THE DEVELOPMENT OF BEHAVIORAL SELF-REGULATION ACROSS PRESCHOOL AND ITS ASSOCIATION WITH ACADEMIC ACHIEVEMENT

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ABSTRACT

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A fundamental accomplishment of early childhood is the development of self-regulation. Specifically, the advances children make in self-regulation during preschool (ages 3-5 years) are of interest as it appears that this is when children typically progress to more advanced, cognitive behavioral forms of self-regulation (e.g., Diamond, 2002). Likewise, past research suggests wide variation in the level of self-regulation skills children manifest during preschool (e.g., McClelland et al., 2007). However, despite mounting evidence that preschool is an important time period for the development of self-regulation, little longitudinal work has been done investigating the developmental dynamics of self-regulation across more than two time points during preschool, particularly work that has evaluated possible heterogeneity in the trajectories of self-regulation across children. In this dissertation, I examined the development of behavioral self-regulation across preschool via latent growth curve modeling. I also evaluated possible heterogeneity in the developmental trajectories of children's behavioral self-regulation via growth mixture modeling. I then investigated the relationship between children's behavioral self-regulation trajectories and academic achievement at the end of preschool.

Behavioral self-regulation and academic achievement were assessed for 652 preschool aged children across four years of study. Depending on the year, children were tested in the fall and spring (2 time-points) or across four time-points with the Head-Toes-Knees-Shoulders behavioral self-regulation task (Ponitz et al., 2008). Children were also tested on three literacy measures assessing phonological awareness, letter knowledge and early decoding skills, and an early math measure. Results suggested that the development of behavioral self-regulation across preschool is best represented by an exponential growth curve, and that there is variation in trajectories across children. Specifically, a three class model best represented the data with majority of children making exponential gains that either 1) began with lower initial levels of behavioral self-regulation and gains that accelerated across the preschool time period, or 2) began with higher levels of initial behavioral self-regulation with rapid gains early that decelerated across preschool. A third group of children demonstrated a no growth trajectory with low levels of initial behavioral self-regulation and little to no gains across the preschool time period. Results from the latent growth curve analysis suggested that the rate of gain across the preschool time period was associated with higher levels of early literacy and mathematics achievement at the end of preschool. Likewise, findings from the growth mixture analysis suggested that children who began preschool with higher levels of behavioral self-regulation and grew rapidly early following a decelerating exponential trajectory had higher levels of spring early literacy and mathematics achievement compared to children who began with lower levels of behavioral self-regulation and gained at an accelerating rate across preschool. However, any gains made by children in behavioral self-regulation, whether accelerating or decelerating were associated with higher levels of spring early literacy and mathematics achievement compared to children who made little to no behavioral self-regulation gains. Overall these findings indicate the importance of evaluating self-regulation skills early and providing support to children, particular children who may be at risk to make few gains across preschool in self-regulation as self-regulation is an important aspect of the skills children need in order to be prepared for kindergarten.

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CHAPTER 1: INTRODUCTION

A fundamental accomplishment of early childhood is the development of effective self-regulation. Changes from rudimentary types of early reflexive and reactive regulation in infancy to burgeoning attempts at volitional and proactive control in toddlerhood to reflective self-regulation during preschool that requires conscious planning processes, represent important shifts in child functioning across the first five years of life (Blair, 2002; Bronson, 2000; Kopp, 1982; Ochsner & Gross, 2005). Specifically, the advances children make in self-regulation during preschool (ages 3-5 years) are of particular interest as this time period appears to be when children typically progress to more advanced, volitional forms of self-regulation (Diamond, 2002; Kopp, 1982) that likely require the integration of many skills such as attention, working memory and inhibition (Calkins, 2007; Diamond, 2002; McClelland & Cameron, 2012). For instance, children must utilize their attentional skills to pay attention to instructions given to them, their working memory skills to remember those instructions throughout a task, and their inhibition skills to ignore appealing alternative responses (McClelland et al., 2007). Thus all three skills are necessary to manifest regulated behavior and complete tasks. This seems to be particularly salient when children are asked to maintain two related pieces of information in mind (e.g., dimensions during task switching, Diamond, 2002). Likewise, past cross-sectional research has demonstrated that there is wide variation in the level of self-regulation children manifest during preschool (McClelland & Wanless, 2012; McClelland et al., 2007) and that this variation is consistently linked to school readiness, later school success, and appears to be an important early life marker for long term outcomes across many domains (Howse, Calkins, Anastopoulos, Keane, & Shelton, 2003; McClelland, Acock, Piccinin, Rhea, & Stallings, 2013; McClelland et al., 2007; Mischel et al., 2011; Moffitt et al., 2011).

However, despite mounting evidence that preschool is an important time period for the development of self-regulation, little longitudinal work has been done investigating the developmental dynamics of self-regulation during this time period, particularly work that has evaluated heterogeneity in trajectories of self-regulation across preschool and their relation to important outcomes such as early academic achievement. This is surprising given recommendations that to truly understand and to support the development of complex skills such as self-regulation, it may be necessary to identify whether there are meaningful individual differences between individual's developmental trajectories (Bergman, Magnusson, & Khouri, 2002; Muthén & Muthén, 2000; Nagin, 1999). In the case of the development of self-regulation, we may particularly expect a wide level of variation in children's preschool growth trajectories given that, theoretically, reflective self-regulation is thought to require the coordination and processing of multiple skills across several domains (Calkins, 2007), and that there are individual differences related to when the integration of these skills begin to manifest as well as differences in the patterns of how they are manifest as regulated behavior (Blair & Raver, 2012; Blair, 2010; Calkins, 2007). Importantly, the few studies that have evaluated the development of self-regulation across preschool not only suggest individual differences in these skills, but that this variation is linked with the development of early academic skills (McClelland et al., 2007). However, these past studies have only focused on growth in self-regulation across two time points (fall and spring), thus severely constraining the forms of growth, limiting the evaluation of heterogeneity in these growth trajectories (Rogosa, 1988), and how these differences are linked to early academic achievement. Put another way it is not clear what, in general, is the broad trajectory for the development of self-regulation across preschool, what is the nature of heterogeneity within this development resulting in multiple trajectories, and how these different trajectories, in turn, are associated with and predict key differences in the development of early academic achievement skills.

Thus, the aims of this dissertation were twofold: First, I examined the developmental dynamics of self-regulation across preschool, including possible heterogeneity in the developmental trajectories of children's early self-regulation skills. I then investigated the relationship between children's self-regulation trajectories across preschool and children's early academic skills at the end of preschool. Particular attention was given to whether heterogeneity in children's self-regulation trajectories across preschool differentially predicted early academic achievement skills.

Defining of Self-regulation

Self-regulation has been variably named and defined with much debate about what should be considered self-regulation. This, in part, is due to the fact that regulation of behavior is relevant to many researchers across multiple perspectives including personality/temperamental (effortful control; Aksan & Kochanska, 2004), cognitive (executive function; Zelazo & Müller, 2002) and educational traditions (McClelland et al., 2007). An additional element of the broadness in defining self-regulation is related to the way in which it changes over time. Self-regulated behavior has one of the longest developmental periods due to its dependence on the prefrontal cortex (which does not fully develop until about age 20; Beauregard, 2004; Diamond, 2002; Fjell et al., 2012). Throughout this elongated development, the skills that support the ability to flexibly plan and modulate behavior increase markedly with multiple skills integrated at multiple levels of functioning in order to produce a behavior. This is further compounded by the fact that as many of these skills are acquired they require conscious processing (and are thus considered by many in a regulatory framework). However, as these skills become more automatic, they often are no longer considered under the umbrella of self-regulation (e.g., Baddeley, 1986), yet possibly they may still support the continued development and manifestation of self-regulation (e.g., Chasiotis, Kiessling, Winter, & Hofer, 2006). Consequently this makes it difficult to provide a narrow definition of self-regulation with a clear delineation of what components and skills are coming together at a given time to produce regulated behavior.

That said, it is generally agreed upon across fields that self-regulation is a multiple component construct (Blair & Raver, 2012; McClelland, Cameron Ponitz, Messersmith, & Tominey, 2010; Schunk & Zimmerman, 1997; Vohs & Baumeister, 2011) operating across multiple levels of function (e.g., physiological, social-emotional, cognitive, behavioral and motivational), that in its broadest sense represents the ability to volitionally plan and, as necessary, modulate one's behavior(s) to an adaptive end (Barkley, 2011; Gross & Thompson, 2007). In order to better clarify and ultimately operationalize self-regulation, in the following sections I will unpack this broader definition piece by piece. I will then discuss the early development of self-regulation, within the context of this framework.

Multiple components across multiple levels of functioning. One way to approach the complexity of self-regulation is to view the physiological, social-emotional, and cognitive aspects of self-regulation that result in behavior as being hierarchically organized and eventually reciprocally integrated (Blair & Raver, 2012; Calkins, 2007), with many changes occurring across development in terms of automatic versus controlled, complexity, and integration. Put a little bit differently, self-regulation appears to depend on an interplay between processes generally considered within cognitive traditions as "top down" or control processes (i.e., executive function), that develop out of basic processes and ultimately play a role in coordinating multiple systems, and “bottom up” physiological and emotional processes, including emotional arousal, the coordination of motor movements, stress-related physiology and basic attending processes (Blair & Raver, 2012).

Bottom up processes. Bottom-up processes are thought to be largely biologically based processes that drive basic sensation, awareness and perception of both the outside world and the internal world (i.e., the system’s physical needs) as well as lay a foundation for increasingly complex processes (Blair & Raver, 2012; Calkins & Marcovitch, 2010; Porges, 1996). Generally, early childhood researchers have emphasized aspects of temperamental reactivity (measured by physiological and emotional arousal such as physical changes in heart rate oscillations associated with parasympathetic arousal), behavioral changes in the intensity of an emotional reaction, and basic attention processes such as alerting and orienting when considering bottom up aspects of self-regulation (Derryberry & Rothbart, 1997; Porges, 1996; Rothbart, Posner, & Kieras, 2006). From this standpoint, basic bottom up processes must be brought under control and functioning properly for higher level functions (i.e., emotional and cognitive control) to function properly in order to exert higher levels of self-regulation (Blair & Raver, 2012; Calkins, 2007). Following from this it is expected that variations linked to bottom up processes both in a trait sense, but also in a state sense (e.g., sensation of hunger) will ultimately affect the manifestation of self-regulated behavior (trait and state). For example, within development, children who exhibit very high levels or very low levels of temperamentally based reactivity, and/or difficulty with attentional orienting when stimulation/overstimulation is presented tend to also struggle with self-regulation (Calkins & Fox, 2002; Calkins & Leerkes, 2011). Likewise, from a state standpoint, individuals with low glucose levels (usually linked to hunger) also struggle with self-regulation (Gailliot & Baumeister, 2007) until this bottom up need is met. In summary this suggests that bottom up or basic processes linked to the control/modulation of the physiological system play a role both within the manifestation of self-regulation, and the development of self-regulation that engages higher order, top down processes.

