blackwell Press.

Sheridan, M., Kharitonova, M., Martin, R.E., Chatterjee, A. & Gabrieli, J. (2014). Neural substrates of the development of cognitive control in children ages 5-10 years. *Journal of Cognitive Neuroscience, 26,* 1840–1850. https://doi.org/10.1162/jocn_a_00597

Spooner, D. M., & Pachana, N. A. (2006). Ecological validity in neuropsychological assessment: A case for greater consideration in research with neurologically intact populations. *Archives of Clinical Neuropsychology, 21(4),* 327–337. https://doi.org/10.1016/j.acn.2006.04.004

St. Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology, 59(4),* 745–759. https://doi.org/10.1080/17470210500162854

Sung, J., & Wickrama, K. A. S. (2018). Longitudinal relationship between early academic achievement and executive function: Mediating role of approaches to learning. *Contemporary Educational Psychology, 54(June),* 171–183. https://doi.org/10.1016/j.cedpsych.2018.06.010

Taylor Tavares, J.V., Clark, L., Cannon, D.M., Erickson, K., Drevets, W.C., & Sahakian, B.J. (2007). Distinct profiles of neurocognitive function in unmedicated unipolar depression and bipolar II depression. *Biology Psychiatry, 62,* 917–924. https://doi.org/ 10.1016/j.biopsych.2007.05.034

Tourangeau, K., Nord, C., L. e, T., Wallner-Allen, K., Vaden-Kiernan, N., Blaker, L. & Najarian, M. (2019). *Early Childhood Longitudinal Study, Kindergarten Class of 2010-11 (ECLS-K:2011) User's Manual for the ECLS-K:2011 Kindergarten-Fifth Grade Data File and Electronic Codebook, Public Version* (NCES 2019-051). U.S Department of Education. Washington, DC: National Center for Education Statistics.

Ursache, A., Blair, C., & Raver, C. C. (2012). The promotion of self-regulation as a means of enhancing school readiness and early achievement in children at risk for school failure: Promotion of self-regulation in school. *Child Development Perspectives, 6*(2), 122-128. https://doi.org/10.1111/j.1750-8606.2011.00209.x

Ursache, A., & Noble, K. G. (2016). Socioeconomic status, white matter, and executive function in children. *Brain and Behavior, 6(10)*. https://doi.org/10.1002/brb3.531

Usai, M. C., Viterbori, P., Traverso, L., & De Franchis, V. (2014). Latent structure of executive function in five- and six-year-old children: A longitudinal study. European Journal of Developmental Psychology, 11(4), 447–462. https://doi.org/10.1080/17405629.2013.840578

Vitaro, F., Brendgen, M., Larose, S., & Trembaly, R. E. (2005). Kindergarten disruptive behaviors, protective factors, and educational achievement by early adulthood.

Journal of Educational Psychology, 97(4), 617–629. https://doi.org/10.1037/0022-0663.97.4.617

Vygotsky, L. S. (1986). Thought and language (A. Kozulin ed). Cambridge, Mass: MIT Press.

Wallace, Gregory L., Peng, Cynthia S., & Williams, D. (2017). Interfering with inner speech selectively disrupts problem solving and is linked with real-world executive functioning. *Journal of Speech, Language and Hearing Research, 60(December)*, 3456–3461. https:doi.org/ 10.1044/2017_JSLHR-S-16-0376

Wang, J., & Wang, X. (2012). Latent growth models for longitudinal data analysis. In Structural Equation Modeling: Applications Using Mplus (pp. 141–206). John Wiley and Sons Ltd. http://ebookcentral.proquest.com/lib/herr-ebooks/detail.action?docID=989223.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development, 72(3),* 655–684. https://doi.org/10.1111/1467-8624.00304

Willoughby, M. T., Wirth, R. J., & Blair, C. B. (2011). Contributions of modern measurement theory to measuring executive function in early childhood: An empirical demonstration. *Journal of Experimental Child Psychology, 108(3),* 414–435. https://doi.org/10.1016/j.jecp.2010.04.007

Willoughby, M. T., Wirth, R. J., & Blair, C. B. (2012). Executive function in early childhood: Longitudinal measurement invariance and developmental change. Psychological Assessment, 24(2), 418–431. https://doi.org/10.1037/a0025779

Wilson, C. R. E., Gaffan, D., Browning, P. G. F., & Baxter, M. G. (2010). Functional localization within the prefrontal cortex: Missing the forest for the trees? Trends in Neurosciences, 33(12), 533–540. https://doi.org/10.1016/j.tins.2010.08.001

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18(5),* 459–482. https://doi.org/10.1002/cne.920180503

Zelazo, P. D., & Reznick, J. S. (1991). Age-Related Asynchrony of Knowledge. *Child Development, 62(4),* 719–735. http://www.jstor.org/stable/1131173

Zelazo, P. D., Carter, A., Reznick, J. S., & Frye, D. (1997). Early development of executive function: A problem-solving framework. *Review of General Psychology, 1(2),* 198–226. https://doi.org/10.1037/1089-2680.1.2.198

Zelazo, P. D., & Müller, U. (2002). The balance beam in the balance: Reflections on rules, relational complexity, and developmental processes. *Journal of Experimental Child Psychology, 81(4),* 458–465. https://doi.org/10.1006/jecp.2002.2667

Zelazo, P. D., Muller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function. *Monographs of the Society for Research in Child Development, 68(3),* 1–27. https://doi.org/10.1111/j.0037-976x.2003.00261.x

Zelazo, P.D. (2004). The development of conscious control in childhood. *Trends in Cognitive Sciences, 8,* 12-17. https://doi.org/ 10.1016/j.tics.2003.11.001

Zelazo, P. D., Craik, F. I. M., & Booth, L. (2004). Executive function across the life span. *Acta Psychologica, 115,* 167–183. https://doi.org/10.1016/j.actpsy.2003.12.005

Zelazo, P.D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1(1),* 297–301. https://doi.org/10.1038/nprot.2006.46

Zelazo, P. D., & Lee, W. C. (2010). Brain development; An overview (ed. Overton, W.F. & Lerner, R.M). *The Handbook of Lifespan Development, 1*. John Wiley & Sons, 89-114.