Top down processes. Within this context top down processes refers specifically to executive function (EF) processes that are linked to prefrontal cortex functioning including working memory, the shifting and focusing of attention, and inhibition that, together, enable planning, future oriented thinking, and temporal understanding (Barkley, 2011; Blair & Raver, 2012; Hongwanishkul, Happaney, Lee, & Zelazo, 2005). Attention refers to the ability to engage with or focus on items, and sustain focus as well as shift focus between objects (Rothbart et al., 2006). Working memory is the ability to process and simultaneously store information as well as keep track of temporal information (Baddeley, 1992; Gathercole, Pickering, Knight, & Stegmann, 2004). Inhibition refers to three related sub-skills: the ability to withhold a pre-potent response in favor of a less dominant, more adaptive response alternative; the ability to stop current behavior in order to evaluate other behavioral courses of actions that may be more adaptive (error detection), and the ability to ignore distracting or interfering information (Barkley, 2011).

EF's have also been categorized through the distinction of "hot EFs" or EF's that help an individual understand, monitor, and control emotions as well as aspects of motivation associated with environments that include affective processing, and "cool EFs" or the EF's that help an individual problem solve, particularly within tasks that are more decontextualized (i.e., testing situations) or abstract in nature (Hongwanishkul et al., 2005). This distinction has been supported within neuro-scientific literature suggesting that EF tasks that require handling affect tend to activate neural circuits through the ventro-medial prefrontal cortex (VMPFC), while EF tasks that require problem solving tend to activate the neural circuits associated with the dorsal-lateral prefrontal cortex (DLPFC; Hongwanishkul et al., 2005). Although, it must be noted that tasks that require top down control (or put another way environments that elicit the utilization of top down control) generally require a combination of both hot and cool EF's, just as they often also require the coordination of several EF skills (attention, working memory, and inhibition) (Manes et al., 2002). Thus it is useful when considering this distinction between hot EF and cool EF to also consider differences as a matter of degree.

Top down control in particularly is thought to be hierarchically organized with greater levels of integration throughout developmental time (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Zelazo, Carlson, & Kesek, 2008). It has long been recognized that skills such as attention and working memory build upon simpler skills (i.e., a child must be able to hold information in mind, before they can mentally process and manipulate it; Baddeley, 1986). Importantly one of the central elements of high levels of top down control is the coordination of multiple skills (Garon et al., 2008; Zelazo et al., 2008), both across levels of function (Rothbart et al., 2006) and within the level of executive function (Espy & Bull, 2005).

Integration across levels. The notion that the ability to self-regulate requires integration across multiple systems is supported both within recent neuro-scientific and behavioral literature (Ayres & Robbins, 2005; Blair & Raver, 2012; Calkins, 2007; Chasiotis et al., 2006). From a neuro-scientific point of view, the neural networks of the PFC are interconnected with posterior cortical and sub-cortical regions, particularly the limbic and brain stem structures (Blair & Raver, 2012; Diamond, 2000). As one example (although others could be considered; see D'Esposito, 2008), we may consider the interconnected neural circuits from PFC to posterior cortical and sub-cortical regions that operate via the anterior cingulate cortex (ACC; Posner &

Rothbart, 2000). Similar to the distinctions made with the prefrontal cortex associated with hot and cool EFs (VMPFC vs. DLPFC respectively), the ACC also appears to have two subdivisions with reciprocal relations (Davis, Bruce, & Gunnar, 2002): one subdivision (associated with cognition) connected to lateral prefrontal, parietal and motor regions, and one subdivision (associated with emotion) connected with the orbital prefrontal cortex, other aspects of the limbic system as well as the peripheral autonomic, visceromotor and endocrine systems (Bush, Luu, & Posner, 2000), thus allowing synergistic communication between these systems. Recent evidence suggests that not only does the PFC affect arousal in the limbic system and many sub cortical structures via excitatory and inhibitory pathways associated with changes in the levels of neurotransmitters (norepinephrine, glutamate, glucocorticoids and dopamine), but also that these systems (through the release of neurotransmitters) affect the pattern of synaptic firing within the prefrontal cortex (Barbas & Zikopoulos, 2007; Ramos & Arnsten, 2007; Robbins & Arnsten, 2009). In particular, very high and very low levels of arousal appear to inhibit synaptic firing within the PFC, with less regulated behavior observed as a result (Blair & Raver, 2012).

Similar results have been found within behavioral studies which may suggest a structure-function relationship, although care must be taken in drawing these conclusions, particularly in a developmental framework (Shonkoff & Phillips, 2000). For example, the now classic Yerkes-Dodson law suggests that performance on complex tasks (that we would expect to engage top down control processes) tends to be optimal at moderate levels of arousal, with poorer performance linked to both low and high levels of arousal suggesting an integrated system (Blair & Raver, 2012). Moreover, there is a growing literature suggesting an interaction between motor development and the development of self-regulation such that difficulties with motor development (or late on-set motor development in the case of crawling and walking), particularly gross motor development, are linked with lower levels of or delays in self-regulation, while motor training is linked with gains in top down control and self-regulation (Chasiotis et al., 2006; Diamond & Lee, 2011; Piek, Dawson, Smith, & Gasson, 2008) suggesting, again a reciprocal relationship across multiple levels of functioning.

Integration within level. As mentioned previously a key aspect of top down processes is the coordination and integration of executive function skills (Best & Miller, 2010; Garon et al., 2008; Zelazo et al., 2008). Within adults, EF theories focus upon the role of a common EF mechanism along with dissociable EF components with the common component essentially coordinating the subcomponents (Baddeley, 2002; Miyake et al., 2000). This appears to also be the case in early childhood (although it must be noted the components appear even less independent during childhood, (Wiebe et al., 2011; Willoughby, Blair, & Greenberg, 2012). From a developmental perspective, attention has been proposed as the common EF component (Posner & Rothbart, 1998) that helps coordinate other EF processes. Critically, for the process of self-regulation, the systems that support attention across multiple levels of function appear to integrate during preschool (Rueda, Posner, & Rothbart, 2005). Likewise, along with this across level integration of attentional abilities after the first three years, it also appears that the process of attention, working memory and inhibition also become more integrated during preschool (Garon et al., 2008). For example, on average children appear to be incapable of accurately responding to tasks that require the integration of several aspects of top down control until during the preschool time period (Diamond, 2002 for review), and notably, this ability to coordinate EF skills is recognized across fields as a hallmark of complex top down control both in children and adults (Best & Miller, 2010).

Volition and self-regulation. Another key aspect that most researchers agree defines self-regulated behavior is that it is a volitional act (Eisenberg & Spinrad, 2004; McClelland et al., 2010) with volition referring to the exertion of conscious effort to reach a goal or complete a task (although see Fitzsimons & Bargh, 2004 for an alternative view). As mentioned previously the role of volitional processes versus automatic processes must be considered carefully when evaluating the development of self-regulation, as many skills require conscious self-regulation as they are first learned and developed. This can most clearly be seen when we consider toddlers as they first learn to coordinate movement. In a study evaluating 13 month olds, Berger (2010) found that children who had just learned to walk (novice walkers) compared to expert crawlers at the same age had more difficulties completing an inhibition task that first required movement over a difficult terrain (stairs). Likewise, novice crawlers compared to expert crawlers also tended to make more errors during the inhibition task (i.e., engage in a pre-potent response) despite the fact that they were the same age as the expert crawlers. In short, because some of the children had not yet mastered the motor movement (or were engaging in a new type of motor movement) necessary to complete this task, they had to consciously self-regulate their movement processes, at the cost of completing the cognitive requirements of the task (Berger, 2010). The motor processes still required top down control to execute, drawing these resources away from the cognitive requirements of the task.

Indeed, it appears that part of the process of integrating skills across levels is shifting from conscious control of a skill (requiring top down processes), to more automatic processing (Grouios, 1992). Related to this point, it must also be considered whether automating certain skills may in fact be a prerequisite, or play a large role in the further development and manifestation of top down skills and, in turn, high levels of self-regulation (Baumeister, Masicampo, & Vohs, 2011; Bushnell & Boudreau, 1993; Chasiotis et al., 2006). For instance, recent research suggests that preschoolers with sensory integration deficits, particular motor control deficits struggle with self-regulation (Chasiotis et al., 2006). Importantly these children performed significantly worse than their typically developing peers on a self-regulation task that did not require any motor movement to respond, suggesting at the very least motor control contributes to the development of self-regulation, and may, in fact be in part, a pre-requisite. In summary, conceptualizations of self-regulation (particularly from a developmental perspective) must not only consider the multiple levels of functioning required for the manifestation of self-regulated behavior, but also the effect of different levels of processing (volitional versus automatic) upon individual differences within this manifestation.

Self-regulation in context. Finally, because by definition self-regulation includes adapting behavior to meet a specific end, it is necessarily contextual bound (Barkley, 2011). Specifically, one could consider that the overarching purpose of self-regulation is navigating the environment, particularly the social environment that is thought to be critically linked to the development and manifestation of self-regulation (Calkins & Leerkes, 2011; Kopp, 1982; Sameroff, 2010). Within a developmental framework the role of context is often evaluated in terms of how parents and environments such as home and classroom environments help children develop and manifest self-regulation (Baker, Cameron, Rimm-Kaufman, & Grissmer, 2012; Calkins & Leerkes, 2011; Grolnick & Farkas, 2002; Rimm-Kaufman, La Paro, Downer, & Pianta, 2005). Indeed, dozens of both behavioral and neuro-scientific studies have demonstrated the key role of experiences (particularly social experiences) in developing both the neural circuits that support self-regulation and the manifestations of the behaviors themselves across multiple contexts (Baker et al., 2012; Bronson, 2000; Calkins & Leerkes, 2011; Diamond & Lee, 2011; Diamond, 2002; Grolnick & Farkas, 2002; Gross & Thompson, 2007; Sameroff, 2010; Zelazo et al., 2008).

In particular, two main factors appear critical for children to succeed at manifesting high levels of self-regulation. First, children require the influence of caregivers, and eventually peers, who support self-regulatory behavior through many interactions that both model and reinforce high levels of self-regulation for the child across development (Bronson, 2000; Grolnick & Farkas, 2002; Gross & Thompson, 2007; Kopp, 1982; Sameroff, 2010; Vygotsky, 1977). For instance, parental support of different self-regulation strategies (via both parent modeling of multiple strategies embedded within interactions with their child, and direct instruction) is linked with better self-regulation during toddlerhood and preschool, as well as a larger repertoire of top down control regulation strategies exhibited by the children themselves (Eisenberg et al., 1993; Gilliom, Shaw, Beck, Schonberg, & Lukon, 2002; Stansbury & Sigman, 2000). Likewise, it is critical within these interactions that children also have an opportunity to practice self-regulation (Grolnick & Farkas, 2002; Grolnick, 2003). For example, mothers who consistently take responsibility for regulating their children's distress beyond what is called for by the child's distress levels, without allowing the child an opportunity to practice a regulated response appear to undermine children's developing self-regulation (Grolnick, Kurowski, McMenamy, Rivkin, & Bridges, 1998). Specifically, in situations where children had to exhibit self-regulation when mother was not present, these children demonstrated lower levels of self-regulation than children whose mothers allowed them opportunities within mother-child interactions to practice regulating their own behavior. Thus, the development of self-regulation via interpersonal interactions requires both the modeling of self-regulated behavior and self-regulation reinforcement (via positive responsiveness and opportunities to practice).

Additionally environments (such as classrooms and homes) that are structured in such a way as to help children focus on developing and practicing higher order, top down skills also contribute to the development of self-regulation (Bradley & Corwyn, 2002; Evans & English, 2002; Evans, Shaw, & Bell, 2000; Rimm-Kaufman, Curby, Grimm, Nathanson, & Brock, 2009; Rimm-Kaufman et al., 2005). This includes aspects of the physical environment (Baker et al., 2012), particularly items such as noise level, chaos, crowding, and availability of instructional materials (Bradley & Corwyn, 2002; Evans et al., 2000). Importantly, it is clear that these physical aspects interact with the above mentioned support given by caregivers (both parents and teachers; Evans & English, 2002). For example within the home, both parental support, and aspects of the physical environment such as how many books are present predict children's self-regulation at school (Baker et al., 2012).

Self-regulation in the classroom. The ability to regulate one's own behavior becomes increasingly important as children enter primary school where they are consistently exposed to peers and a structured setting that requires the exhibition of self-regulation on a regular basis (Phillips, McCartney, & Sussman, 2006). In particular, because of recent shifts in school's focus on enhancement of academic skills (Kagan, Kauerz, & Tarrant, 2007; Stipek, 2011), especially during the early years of education, the ability to regulate behavior is key as it often drives classroom adaptive behaviors such as task persistence, the ability to stay focused, the ability to attend to learning goals and teacher instruction, as well as participate with peers within the classroom; all of which are linked to academic achievement gains (Howse et al., 2003; McClelland, Acock, & Morrison, 2006; McClelland, Morrison, & Holmes, 2000; Rimm-Kaufman et al., 2009). Accordingly, within educational traditions self-regulation is generally conceptualized and focused upon in terms of its role in successful classroom functioning

(McClelland & Cameron, 2012). Effective classroom self-regulation often takes the form of overt behaviors such as taking turns in play, remembering directions, raising one's hands, and persisting on a task with this success relying, in part, on the child's ability to integrate multiple skills. Consequently self-regulation in this context is operationalized as the integration of top down control processes such as attention, working memory, and inhibition into the appropriate overt behavioral response, with this behavioral response often requiring the coordination of other processes such as motor processes (Barkley, 2011; Calkins, 2007; McClelland et al., 2007). Due to the fact that this type of regulation requires not only what have been traditionally considered cognitive skills, but also an overt motor response, this type of regulation has been termed "behavioral self-regulation" (Cameron Ponitz et al., 2008; McClelland et al., 2007). Within the current dissertation, I focus on and operationalize self-regulation as behavioral self-regulation as it appears that preschool represents a sensitive time period for the development of behavioral self-regulation when children are just beginning to integrate the multiple skills needed to produce regulated behavior, particularly executive function (top down control) skills (Diamond, 2002; Garon et al., 2008). Additionally, and importantly, the development of behavioral self-regulation during preschool is consistently linked to concurrent and later academic achievement across the life span suggesting that behavioral self-regulation in preschool is a salient early marker of academic achievement (McClelland et al., 2007; Mischel et al., 2011). Thus it is critical to understand how it develops and unfolds during this time period, and how individual differences in this development are then linked to early academic achievement outcomes. However, in order to focus in on the development of behavioral self-regulation in preschool and its links to early academic achievement, we must first consider broadly what the development of self-regulation looks like.

The Development of Behavioral Self-regulation

Throughout the following sections, I will outline the development of self-regulation across the first five years, with a particular emphasis given to theory and research evaluating self-regulation in preschool (ages 3-5 years). Specifically, I will focus on the development of the top down control processes (attention, working memory and inhibition) required for the modulation of behavioral responses via self-regulation (i.e., the development of behavioral self-regulation). I will also explore individual differences within the manifestation of self-regulation throughout development with the ultimate goal of clearly describing the expected general trajectory of self-regulation in preschool, and why variation in this trajectory across children is expected. I will then focus on the link between the development of self-regulation and emergent academic achievement.

Development during infancy and the toddler years. One key aspect of self-regulation that manifests early in development is attention (Posner & Rothbart, 1998). Researchers Rothbart and Posner (2006) have proposed that the development of attention, as supported by integration of functioning across three related attentional systems during the first five years is key in the development of self-regulation as attention is a driving force in organizing incoming information from the environment as the child moves from passive-reactive regulation to volitional self-regulation. The first efforts at attentional regulation are rooted in early alerting behavior, that is, the heightened awareness to sensory input during the first three months of life, as well as the regulation of sleep-wake cycles (Derryberry & Rothbart, 1997).

Between the ages of 3-6 months research suggests that the ability to voluntarily orient or select information to attend to a sensory input (along with increases in the regulation of simple motor development) develops and acts as an emotional state regulator (particularly in the context of distress; see Rueda et al., 2005). The emergence of this type of attention is linked with the ability to flexibly engage and disengage attention as well as the ability to focus in on details or focus out in a gestalt manner (Posner & Rothbart, 1992). Along with the support provided by caregivers, the attentional orienting system also supports increases in the number of strategies infants engage in to regulate behaviors, (Harman, Rothbart, & Posner, 1997). In particular, between 3-13 months, passive regulatory actions (e.g., avoiding through disengaging attention and looking away) and self-soothing tend to decrease, while more active strategies such as engaging with the environment, and using physical body movement (kicking and arm movements) to regulate increase. Patterns of regulation also emerge during this time period with types of regulation becoming more habitual within the child, and subsequently individual differences across children in these patterns of how the infants utilize attention to soothe distress also emerge (Rothbart et al., 2006). For instance, around three-four months of age, individual variation in infants' abilities to disengage when over-stimulated manifest, with infants who struggle to disengage generally persisting across the first year of life in utilizing simpler forms of regulation such as self-soothing as well as, on average, demonstrating more negative affect at 13 months compared to their peers who are more able to disengage attention early in development (Rothbart, Ziaie, & O'Boyle, 1992).

The third attentional system, which matures and develops during toddlerhood (14 – 36 months), as well as throughout preschool, is the anterior attentional system, also called the executive attention system. Executive attention is viewed as the system that evaluates (top down) and regulates incoming sensory information, and ultimately plays a role in directing action (Rothbart, Derryberry, & Posner, 1994). In particular it is linked to resolving conflict between feelings, thoughts and responses such as when a child (or adult) must withhold an emotional response elicited by the environment (Posner & Fan, 2004). Posner & Rothbart (1998) suggest that the executive attention system, along with the other two attentional systems that eventually become integrated, underlie effortful control, with integration across systems being critical for subsequent self-regulation.

Effortful control has been broadly defined as the "ability to suppress a dominant response to perform a subdominant response" (Kochanska & Knaack, 2003, p. 1087). This definition fits very closely with cognitive conceptions of inhibitory control (Barkley, 2011), which also develops markedly across infancy and toddlerhood and plays a critical role in suppressing and delaying behavior (Kochanska, Murray, & Harlan, 2000). Similar to the development of attention, inhibitory control manifests during the first year of life with infants able to inhibit a dominant motor response in favor of a less dominant gross motor response (Diamond, 2002). For instance, by about one year of age, most infants can complete the 'A not B' task where they must reach to a new location to find a reward versus an old location they had been trained to reach to previously (Diamond, 1991). Likewise, the period of delay between seeing a reward being hidden and correctly reaching for it also increases during the latter half of infancy (Diamond & Doar, 1989).

Inhibitory control increases across toddlerhood with increases in the ability to withhold a response, delay longer, as well as correct errors; and is considered foundational to the further development of executive function and behavioral self-regulation (Barkley, 2011; Diamond, et al., 1997; Garon et al, 2008). Specifically, Barkley (2011) suggests that the development of inhibition is a prerequisite of self-regulatory behavior as one cannot volitionally redirect actions in order to meet a more adaptive end if one has already acted impulsively. Put another way, as children in toddlerhood develop their sense of self as independent and capable of exerting some control over the environment, they are no longer subject only to emotional states that must be moved in and out of. Rather, toddlers can actively approach or shy away from the environment, as well as inhibit responses that do not necessarily lead to desired goal/ outcomes that are in line with the environment (Rothbart et al., 2006). In this sense, inhibitory control is considered as central to the integration of early temperamental factors related to emotionality and attention in infancy and later emotion and behavioral self-regulation in preschool (Kochanska, et al., 2000), with individual differences in the amount of inhibition required to regulate behavior (Rothbart et al., 2001). For instance, children who exhibit a fearful emotional response within a novel context during toddlerhood are more likely to demonstrate more inhibition in reaching out to touch a novel toy and are more likely to delay behavior in preschool (Aksan & Kochanska, 2004).