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives, 6(4),* 354–360. https://doi.org/10.1111/j.1750-8606.2012.00246.x

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). NIH toolbox cognition battery (CB): Measuring executive function and attention. *Monographs of the Society for Research in Child Development*, *78(4),* 16–33. https://doi.org/10.1111/mono.12032

Zelazo, P. D. (2015). Executive function: Reflection, iterative reprocessing, complexity, and the developing brain. *Developmental Review, 38,* 55–68. https://doi.org/10.1016/j.dr.2015.07.001

Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). Executive Function: Implications for Education (NCER 2017-2000) Washington D.C: National Center for Education Research, Institute of Education Sciences, U.S Department of Education. Report available on the Institute website at http://ies.ed.gov/.

Table 1

Participant Characteristics

Characteristic	N	Percent
Race		
Hispanic	4324	23.8
White	12,688	69.8
Black/African American	2840	15.6
Asian	1765	9.7
American Indian/Alaska Native	430	2.4
Native Hawaiian/Pacific Islander	249	1.4
Gender		
Male	9288	51.2
Female	8847	48.8

Table 2

Scores on Dimensional Change Card Sort

Wave	Grade	N	Min	Max	Mean	Std. Deviation
1	Kindergarten Fall	15291	0.0	9.99	7.85	1.80
2	Kindergarten Spring	17149	0.0	9.99	8.33	1.54
3	1st Grade Fall	4332	0.0	9.99	8.67	1.31
4	1st Grade Spring	12900	0.0	9.99	8.85	1.26
5	2nd Grade Fall	4708	3.35	9.67	6.62	.903
6	2nd Grade Spring	13774	3.97	10.00	6.94	.848
7	3rd Grade Spring	12744	4.34	10.00	7.31	.806
8	4th Grade Spring	12021	4.76	10.00	7.68	.795
9	5th Grade Spring	11386	5.04	10.00	8.01	.813

Table 3

Scores on preLAS 2000

preLAS	N	Percent
Passed	14215	90.1%
Did not Pass	1569	9.9%
Overall	15874	100

Note. Passed = Score of 16-20, Not Passed = Score of 0-15

Table 4

Fit Statistics for Single-Group (Nonmixture) Models

Model of Change	CFI	TLI	RMSEA	SRMR	BIC
Linear	0.000	0.000	0.107	0.680	365,570.589
Quadratic	0.000	0.000	0.100	0.777	361,972.247
Cubic	0.108	0.132	0.084	0.581	343,895.562
Piecewise Quadratic	0.976	0.965	0.017	0.028	319,483.868

Note. CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual; BIC = Bayesian Information Criteria.

Table 5

IC's, Entropy, Likelihood Ratio Tests for LCGA Unconditional Model

Measure	3 Classes	4 Classes	5 Classes
BIC	316,610.101	312,725.118	308,732.965
Entropy	.940	.775	.807
LMR-LRT test	.4379	.2423	.1646

Note. BIC = Bayesian Information Criteria, LMR-LRT = Lo, Mendell, and Rubin Likelihood Ratio Test

Table 6

IC's, Entropy, Likelihood Ratio Tests for LCGA Conditional (SES) Model

Measure	2 Classes	3 Classes	4 Classes	5 Classes	6 Classes
BIC	308901.211	303486.032	299,288.595	299,418.994	***
Entropy	.936	.967	.981	.816	***
LMR-LRT test	.0020	.5302	.1624	.0004	***

***No Convergence

Note. BIC = Bayesian Information Criteria, LMR-LRT = Lo, Mendell, and Rubin Likelihood Ratio Test

Table 7

IC's, Entropy, Likelihood Ratio Tests for GMM

Measure	4 Classes	5 Classes	6 Classes
BIC	284,425.311	283,739.283	283,653.929
Entropy	.985	.970	.908
LMR-LRT test	.0829	.0385	.3629

Note: BIC = Bayesian Information Criteria, LMR-LRT = Lo, Mendell, and Rubin Likelihood Ratio Test

Table 8

Multinomial Logistic Regression Results

Class Number	Estimate	Standard Error	p value	Probability
Class 1	-3.034	.286	0.000	54%
Class 2	-1.60	.159	0.000	28%
Class 3	-.249	.303	.411	1%
Class 4	-454	.274	.097	2%
Class 5	*****	****	****	15%

Note. Class 5 is the reference class

Table 9

Multinomial Logistic Regression Equations for Probabilities, Intercept and Slope

$$P(Class1) = \frac{\exp(-3.034)}{\exp(-.249) + \exp(-.454) + \exp(-1.6) + \exp(-3.034) + 1} = .54 \qquad (1)$$

$$P(Class2) = \frac{\exp(-1.6)}{\exp(-.249) + \exp(-.454) + \exp(-1.6) + \exp(-3.034) + 1} = .28 \qquad (2)$$

$$P(Class3) = \frac{\exp(-.249)}{\exp(-.249) + \exp(-.454) + \exp(-1.6) + \exp(-3.034) + 1} = .01 \qquad (3)$$

$$P(Class4) = \frac{\exp(-.454)}{\exp(-.249) + \exp(-.454) + \exp(-1.6) + \exp(-3.034) + 1} = .02 \qquad (4)$$

$$P(Class5) = \frac{1}{\exp(-.249) + \exp(-.454) + \exp(-1.6) + \exp(-3.034) + 1} = .15 \qquad (5)$$

Table 10

Multinomial Logistic Regression Equations for Probabilities, Intercept only

$$P(\text{Class1}) = \frac{\exp(1.275)}{\exp(.629) + \exp(-1.856) + \exp(-2.75) + \exp(1.275) + 1} = .79 \quad (6)$$

$$P(\text{Class2}) = \frac{\exp(.629)}{\exp(.629) + \exp(-1.856) + \exp(-2.75) + \exp(1.275) + 1} = .05 \quad (7)$$

$$P(\text{Class3}) = \frac{\exp(-2.75)}{\exp(.629) + \exp(-1.856) + \exp(-2.75) + \exp(1.275) + 1} = .01 \quad (8)$$

$$P(\text{Class4}) = \frac{\exp(-1.856)}{\exp(.629) + \exp(-1.856) + \exp(-2.75) + \exp(1.275) + 1} = .013 \quad (9)$$

$$P(\text{Class5}) = \frac{1}{\exp(.629) + \exp(-1.856) + \exp(-2.75) + \exp(1.275) + 1} = .15 \quad (10)$$