Particularly important to the exhibition of self-regulation, both attention and inhibitory control processes contribute to the ability to resolve response conflict of some sort or another (Diamond, 2002; Zelazo, et al., 2003). For example, although often measured in laboratory settings via tasks such as modified Stroop tasks or delay of gratification paradigms (Rothbart et al., 2006; Rueda et al., 2005), within children's usual environments the attentional and inhibitory processes that resolve conflict are thought to be linked to activity such as compliance (e.g., pulling one's hand back from a hot stove because mother said 'no'; Kochanska, Coy, & Murray, 2001). This ability is linked to whether the conflict in response is reflexive or non-arbitrary, versus based on the representation of an abstract rule, with differences in the developmental course of when tasks can be completed based on the strength of response to be inhibited and the level of representation required (Zelazo et al., 2003). However, in order to apply a rule to resolve conflict, one must first be able to represent that rule in mind.

Although it still unclear what the very early trajectory of working memory is, there is evidence that the ability to remember develops within the first year of life (Pelphrey & Reznick, 2004). Specifically during delayed response tasks where children must hold the location of a hidden object in mind over a short interval of time, most infants near a year of age can complete this task if the delay is short (Diamond, 2002). This ability to hold information in mind over longer periods of time, particularly in service of regulating behavior, continues to increase across toddlerhood with children also able to hold more pieces of information in mind at once (Garon et al., 2008). Likewise, the ability to manipulate or actively process information within the mind also unfolds during toddlerhood. For example, during a simple displacement task, toddlers can both mentally track and successfully locate a toy that is hidden first in a small container, and then (in front of the child, but hidden from view) displaced to one of two larger containers (Corrigan, 1981). In order to keep track of the toy, the child must hold a representation of the item in mind and mentally manipulate the movement of the toy from the small container to one of the large containers.

However, although each of these top down control skills develop markedly during the first three years of life (Diamond, 2002), and appear to be interconnected (Wiebe et al., 2011; Willoughby et al., 2012) children younger than three appear to have difficulty coordinating all of these skills at once into a behavioral response (Carlson, Moses, & Breton, 2002; Diamond, 2002; Zelazo et al., 2003). Likely this is linked to two aspects of development. First during infancy and toddlerhood, children are still *consciously engaged* in basic processes such as motor movement, emotion processing, and early language/representational processes foundational to the manifestation of regulated behavior. Critically much of this conscious learning/engagement requires developing attentional resources (Berger, 2010; Bushnell & Boudreau, 1993; Calkins, 2007). Due to biological system constraints linked with maturation the resources required to navigate these learning tasks are limited (Best, & Miller, 2010; Posner & Rothbart, 1998). Thus, it is particularly important to recognize that during development, attentional resources are not as available for top down control because motor and emotional aspects of a task utilize some of those resources (Bushnell & Boudreau, 1993; Kuhl & Kraska, 1993). Secondly, attention itself is developing during this time (Rothbart et al., 2006). Recalling the theory that attention appears to be both a component of top down control (EFs) as well as the organizer of other components of EF (Garon, et al, 2008; Posner & Rothbart, 1998), both the ability to orient and sustain attention, as well as the ability to shift attention via top down control are still developing. Notably during toddlerhood these processes are negatively related to each other (Rueda, et al., 2005). This negative relationship between two aspects of attention (aspects that are likely to some degree manifestations of activation in different brain structures) is taken as evidence that those processes have not fully functionally or structurally integrated yet (Rueda et al., 2005). As a result of both the limits of attentional resources linked both to development and maturation of the attentional system itself, and to the development of basic motor and emotional processes that still require a high level of conscious attentional control, it is difficult for children to perform complex tasks that additionally require the coordination of other top down skills such as working memory and inhibition (Garon et al, 2008).

However, children are capable of completing simpler regulatory tasks that do not require as complex of integration of skills (Calkins, 2007; Kopp, 1982). Support of this idea comes from research evaluating children’s ability to comply, a precursor of self-regulation (i.e., modifying one’s behavior to accommodate a request from the environment) during toddlerhood. Specifically, children were able to comply a larger percentage of the time in contexts where they must inhibit a behavior (i.e., don’t touch the toys), termed the “don’t” context versus sustain a less desirable behavior (i.e., clean up toys when the caregiver indicates play time is over) termed the “do” context (Kochanska et al., 2001). Likely these contextual differences in the child’s ability to comply are linked not only to ecological aspects of the tasks (i.e., parents tend to prohibit behaviors more than they enforce behaviors early in development, (Gralinski & Kopp, 1993), but also to the fact that children must execute and coordinate multiple skills (Thelen, Ulrich, & Wolff, 1991) across multiple levels of functioning in the do context. For instance, children must engage many motor processes (walking, reaching, bending) that arguably still take conscious control during toddlerhood, but they also must process and modulate their emotions (e.g., avoiding tantrums because the child still wishes to play with the toys versus pick them up) which likely also requires both attentional and inhibitory aspects of top down control, as well as deploy top down control in order to persist at the task. Versus in the don’t context fewer skills, in general, appear to be necessary. For instance, an initial disengaging of attention from the toy by focusing on a distraction may be all that is needed, although individual differences in temperament and caregiver support were also linked to children’s success in both contexts and possibly to what, and how many processes children needed to draw upon to produce a regulated response.

However, despite difficulties in the do context, the ability to regulate increased in both the do and don’t contexts across developmental time (Kochanska et al, 2001). Importantly, within the don’t context, gains were rapid during toddlerhood and leveled off as children reached about age three years, while in the do context gains were more modest overall, but the rate of gains were more rapid beginning as about age three. Put another way, children quickly reached high levels of self-regulation (complying about 80% of the time) within the easier don’t self-regulatory context that required fewer skills than the do context, with more rapid gains in the do context occurring later in development and proximally during the preschool time period.

In summary, children make remarkable gains in top down control systems that support self-regulation during the first three years of life. However, although these systems are related to each other and develop in concert, it is not until about the age of three, or when most children begin preschool, that children typically appear to be able to integrate all three top down control skills together at the same time to produce a behavior (Carlson et al, 2002; Diamond, 2002; Garon et al., 2008), with both the development of top down control and the coordination of multiple skills linked to individual differences.

Individual differences in early self-regulation. It is clear from infancy that some children are more likely to become over-stimulated and express negative emotions than others and thus must work to decrease stimulation, while other children appear to seek stimulation (Calkins, Dedmon, Gill, Lomax, & Johnson, 2002; Calkins, 1994). Likewise, within the first few years children demonstrate differences in the level of temperamental fearfulness and, in turn, the inhibition of behavior based on this fearfulness that ultimately affects how they later exhibit regulated behavior (Aksan & Kochanska, 2004). Thus, linked to these temperamental differences, children differ greatly in the amount of top down processing needed to modulate their behavioral responses (i.e., to overcome their habitual response patterns), and ultimately the type of strategies they adopt in order to self-regulate behavior (Calkins, 2007).

Likewise, individual differences in other physiological systems (likely in concert with the developmental environment) such as systems linked to sleep-wake cycles also are expected to play role in the differences in the development of self-regulation (Feldman, Weller, Sirota, & Eidelman, 2002). For instance, longitudinal studies of children's sleep patterns around one year of age (including total quantity of sleep and how much sleep occurred at night) found that higher quantities of sleep (particularly night sleep) were associated with higher levels of top down control in preschool even after controlling for parent's socio-economic status (SES) and prior cognitive ability (Bernier, Beauchamp, Bouvette-Turcot, Carlson, & Carrier, 2013), suggesting that basic physiological processes play a role across developmental time, (and concurrently, see Bub, Buckhalt, & El-Sheikh, 2011 for review of concurrent effects of sleep on top down control). Together these studies support the idea that individual differences in bottom up processes, starting very early in development, affect top down control and lead to individual difference in the manifestations of self-regulated behavior.

Importantly, these early individual differences across children suggest possible variations in the overall developmental trajectories of self-regulated behavior as well (Calkins, 2007). For instance, studies evaluating the role of language as a tool to help children regulate emotion suggest that trajectories of self-regulation vary between children based on the child's observed vocabulary skills (Vallotton & Ayoub, 2011). Thus, given the role that multiple levels of functioning and multiple skills play in the development of self-regulation, it is reasonable to expect a wide range of individual differences in the trajectories of self-regulation across development; this may become particularly salient during the developmental time period when many of these processes become integrated in order to produce regulated behavior (Blair & Raver, 2012; Calkins, 2007; Diamond, 2002; Kuhl & Kraska, 1993); in other words during preschool.

Development during preschool. Preschool self-regulation has received a great deal of attention as these years are consistently linked to the rapid development of self-regulation (Diamond, 2002; Garon et al, 2008; Zelazo et al., 2003), and because self-regulation in preschool is a key aspect of concurrent and later academic achievement throughout childhood and into adulthood (e.g., Blair & Razza, 2007; Duncan et al., 2007; McClelland & Wanless, 2012; McClelland et al., 2007, 2013). Despite this, as stated earlier, little longitudinal work has been done evaluating the development of self-regulation during this time period (Cameron Ponitz et al., 2008; McClelland et al., 2007; Tominey & McClelland, 2011). Thus, most of what we currently know as a field about the development of self-regulation in preschool (beyond that children gain in the ability to regulate and that there are individual differences in these gains; McClelland et al., 2007) is based on both what we know about the development of the specific top down processes that support self-regulation and what we know by comparing performance on a multitude of self-regulation tasks (that require the integration of top down and bottom up processes) across children at different ages (e.g., Best & Miller, 2010; Diamond 2002; Garon et al., 2008; Rothbart et al., 2006).

Developmental trajectories of top down processes. What is critical about the development of the top down control processes that ultimately support behavioral self-regulation is that many of them converge upon the ages of 3-5 years as a time of rapid development (Best & Miller, 2010; Garon et al., 2008; Zelazo et al., 2008). These changes appear to result in gains both in the individual top down processes, which I focus on next, and in the capacity to coordinate processes that ultimately support children's ability to regulate their behavior in a multitude of contexts.

Attention. As suggested early, the development of attention appears to be particular key to the development of self-regulation as executive attention may act as a central organizer of information linked both to bottom up processes and to the other top down processes (Fan & Posner, 2004). Rueda et al., (2005) theorize that the early childhood years (beginning in preschool) represent an important developmental time period when executive attention becomes more integrated with the other attentional systems. Once this occurs, attention processes (i.e., focusing attention, and shifting) become positively linked (both also become linked to inhibition whereas only focusing is linked earlier in development), and children begin to resemble adults in terms of attentional capacity and accuracy on tasks that require top down control. For example, during a modified flanker task children must feed a computerized fish on the center of the screen by attending to what direction the fish is pointing and pressing a corresponding button on the key board, while ignoring distracting fish (Fan & Posner, 2004). This requires both attentional focusing and shifting. Children rapidly improve in their ability to correctly respond between the ages of four and seven whereas after age seven, accuracy is similar to adults, but children still make gains in efficiency (Rueda, et al., 2005).

Working memory. Working memory also appears to develop rapidly during preschool, although there is a great deal a variation linked to what is to be recalled (e.g., words versus numbers versus objects; see Garon et al., 2008). Evidence of this trajectory comes from work done by Adele Diamond and colleagues (1997) evaluating children between the ages of three and half and age seven on multiple working memory tasks. Findings from two memory tasks (with arguably fewer processing components) indicate that children make rapid gains between ages three and half and seven in their ability to accurately recall information. For example in a recognition task where children are shown a sequence (varying in length) of individual pictures followed by two pictures displayed at once and asked which picture they have seen before, children between ages three and a half and four and a half increase significantly in the ability to accurately identify the previously seen pictures, with most children reaching and maintaining 85% accuracy by age five and a half. Similarly, in a task where children must open six stationary boxes without re-opening a previously opened box, children tend decrease in the number of reaches required to open all six boxes between the ages of three and a half and four and a half. Likewise they tend to gain in the number of unique boxes opened before an error (i.e., at three and a half years of age children tend to open three boxes before repeating a box, while at four and a half years of age they open four boxes before repeating). This error rate tends to remain similar through age seven.

Inhibition. Similarly, children's ability to utilize inhibition, particularly to inhibit a dominant response, in favor of a sub-dominant response, rapidly increases during preschool. This can be seen in terms of rapid performance gains on a battery of tasks developed by Grayzna Kochanska and colleagues (1996) measuring children's ability to stand still for long periods of time, walk slowly, whisper, and take turns. Evidence also comes from tasks such as the Day/Night task and Luria's tapping task (Diamond & Taylor, 1996; Gerstadt, Hong, & Diamond, 1994). For example, within a modified version of Luria's tapping task, children must tap a wooden dowel once when an experimenter taps twice, or tap twice when the experimenter taps once (Diamond & Taylor, 1996). Between the ages of three and a half and age five, there were large gains in the number of trials children responded accurately on (e.g., about a 25% increase in accuracy), with more rapid gains between ages three and half and age four.

However, it must be noted that most researchers consider complex tasks such Luria's tapping task and the Day/Night task to require not just inhibition, but also the coordination of the other top down control processes including executive attention, and, particularly, working memory (Best, & Miller, 2010; Garon et al., 2008). These tasks will be discussed further in the next section, but notably, the difficulty of creating "pure" measures of inhibition that children are not at ceiling on may possibly indicate the interconnected nature of these processes. Indeed, during preschool, research suggests top down control skills consistently load on one factor suggesting that these skills are developing together (Wiebe et al., 2011; Willoughby,et al., 2012). Consistent with the evidence from studies evaluating the separate trajectories of these processes, when considered together, both longitudinally as a factor (Willoughby et al., 2012), and within tasks that require the integration of attention, working memory and inhibition, there is a rapid increase in these skills between ages three and five.

Cross-sectional performance on self-regulation tasks. Cross sectional work with a multitude of tasks such as the Head-Toes-Knees-Shoulders (HTKS), Day/Night task, Luria's tapping task and the Dimensional Change Card Sort (DCCS) indicate that between the ages of three and five there is a rapid increase or "leap" in performance on tasks that clearly require the integration of several skills into behavior (Diamond, 2002; Gerstadt et al., 1994; Rothbart et al., 2006; Zelazo et al., 2003), or put another way, in behavioral self-regulation. For instance, on the Day and Night task which requires children to hold two related rules in mind (say 'day' if a picture with the moon is presented; say 'night' if a picture with the sun is presented), and inhibit the pre-potent response to respond with what the card is actually displaying, children appear incapable of completing this task before age three. However, by age four children are able to complete the task at about 80% accuracy across trials. This pattern is similar across other tasks as well, despite the fact that all draw on a different array of behavioral responses (Calkins, 2007; Cameron Ponitz et al., 2008; Diamond, 2001; 2002; Diamond et al, 1997; Rueda et al., 2005).

In further support of the integration hypothesis, studies utilizing modified versions of self-regulation tasks that require fewer processes are more manageable for younger children, particular three year olds. For example, if the Day/Night task is altered so that the cards do not match the concepts of day and night (i.e., children say 'day' if they see a picture of a pig and ‘night’ if they see a picture of a dog), even children younger than three had little trouble remembering the instructions, attending to what is on the card, and executing the verbal response (Diamond, 2002). It is only when the inhibition piece is added on top of the attentional, working memory and verbal execution requirements do younger children struggle.

Likewise, much work evaluating differences between three, four and five year old children’s performance has been done with the DCCS task (Zelazo, et al., 2003). During this task children sort cards based on two dimensions: color and shape. They first sort on one dimension, and then are asked to switch to sorting based on the other dimension which requires attention to focus on the directions, as well as on what dimension is relevant, working memory to remember instructions, and inhibition to overcome both the urge to place all the cards together and to switch by inhibiting the old dimension in favor if the new dimension. With this task, children as young as two and half can remember the instructions, but cannot sort (i.e., they place all the cards in one pile; Zelazo & Reznick, 1991). By age three they can sort the cards based on one dimension, but cannot switch dimensions, whereas by age four most children are successful at switching dimensions (Zelazo et al., 2003). Here again we see increases in the number of skills children must use across the DCCS task variations in order to successfully complete the task and a rapid increase between ages two and half and four in their ability to utilize multiple top down skills in conjunction with the ability to execute the correct gross motor response. Based on these comparisons, the ability to regulate behavior appears to qualitatively shift during preschool (Best & Miller, 2010; Garon et al., 2008; Rothbart et al., 2006).

Finally, in the only study to evaluate behavioral self-regulation longitudinally across preschool and kindergarten, results suggest non-linear growth with rapid gains followed by a decelerated rate of gains in performance on the HTKS task (Cameron Ponitz et al., 2008). In this task, children are asked to do the opposite of what they are told. For example, if the researcher says “touch your head,” the child is supposed to touch his/her toes. Thus attention is required to track what the researcher instructs, working memory to recall the rules, and inhibition to withhold the dominant response to do the action the researcher said, and complete the opposite gross motor action. Notably, within this study, when self-regulation scores were graphed by age, there was support of a sigmoidal s-shaped trajectory, although this possibility was not considered within the analyses. Overall, these studies provide evidence of rapid gains in the ability to regulate behavior that are likely conceptual in nature (Best & Miller, 2010). Increasingly researchers suggest that this leap is linked to the integration of multiple processes, but particularly top down control processes to produce regulated behavior (Cameron Ponitz et al., 2008; Diamond, 2002; McClelland et al., 2007; McClelland & Cameron, 2012; Rothbart, et al., 2006; Rueda, et al., 2005).

Expected general trajectory of self-regulation across preschool. Both theory and research suggest that trajectory for the development of self-regulation in preschool is likely best represented by a modified logistic function, specifically an s-shaped sigmoidal trajectory (Diamond, 2002). In particular, it is expected that between the ages of three and five years, gains in self-regulation will increase, rapidly accelerate, and then decelerate (e.g., Cameron Ponitz et al., 2008; Diamond, Prevor, Callender, & Druin, 1997; Rueda et al., 2006). However, it must be noted that there are important limitations to utilizing mostly cross-sectional work, longitudinal work consisting of two time points, and comparisons across individual top down processes to determine the developmental trajectory of behavioral self-regulation.

In regards to cross sectional work, this approach makes it difficult to disentangle within individual differences from between individual differences in development (Davis-Kean et al., 2008). As for longitudinal work that only evaluates two time points: these studies do indicate change and often direction of change, however, it is not possible to determine the exact trajectory of change as only a linear model can be fit even if growth is, in reality, non-linear. It is also difficult to adequately evaluate individual differences given the possibility of non-linearity (Rogosa, 1988). Finally, although evaluating growth in the individual top down control processes that support self-regulation across different tasks does provide insight into what type of growth can be expected, it is not possible to rule out task related effects (given that these processes have been measured with many different tasks both across processes and across developmental time), nor is it possible to determine with precision whether the process of actually integrating skills affects the manifestation of a behavior (i.e., of self-regulation) over developmental time differently compared to the manifestation of one process over time. Thus longitudinal approaches are necessary at this point in order for researchers to more precisely assess and understand the development of behavioral self-regulation. The current study evaluates via structural equation modeling the general developmental trajectory of behavioral self-regulation across multiple observations during the preschool years.

Individual differences in preschool. Past research on self-regulation clearly indicates wide variation in the level of self-regulation children exhibit in preschool, with this variation linked both to previous development and the concurrent development of multiple processes (Blair & Ursache, 2011; Calkins, 2007 Cameron Ponitz, McClelland, & Morrison, 2009; Carlson & Wang, 2007; McClelland et al., 2007; McClelland & Wanless, 2012; Sethi, Mischel, Lawrence, Shoda, & Rodriguez, 2000; Ursache, Blair, Stifter, & Voegtline, 2013). For instance, past research supports a relationship between earlier regulatory functioning and self-regulation during preschool such that higher levels of early attention and emotion regulation during toddlerhood is associated with higher levels of self-regulation during preschool (Sethi et al, 2000; Ursache et al., 2013). Likewise, during preschool there is evidence that multiple levels of functioning interact to ultimately produce regulated behavior. For instance, emotional-regulation is consistently associated with inhibitory control during preschool such that the development of and manifestation of one appears to affect the other; although notably this relationship is complex in nature with gains in both over time, however high levels or low levels of inhibition are associated with lower emotional regulation, compared to moderate levels (Carlson & Wang, 2007).

Finally, because self-regulation and its development is contextually bound by definition, how children regulate their behavior at a given time is not only linked to biological and maturational differences, but to differences in environment, such as poverty level (e.g., Blair, 2010; Blair & Raver, 2012), and caregiver modeling and reinforcement of self-regulation (Grolnick & Farkas, 2002). In particular, Clancy Blair and colleagues suggest that different patterns of regulation can be expected based on the environment in which a child was raised in such that children raised in middle to high SES environments are more likely to demonstrate behavioral self-regulation that relies upon top down control, whereas children from poverty contexts may, in fact, demonstrate a completely different trajectory of regulation- one that is more reactive in nature (Blair, 2010; Blair & Raver, 2012).