Figure 1: Growth Mixture Model Path Analysis

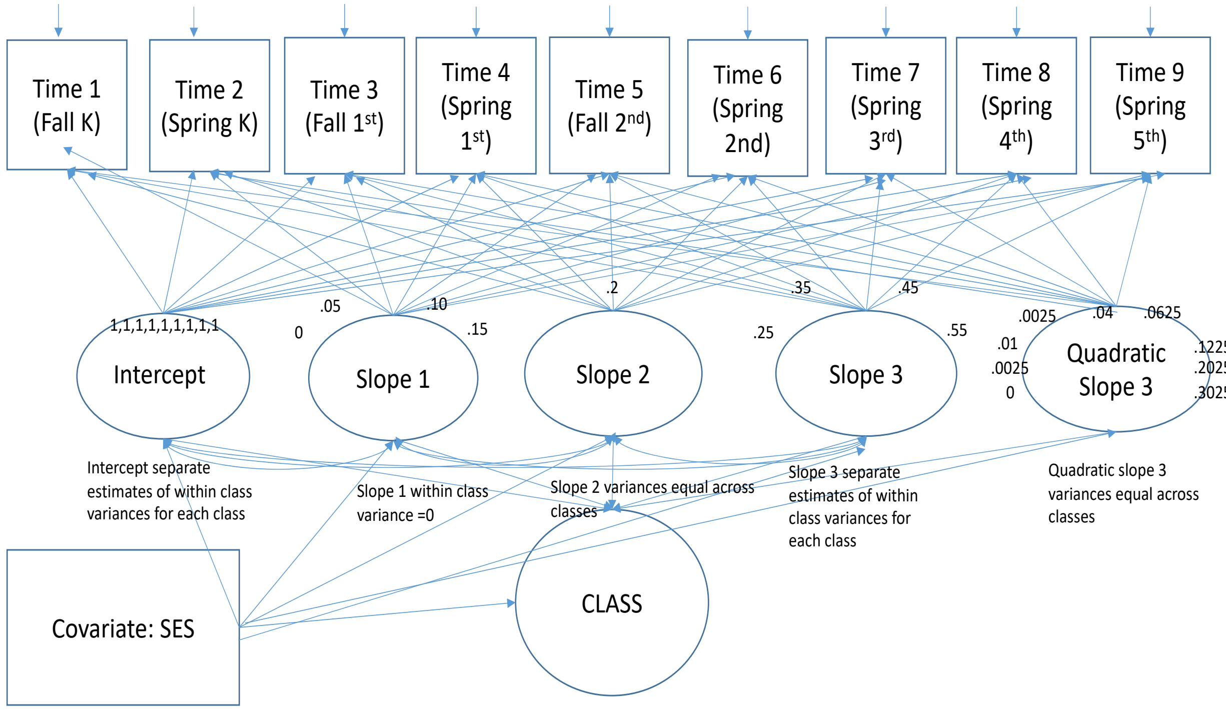


Figure 2: Individual Observed Values of Whole Sample

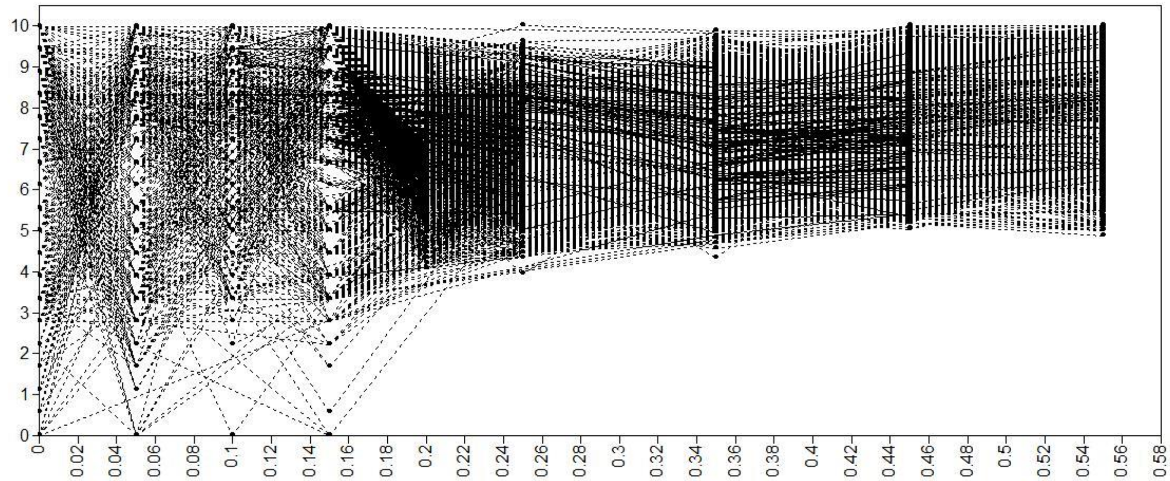
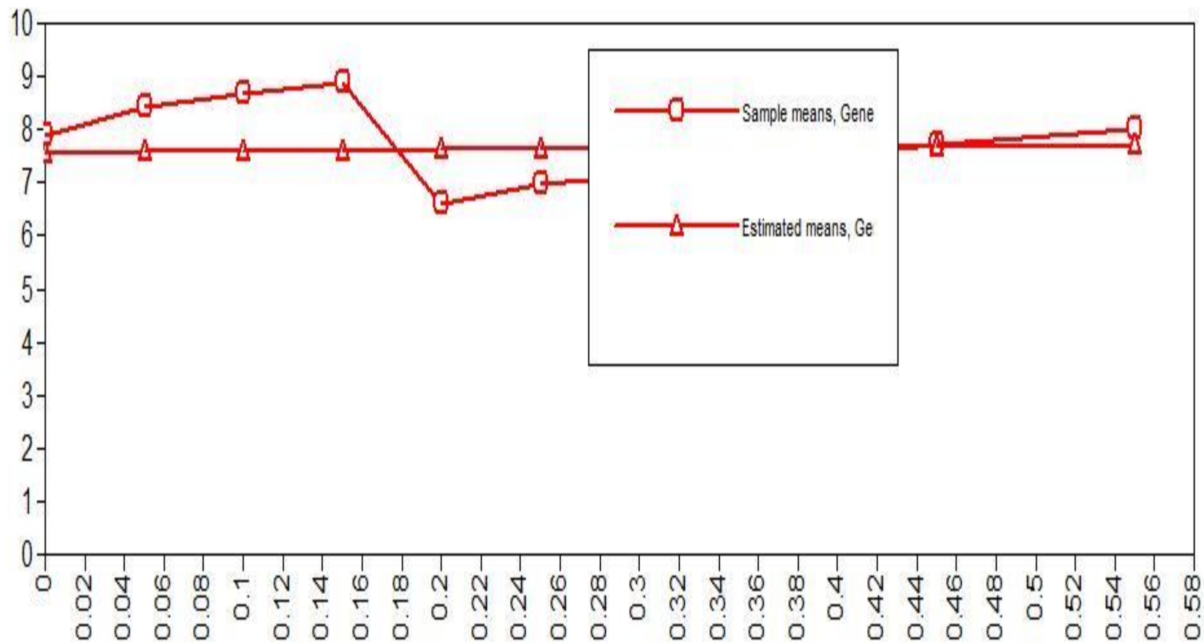
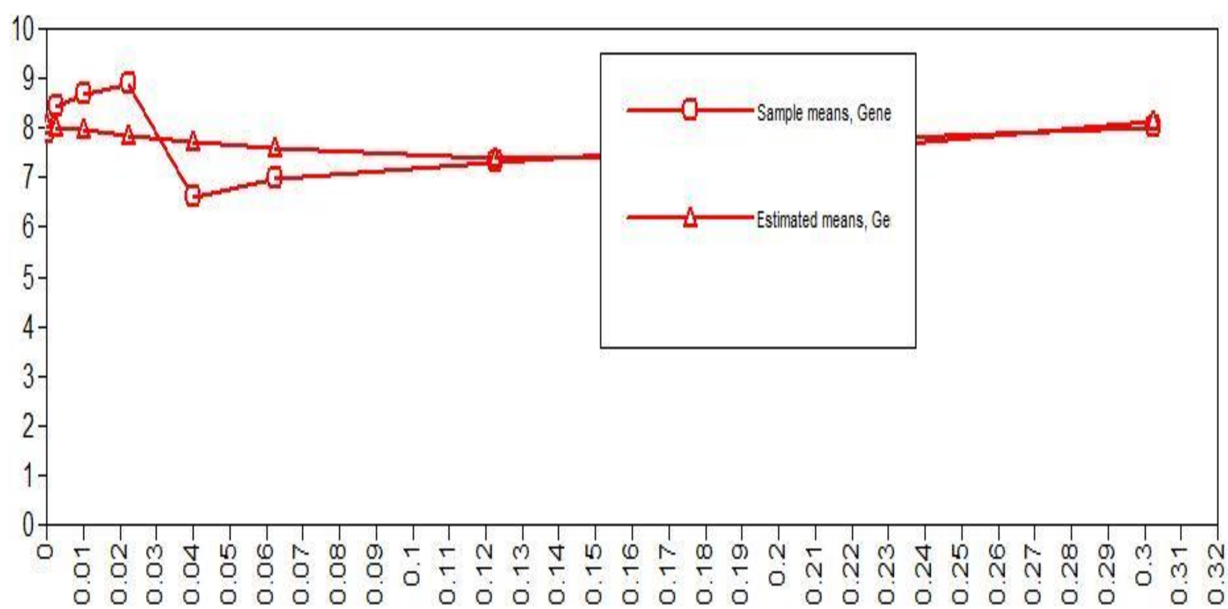