However, based on current empirical evidence, it is unclear whether there are trajectory differences in self-regulation such that children develop behavioral self-regulation both in differing ways (i.e., trajectory differences) and/or at different rates. Although evaluation of growth in self-regulation across two time points suggest differences in the quantity of self-regulation gained, without more information about the general trajectory/trajectories of self-regulation it is not possible to conclude whether differences in gains suggest differences in trajectories, or differences in developmental rates across the same trajectory (Rogosa, 1988). Put another way, differences in gains made across two time points may reflect difference in where (or rather *when*) children are in the process of development, as opposed to actual differences in the process. Indeed work evaluating certain predictors of growth in self-regulation suggest that self-regulation growth is similar across children of different genders, race/ethnicities, and importantly varying levels of SES (Cameron Ponitz et al., 2008). However, this is not to say that trajectories do not vary, rather, these factors do not appear to predict variation in self-regulation (i.e., other factors could predict differences). Rather than focusing on predictors of variation in the development of self-regulation, in the current study I investigate heterogeneity of trajectories directly via growth mixture modeling.

Self-regulation and Academic Achievement

Arguably one of the most consistent and influential findings in the last few decades of research is the role that self-regulation plays in predicting academic achievement, and that this link appears to emerge during preschool (McClelland et al., 2007; McClelland & Wanless, 2012; Montroy et al., in press; Mischel et al., 2011; Tominey & McClelland, 2011). For instance, behavioral self-regulation is associated with higher literacy, math, and vocabulary skills in preschool (McClelland et al., 2007). It is also linked with school readiness skills and elementary academic achievement (Blair, 2002; Blair & Razza, 2007; Howse et al., 2003), as well as outcomes such as SAT scores, high school graduation, and college graduation (McClelland et al., 2013; Mischel et al., 2011).

In particular, it appears that children’s ability to regulate their behavior affords them access to learning within the classroom context (Blair, 2002). Indeed given that one of the primary functions of self-regulation is social in nature (Barkley, 2011) and that social interaction is undeniably necessary for not just the development of self-regulation but for all complex psychological processes (Sameroff, 2010; Vygotsky, 1977), it becomes clear that one of the reasons why self-regulation is linked to academic achievement is because it underlies children's social interactions, which in turn, provide them opportunities to learn, and resources to help them learn (Birch & Ladd, 1998; Eisenberg, Valiente, & Eggum, 2010; Montroy et al., 2014, Williford, Vick Whittaker, Vitiello, & Downer, 2013). Put another way, learning is generated through a complex interplay between the child and through meaningful interactions between the child and his or her teachers and/ or peers (Eisenberg et al., 2010; Montroy et al, 2014; Williford et al., 2003). Children who exert more self-regulation tend to have better relationships with their teachers (Birch & Ladd, 1998; Pianta, 1999; Trentacosta & Izard, 2007). For instance, if teachers describe their relationships with children as warm and close, then children tend to show better emotion regulation skills (Shields, Ryan, & Cicchetti, 2001). Better emotion regulation is associated with better behavioral regulation, which in turn, is associated with better academic achievement (Howse et al., 2003). Likewise, research also suggests that one of the mechanisms through which behavioral self-regulation predicts academic achievement is a child's interactions within the classroom such that better behavioral self-regulation is associated with higher social skills, and fewer problem behaviors, which in turn are linked to better academic achievement (Montroy et al., 2014). Likewise, not only are high levels of self-regulation associated with better child teacher relationships (Birch & Ladd, 1997), they are also associated with better peer relationships (Downer & Pianta, 2006; Ladd & Burgess, 2001), and higher engagement in learning (Pessoa, 2009). Positive interactions, and more engagement help children adjust to the classroom (Birch & Ladd, 1997), with this adjustment, children are more likely to feel comfortable enough to ask questions and seek support from teachers and peers, particularly in frustrating or difficult learning contexts (Carr, Taylor, & Robinson, 1991). They adapt to the classroom environment and ultimately demonstrate higher academic achievement particularly literacy achievement in preschool (Montroy et al., 2014), but also higher GPA's throughout elementary school (Valiente et al., 2011; Valiente, Lemery-Chalfant, Swanson, & Reiser, 2008). Whereas children who exhibit low levels of self-regulation, may struggle both to integrate top down control skills in the service of responding to a task's requirements, and modulating their affect (Kuhl & Kraska, 1993). These children also tend to exhibit higher levels of problem behaviors, which are linked to more negative interactions, more command language from teachers, and in many cases removal from the learning environment (Arnold et al., 1999; Gilliam & Shahar, 2006). Likewise, children with lower levels for self-regulation also tend to be rejected by peers. Thus, these children lack the resources and support that children with higher levels of self-regulation receive. Consequently, they tend to have lower levels of academic achievement (Montroy et al., 2014; Valiente et al, 2011).

Although limited, research also suggests that gains in self-regulation across preschool are associated with academic achievement (McClelland et al., 2013; Tominey & McClelland, 2011), with greater gains in self-regulation associated with higher levels of early literacy, mathematics and vocabulary skills near the end of preschool. However, to my knowledge no study has evaluated longitudinally how the development of self-regulation is linked to academic achievement, and, importantly, if heterogeneity in self-regulation trajectories links to different patterns of academic achievement. Understanding how the relationship between the development of self-regulation and academic achievement is critical if we are to give children the tools they need to transition to formal education, especially given that self-regulation is rated by teachers as critical for school success (Lewit & Baker, 1995; Rimm-Kaufman et al., 2000) and that past research suggests that children who begin formal education with lower levels of self-regulation do not catch up to peers academically. In fact, the academic achievement gap between children with high levels of self-regulation at the beginning of kindergarten versus low levels widens across the early elementary school years, suggesting that how self-regulation development unfolds may have profound effects on children's later academic achievement (McClelland et al, 2006). Thus the current study evaluates how the association between the development of self-regulation and heterogeneity in this development is linked to early literacy, and math achievement at the end of preschool.

Research Aims

Self-regulation in preschool has been identified as an important predictor of current and later academic achievement thus providing a solid foundation for future success (Blair, 2002; Mischel et al., 2011). However, it is not yet clear how self-regulation develops across preschool (i.e., what the trajectory of this development is), nor is it clear if there is heterogeneity across children in this development that is, in turn, linked to different patterns of early literacy and math achievement at the end of preschool. The current study utilizes growth curve modeling to evaluate the trajectory of behavioral self-regulation across preschool with the expectation that this development will be best represented by a nonlinear s-shaped sigmoidal model, with gains in self-regulation that rapidly accelerate early in preschool and decelerate near the end of preschool. I then utilize growth mixture modeling to determine whether there is heterogeneity across children in the development of self-regulation. Variation in children's initial levels and rate of development are expected. Finally, I will evaluate the link between the development of self-regulation, variation in this development, and literacy and math achievement at the end of preschool. I expect that higher initial levels of self-regulation, faster growth trajectories, and rapid growth that occurs at an earlier age will be associated with higher levels of literacy and math in the spring.

CHAPTER 2: METHODS

Participants

Data was collected from 652 preschool aged children as part of a larger longitudinal study, the Michigan Longitudinal Study of Early Literacy Development (MLSELD) evaluating cognitive, social and academic skills in preschool aged children from five Midwestern preschools. Data were collected across four academic years (2008-2012). Gender was split fairly evenly in the sample (48% male). The average age of participating children in the fall of their first year of preschool was just under four years of age (M=47.62 months, SD=7.74). The majority of children enrolled in the study reported their race/ethnicity as White, Non-Hispanic (81.1%), with smaller percentages who were African American (2.1%), Hispanic (2.5%), Asian (7.3%), multi-racial (3.9%), or other (3.1%) . English was predominantly spoken in the home for 92% of the children involved in the study. Mothers were also asked to report their highest education level completed. In general, mother education within the sample was high with 1.2% reporting they had not received a high school diploma; 6.6% reporting they had received a high school diploma or equivalent; 33.7% indicating some college or technical training; 29.5% reported receiving their bachelor's degree; and 28.9 % reporting education beyond a bachelor's degree.

Procedure

As part of a larger study, families were invited to participate at the beginning of the school year. Parents were asked to fill out a demographics survey in the fall. Participating children were tested individually in several sessions which lasted no longer than 20 minutes each by trained research assistants. Testing occurred in a quiet place (usually in the hallway outside of the child's preschool classroom), and the order of assessments was randomized. Children were tested in the spring on all of the academic measures. The self-regulation measure was collected fall and spring of each year, and also across four time points (about a month and a half apart) in 2008-2010. All children included in the current data set completed at least two self-regulation assessments throughout the course of the study. Notably, 85% of children in the full dataset had at least 2 assessments of behavioral self-regulation. Some children (n = 147) were included within the study for two years, and thus have up to eight time points of self-regulation data and a small subset of children (N=13) were included in the study for three years, and thus have up to 10 points of data. All academic achievement data for children who were in the study multiple years is from their last year of participation.

Measures

Self-regulation.

Head-Toes-Knees-Shoulders. To directly assess behavioral self regulation, children were given the Head-Toes-Knees-Shoulders task (HTKS; Cameron Ponitz et al., 2008; Matthews, Ponitz, & Morrison, 2009). This task requires the integration of attention, inhibitory control, and working memory into a gross motor behavioral response. During the HTKS task children were asked to play a game in which they were required to recall four paired behavioral rules ("touch your head/touch your toes," "touch your shoulders/touch your knees"). When instructed to perform one rule, the child had to do the opposite. For example, if the experimenter instructed the child to touch their toes (or head), instead of following this command, children were asked to do the opposite and touch their head (or toes respectively). After the task was explained, children were given a chance to practice. Children were given up to three reminders that they were to do the opposite of what the experimenter said. The first 10 items of the task include only two paired commands (either touch your head/touch your toes, or touch your shoulders/touch your knees) with which set of commands children received first randomized across children. If children understood this part of the task (got 5 or more correct), then the additional commands (either touch your shoulders/touch your knees, or touch your head/touch your toes respectively) were added. Children were again given a short practice section with all four commands followed by 10 test items. Children could terminate the task at any time. On each item, children earned 2 points if they responded correctly (did the opposite of the command), 1 point for self-correcting (made an initial movement to the incorrect response but ended with the correct response) or 0 points for responding incorrectly. There were 20 items, with a total score ranging from 0-40.

Previous research indicates that scores from the Head-to-Toes task demonstrate strong inter-rater reliability as well as construct and predictive validity in early childhood (Cameron Ponitz et al., 2008; Matthews et al., 2009; McClelland et al., 2007; Cameron Ponitz, McClelland, & Morrison, 2009; Wanless, McClelland, Acock, Chen, & Chen, 2011). For example, HTKS scores are significantly correlated with self-regulation in the classroom as rated by teachers (r = .29 to .48) as well as parental reports of attention in inhibitory control (r = .20-.25)(Cameron Ponitz et al., 2009; McClelland et al., 2007). Scores are also correlated with executive function and other measures of self-regulation such as the Day/Night task (r = .33) and the DCCS (r = .61) (Duncan, Miao, McClelland, & Acock, 2013). Likewise internal consistency reliability in previous studies is generally above .90 (Wanless et al., 2011).

Children's Behavior Questionaire. A subset of children's parents reported (n = 164) on their child(ren)'s temperament via the Very Short Form of the Children's Behavior Questionaire (CBQ; Putnam, & Rothbart, 2006; Rothbart, Ahadi, Hershey, & Fisher, 2001). This 36 item survey assesses children on several dimensions of temperament including 12 items geared specifically towards assessing one temperamentally based aspect of self-regulation: effortful control. Parents rated on a 7-point likert scale whether a behavior is "*extremely untrue*," "*quite untrue*," "*slightly untrue*," "*neither true or untrue*," "*slightly true*," "*quite true*," or "*extremely true*" of their child(ren). For the current study, only the effortful control subset was included within analyses in order to evaluate the relationship between parent reported aspects of self-regulation and the direct assessment of self-regulation via the HTKS. Examples of items from this subset include "When drawing or coloring in a book, shows strong concentration" or "Approaches places he/she has been told are dangerous slowly and cautiously." Total raw scores were used within the analyses. Internal consistency for effortful control in previous research is general above .65 (Putnam & Rothbart, 2006).

Literacy. Literacy skills were assessed with three different measures: the Letter-word Identification subscale of the Woodcock-Johnson Tests of Achievement (WJ-III; Woodcock & Mather, 2001); the phonological awareness subscale of the Test of Preschool Early Literacy (TOPEL; Lonigan, Wagner, Torgeson, & Rashotte, 2007) and an assessment of letter knowledge. The Letter-word Identification subscale consists of 76-items that required children to first identify letters followed by having them pronounce increasingly more difficult words. Reliability on this measure for children three to eight years of age is excellent (Range = .96 to .99). Results will be presented using *W* scores, the equal-interval scale that takes into account the level of item difficulty and children's age into consideration.

The phonological awareness subtest of the TOPEL consists of 27-items that require children to blend and segment words and sounds. The TOPEL phonological awareness subtest has an internal consistency reliability of .87 for ages three through five. The TOPEL was not utilized to assess phonological awareness during the first year of the study (2008-2009).

To assess letter knowledge, children were asked to respond to the prompt "What is the name of this letter" when shown a letter printed in 150 point font on a flashcard. All 52 letters were presented one at a time during study years 2008-2011 as previous findings suggest that utilizing both upper and lower case letters extends the measure's range, thus enabling more effective measurement, particularly for children with high levels of letter knowledge (Bowles, Pentimonti, Gerde, & Montroy, 2014). Internal consistency based on previous work is .99 (Montroy et al., 2014). In 2011-2012, a subset of eight letters was given to children. These letters span the range of the construct, have been used in previous research and have an internal consistency of .82 (Bowles et al, 2014). All uppercase letters were presented first followed by lowercase letters. Eight forms with different randomized letter orders (within the uppercase and lowercase letters) were used, with form assigned randomly to each child. Scores were converted to Rasch scores (similar to w-scores) based on previous research (Bowles et al., 2014) as Rasch scores provide interval-level measurement, and make it possible to evaluate letter name knowledge ability on the same scale despite the fact that a different number of items was administered from year to year.

Math. Children's early math skills were measured using the Test of Early Mathematics Ability 3rd Edition (TEMA-3; Ginsburg & Baroody, 2007). The TEMA-3 is a 72-item assessment of early math skills (ages 3-8) and concepts such as counting, enumeration, producing sets, addition, and subtraction. Many of the items on the TEMA-3 utilize pictures and manipulatives, such as tokens, blocks, and note cards, in order to make the test more age appropriate for younger children (e.g., can you hand me exactly 19 blocks?). Raw scores were utilized in all analyses. Internal consistency reliability for the TEMA-3 ranges between .94 and .96. TEMA-3 was also not collected during the first year of assessment (2008-2009).

Missing Data

Missing data in this data set were linked to two factors: participant absenteeism and study design. There was no discernible pattern of missingness from one time point to the next based on child absences (i.e., there does not appear to be a pattern of chronic absenteeism from one child to the next). Thus, I will treat this data as missing completely at random; see Table 1 for the number of children tested at each time point and each measure. Notably, during 2008, phonological awareness and math achievement were not collected. Due to the fact that this was by study design, it can be considered missing at random. Therefore, for all analyses year was included as an auxiliary variable given its relationship with the variables containing missingness. Additionally, in the latter years of the study, some measures (TOPEL, TEMA-3) were only collected by design from about half of students because of the length of these assessments.

Table 1

Self-regulation and Academic Achievement Scores by Year

Variables	Time of assessment	N/Total N
Self-Regulation	Fall 2008	100/117
	Early Winter 2008	99/117
	Late Winter 2009	94/117
	Spring 2009	98/117
	Fall 2009	268/273
	Early Winter 2009	263/264
	Late Winter 2010	265/265
	Spring 2010	265/266
	Fall 2010	250/267
	Spring 2011	252/262
	Fall 2011	161/177
	Spring 2012	157/172
Letter Knowledge	Spring 2009	94/98
	Spring 2010	209/265
	Spring 2011	221/252
	Spring 2012	112/157
Phonological Awareness	Spring 2010	132/265
	Spring 2011	143/252
	Spring 2012	109/157
Letter Word Decoding	Spring 2009	72/98
	Spring 2010	144/265
	Spring 2011	146/252
	Spring 2012	109/157
Math	Spring 2010	104/265
	Spring 2011	71/252
	Spring 2012	126/157

Note. Fall = September – October, Early winter = late October – December, Late Winter = January – March, Spring = March through May. The number of academic assessments completed are reported out of the number of children who completed at least two assessments of behavioral self-regulation.

Analytical Plan

The analyses were performed in three parts to (1) describe the general growth trajectory of self-regulation, (2) evaluate the heterogeneity in self-regulation trajectories across children, and (3) investigate the relationship between growth in self-regulation, and individual differences in this growth and academic achievement. First growth curve modeling (Bowles & Montroy, 2013; Browne, 1993; Browne & Du Toit, 1991; Cudeck, 1996; McArdle, 1986; Meredith & Tisak, 1990; Rogosa & Willett, 1985; Singer & Willett, 2003; Skibbe, Grimm, Bowles, & Morrison, 2012) was used to assess the trajectory of growth in behavioral self-regulation, with models fit to repeated assessments of the HTKS across preschool. Next I utilized growth mixture modeling techniques (Muthen, 2004) to evaluate possible heterogeneity in the developmental trajectories of self-regulation across preschool. Finally, based on the results of the latent growth curve and growth mixture modeling analyses, I utilized regression based analyses to predict spring early literacy and mathematics achievement from the development of behavioral self-regulation. Details of these models will be described next.

Latent growth curve analyses. Latent growth curve modeling techniques make it possible to elucidate both average initial levels as well as group changes in behavioral self-regulation (Singer & Willett, 2003). Specifically these models provide information about the average values of how self-regulated children (level of self-regulation) are at a specified time, how rapidly their skills increase or decrease (i.e., rate of growth or slope), and whether this change is constant or might accelerate or decelerate (i.e., linear versus nonlinear growth). The general equation for the latent growth curve models I used is:

$$Self\text{-}reg[t]_n = Level_n + Slope_n \cdot A[t] + u[t]_n,$$

where $Self\text{-}reg[t]_n$ is HTKS score for child n at age t. $Level_n$ represents child *n's* predicted level of self-regulation. $Slope_n$ generally reflects child *n's* predicted rate of growth on the HTKS. A is a vector of coefficients defining the shape of the growth trajectory across age (also known as the basis coefficients) and they determine both the precise interpretation of both the *Level* and the *Slope*, and the nature of change. Specifically, the *Level* is defined as a child's predicted level on HTKS when $A[t]$ equals zero, and *Slope* is defined as the predicted magnitude of growth for a one unit change in $A[t]$. For instance, I can define a linear latent growth curve model by setting $A[t] = age - 36$, where the $Level_n$ is the predicted score at age 36 months for child n while $Slope_n$ is the predicted score change across ages 36-65 months for child n. Importantly, the elements of $A[t]$ can also be defined to follow non-linear trajectories such as exponential growth thus capturing periods of acceleration (i.e., rapid growth) and deceleration. Likewise this type of model also allows flexibility in that growth may best be described by unknown parameters to be estimated by the nonlinear growth curve model.

The first step in this analysis was to determine, via growth mixture modeling, an appropriate age related growth curve for behavioral self-regulation across preschool. I considered five alternative models: *linear, quadratic, exponential, modified logistic, and the latent basis model.* Due to the fact that there were variations in what age children received the behavioral self-regulation assessments and the amount of time between assessment points, HTKS scores were organized based on the child's age at time of assessment. For all models, the children's scores on the HTKS were grouped together into age windows starting at 39 months or less and continuing in three month spans until 61 months or more as opposed to assessment time points. Thus across preschool there were 9 total age windows that were utilized in all analyses. In the linear model:

$$A[t] = age^{i}-1$$

as described above. In the quadratic model, I the shape was defined as:

$$A[t] = (age) + b(age)^2$$

where b is an acceleration parameter. In the exponential model, the shape was defined as:

$$A[t] = 1 - \exp(-r *(age))$$

---

[i] Age in all equations is a short hand reference to the nine pre-defined 3 month age windows.

where *r* reflects a general rate of growth parameter. The exponential is scaled such that the level represents the initial age window (39 months or less) and the slope represents the span between the level, and where the curve asymptotes. In the modified logistic model, I utilized a standard sigmoidal (s-shaped) logistic curve that was scaled to maximize interpretability of the level and the slope parameters. I defined the shape as:

$$A[t] = 4\lambda\left[\frac{1}{1+\exp\left(\frac{-1(age-\alpha)}{\lambda}\right)} - .5\right]$$

where α is the age window at the point of inflection at which growth changes from accelerating to decelerating, and λ is a parameter describing curvature. Notably, α represents the age window at which growth is at its maximum rate. The logistic curve was scaled such that the *Level* represented the child's predicted score at the point of inflection (i.e., at the point of maximal growth), or age window = α. Likewise, the *Slope* parameter in this model was a child's predicted rate of change at the inflection point, or the point of maximal growth.