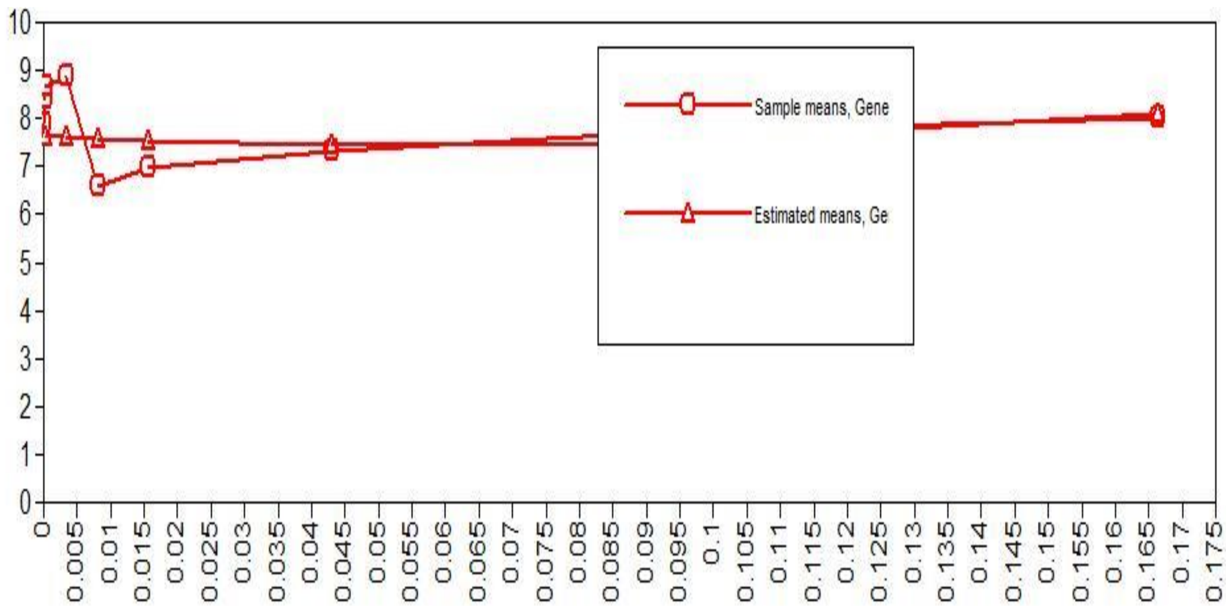
Figure 3: Univariate Growth Models



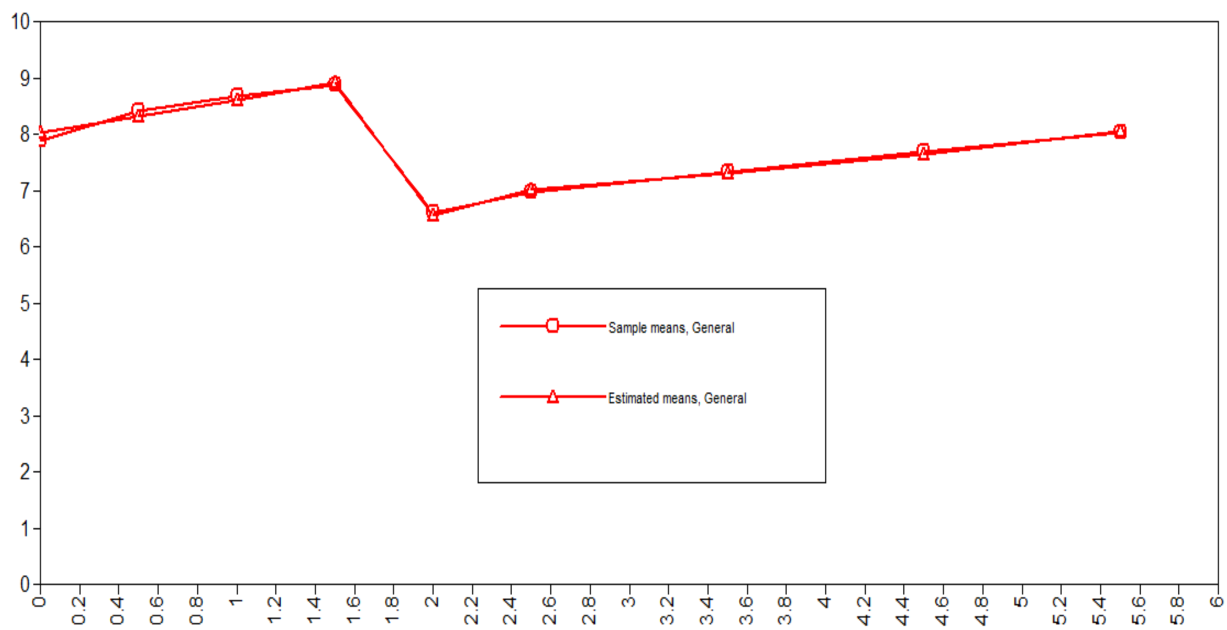
Linear Model



Quadratic Model



Cubic Model



Piecewise Model

Figure 4: Sample and Estimated Growth Means

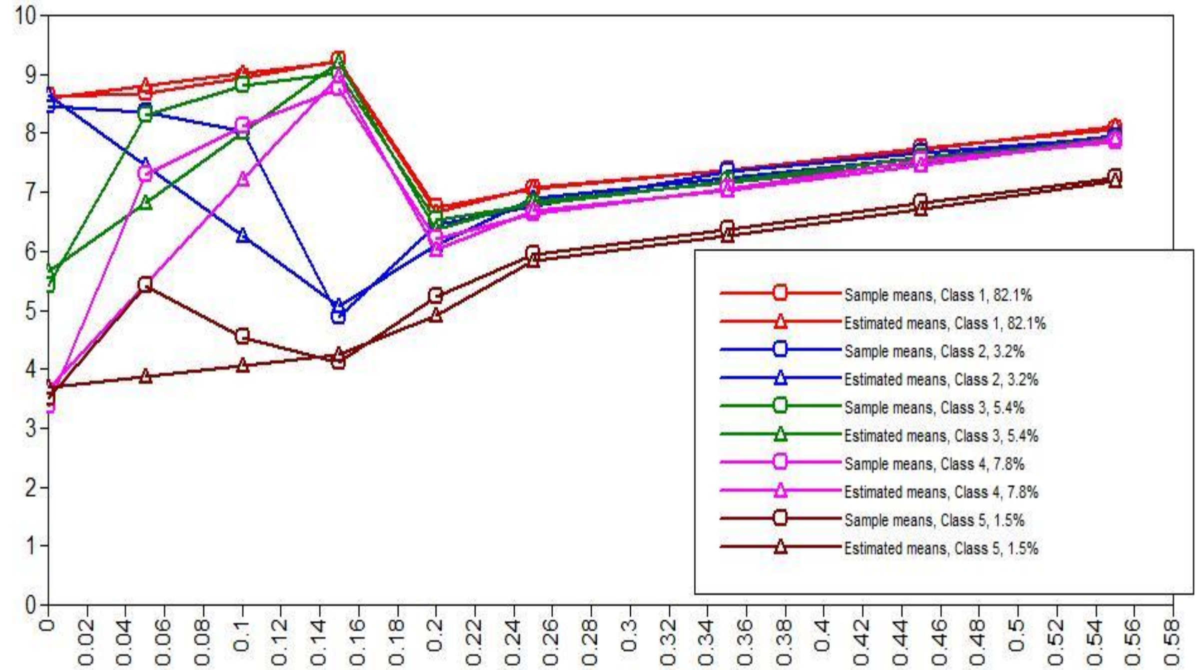
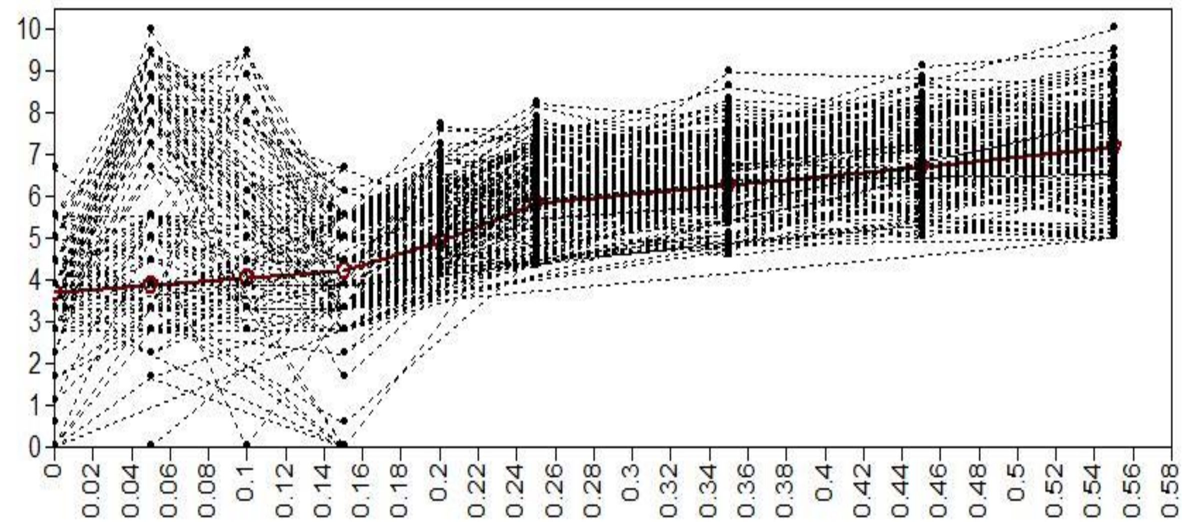
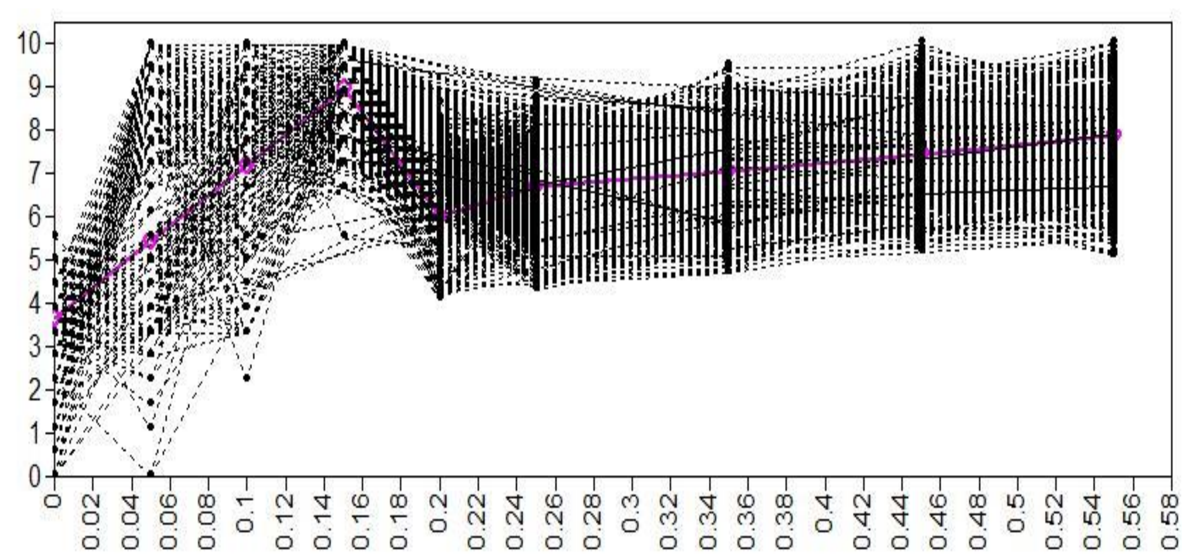


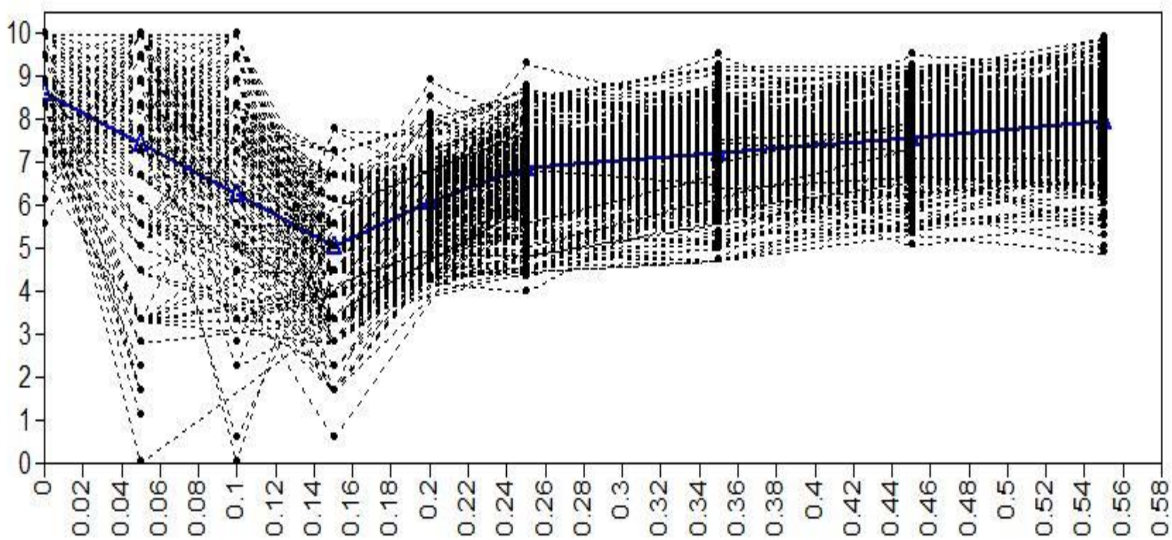
Figure 5: Observed Individual Values and Estimated Mean per Class



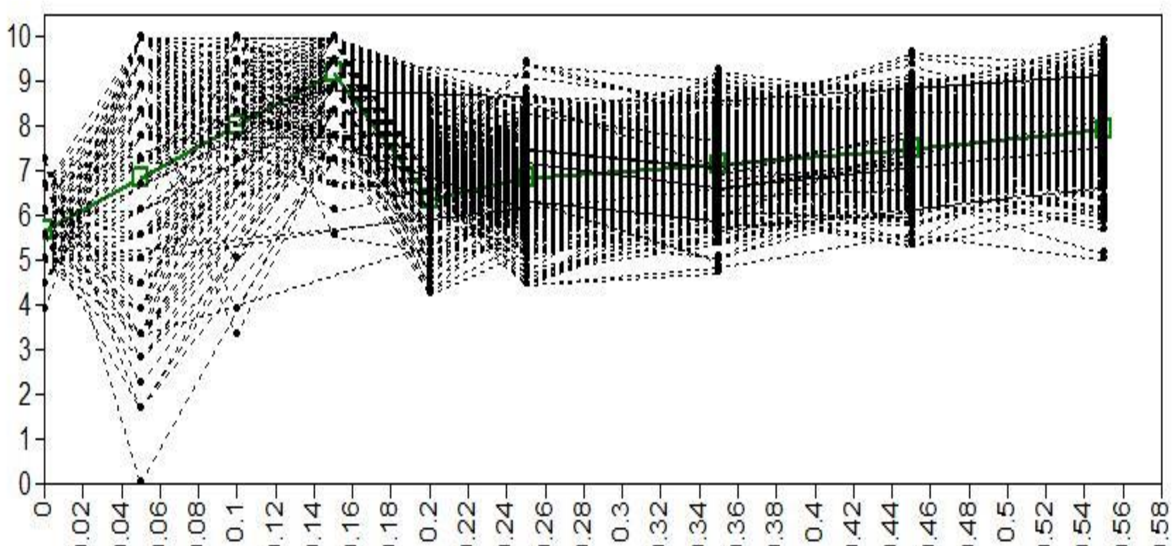
Class 1 -At Risk



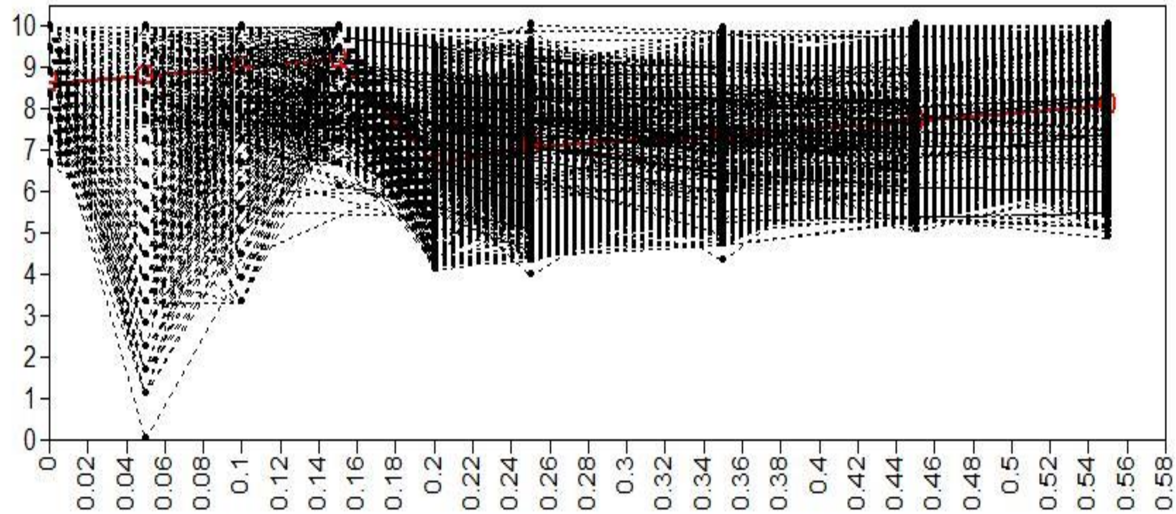
Class 2 – Remediated



Class 3 – Decreasing

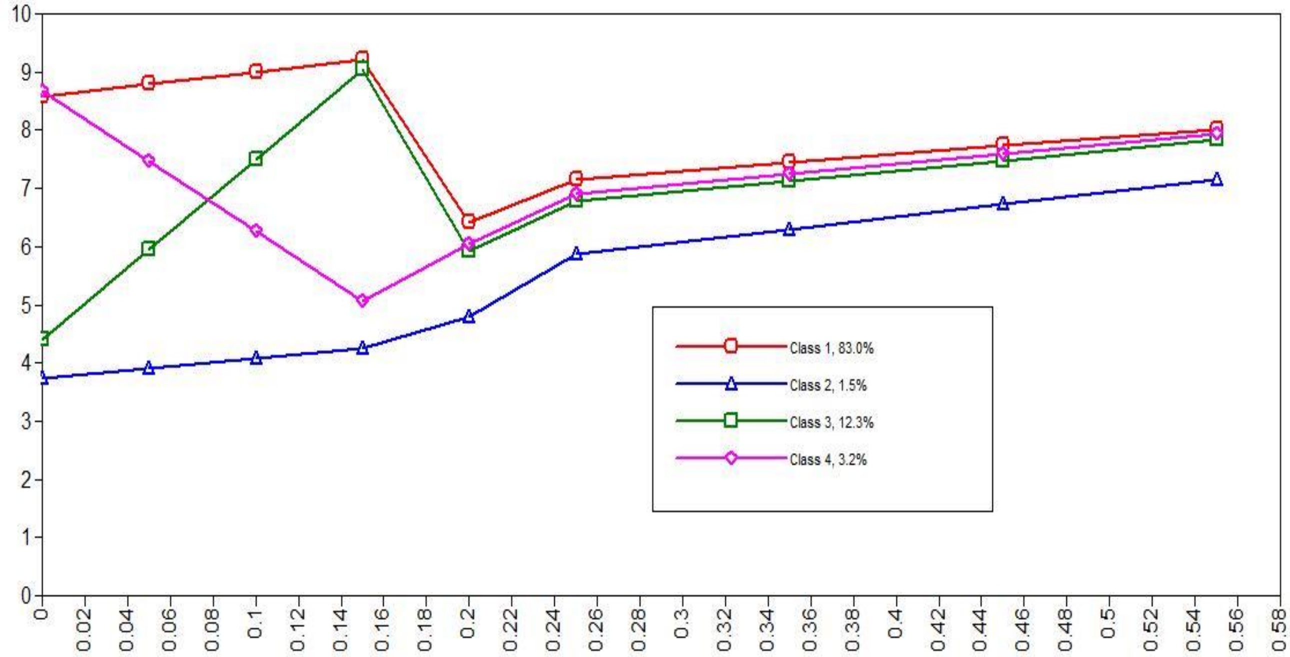


Class 4 – Mid Range

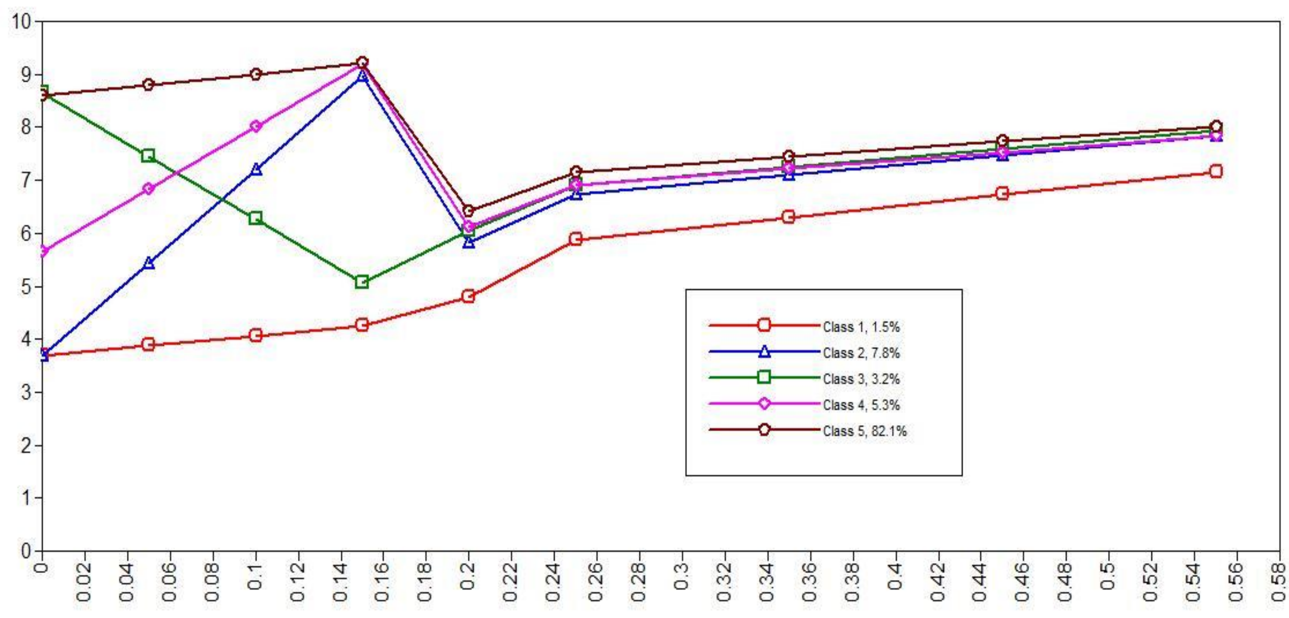


Class 5 – Average

Figure 6: Growth Mixture Models



4-Class Model



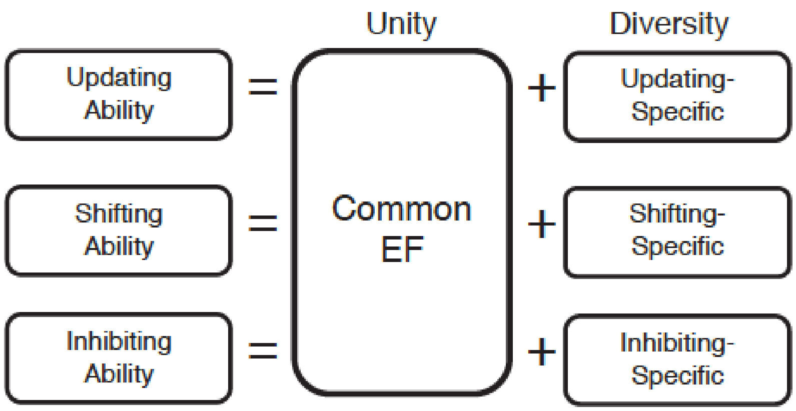
5-Class Model and model with best model fit statistics

Appendix A
Figure of Neurocognitive Skills and Associated Temperaments, Personalities, and Goal-Directed Behavior

(Zelazo, Blair, & Willoughby, 2016, p. 4)

Appendix B

Model of Unity and Diversity



(Friedman, Miyake, Robinson, & Hewitt, 2011, p. 1412)

Appendix C

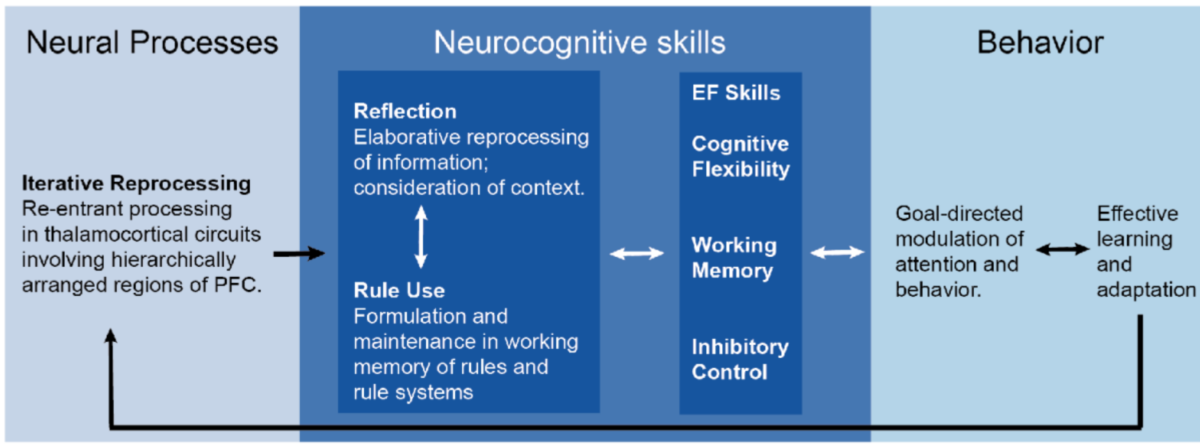
Goldstein and Naglieri Model

Behaviors that reflect EF	Social-Emotional Competence reflects EF	Academic/Work reflects EF
Brain Based Ability reflects EF		

(Goldstein & Naglieri, 2013)

Appendix D

Iterative Reprocessing Model



(Zelazo, Blair, & Willoughby, 2016, p.6)

Biographical Statement

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EDUCATION

- Doctor of Psychology
  Alfred University; Alfred, N.Y May 2021
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