The four previously mentioned models represent parametric linear or nonlinear models, that is, a known function is utilized to determine the structure of the basis coefficients. However, the last model considered here, known as the latent basis model (Meredith & Tisak, 1990) or freed loading model (Bollen & Curran, 2006), does not have a set shape and is exploratory in nature. More specifically, in the latent basis model, *A[t]*, or the basis coefficients are estimated as part of the model which results in a simple nonlinear model with one dimension of change. However, the level and slope must be identified, which is usually done by constraining two of the basis coefficients typically to be zero (to identify level) and one (to identify slope). For ease of interpretability I selected the basis coefficient for the first age window (39 month or less) to be zero, and the coefficient for the last age window (61 months and up) to be one. This makes the level at the first occasion and the slope as the change throughout the course of preschool, with each estimated basis coefficient representing a proportion of the total change (Bowles & Montroy, 2013). This model is somewhat similar to a segmented growth or spline growth curve with a knot point at each measurement occasion, or in this case at each age window (Grimm, McArdle, & Hamagami, 2007).

To evaluate what model optimally described the general growth trajectory of behavioral self-regulation, I utilized two standard parsimony-adjusted fit statistics: the Akaike Information Criterion (AIC) and the Adjusted Bayesian Information Criterion (aBIC). Each of these statistics uses the -2 log likelihood (i.e., the typical maximum likelihood measure of misfit), and add penalties based on the complexity of the model (i.e., less parsimonious), with AIC and adjusted BIC differing in how these penalties are calculated (Raykov & Marcoulides, 2008). However, for each, lower numbers indicate better model fit, optimizing the balance between lower misfit and model complexity.

Growth mixture modeling analyses. To evaluate the different trajectories of behavioral self-regulation development across preschool, I utilized growth mixture modeling to assess whether different classes of trajectories existed within the data. In growth mixture models, the trajectory classes are formed based on the growth factor means (e.g., the means of *Level* and *Slope*) with each class defining a different trajectory across time (Muthén, 2001). Growth mixture modeling also captures individual variation around these growth curves by estimating the growth factor variances for each class (Muthén & Muthén, 2000).

Two main criteria were used to determine the number of latent classes: (1) model fit was evaluated with AIC and aBIC fit statistics as simulation studies suggest these are best for correctly determining the number of classes when the number of classes if fewer than five (Tofighi & Enders, 2006), and (b) whether the trajectories were interpretable and meaningful in practice. For example, how many children are in each class is an important indicator of their meaningfulness (e.g., a two class solution where 99% of children are in one class is not very meaningful, and is likely indicative that there are one or two outliers within the data).

Regression based analyses. Lastly, to investigate the link between growth (and heterogeneity in growth across children) in behavioral self-regulation and early literacy and math achievement, I predicted early literacy and math achievement based on the results from the latent growth curve analyses and the classes established via the growth mixture modeling analyses. Specifically early literacy achievement was defined via an analysis where a latent literacy factor was fit with three indicators: spring letter name knowledge ($\lambda = .77$, $p < .01$), spring phonological awareness ($\lambda = .52$, $p < .01$) and spring letter-word decoding ($\lambda = .98$, $p < .01$). The factor was fully saturated. Mathematics achievement was defined based on the children's spring scores on the TEMA-3. All analyses were conducted within a structural equation modeling framework using Mplus (Muthén & Muthén, 1998-2010) to estimate the latent growth curve models, the growth mixture modeling and regression analyses.

CHAPTER 3: RESULTS

In this section I describe the results for the analysis of behavioral self-regulation development across preschool. I first present descriptive statistics for the behavioral self-regulation task. Next, I evaluate the development of behavioral self-regulation across preschool via growth curve modeling in order to determine the best fitting shape of behavioral self-regulation development. I then apply growth mixture modeling to evaluate whether there is support for multiple behavioral self-regulation trajectories across the preschool time period. Finally, I describe the results evaluating the associations between the behavioral self-regulation trajectory(ies) and early literacy and mathematics achievement in the spring of preschool.

Descriptive Statistics of Behavioral Self-regulation

As can be seen in Table 2, on average, children demonstrated gains in behavioral self-regulation as measured by the HTKS between the ages of three and five. Individual observed trajectories for a random subset of 50 children's scores on the HTKS across age are presented in Figure 1. There is substantial variation in children's behavioral self-regulation across age. Likewise, there appears to be periods of substantial acceleration and deceleration in behavioral self-regulation growth both within children, as well as substantial variation in trajectory patterns across children. Correlations between HTKS assessments across age are presented in Table 3, as well as correlations between HTKS and parent reported effortful control, and several other background variables (mother education, child gender and race/ethnicity).

Table 2

Descriptive statistics for self-regulation, academic achievement and background variables

Variable	%			
Background Variables				
- Gender (male)	48.0			
- Mother education				
-<HS	1.2			
-HS	6.6			
-SC	33.7			
-BA	29.5			
->BA	28.9			
-Race/ethnicity				
-White/Non-Hispanic	81.1			
-Hispanic	2.5			
-African-American	2.1			
-Asian	7.3			
-Multi-racial	3.9			
-Other	3.1			
	N	Mean	SD	Range
-Parent reported effortful control	164	65.13	7.82	40-81
Self-regulation				
-HTKS age 39 months or less	107	3.62	7.57	0-38
-HTKS age 40 -42 months	128	5.50	9.95	0-38
-HTKS age 43 – 45 months	143	7.25	11.38	0-40
-HTKS age 46 – 48 months	185	9.15	11.32	0-40
-HTKS age 49 – 51 months	241	11.95	13.49	0-40
-HTKS age 52 – 54 months	276	16.73	14.27	0-40
-HTKS age 55 – 57 months	295	17.75	14.88	0-40
-HTKS age 58 – 60 months	217	22.78	14.28	0-40
-HTKS age 61 months or more	169	24.96	14.20	0-40
Academic Achievement				
Spring letter name knowledge	623	0.80	1.00	-1.48-2.76
Spring letter word decoding	480	351.68	28.21	264-498
Spring phonological awareness	405	16.82	6.41	0-27
Spring math	193	14.60	9.84	0-51

Note. < HS = less than high school, HS = high school diploma, SC = some college, BA = Bachelor’s degree, and >BA = higher than a bachelor’s degree. Letter name knowledge is presented in Rasch scores.

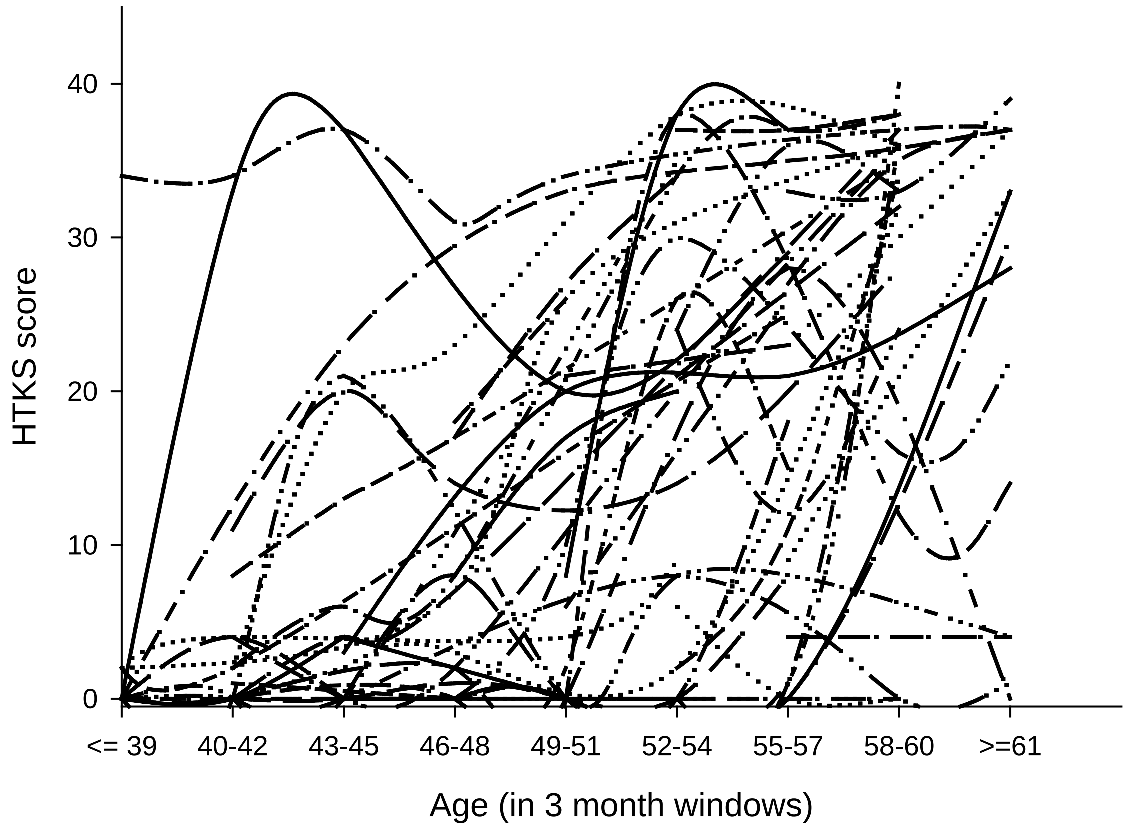

Figure 1. Random subset of 50 children's smoothed behavioral self-regulation trajectories from ages three to five.

Table 3

Correlations among background variables and HTKS scores by age

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1. HTKS age 39 months or less	-												
2. HTKS age 40 -42 months	.20	-											
3. HTKS age 43 – 45 months	.15	.61	-										
4. HTKS age 46 – 48 months	.50	.47	.74	-									
5. HTKS age 49 – 51 months	.45	.49	.41	.59	-								
6. HTKS age 52 – 54 months	-.02	.11	.38	.45	.63	-							
7. HTKS age 55 – 57 months	.07	.09	.49	.57	.55	.63	-						
8. HTKS age 58 – 60 months	.39	.20	.30	.47	.67	.38	.64	-					
9. HTKS age 61months or more	.36	.68	.27	.66	.61	.42	.47	.73	-				
10. CBQ effortful control	.04	.02	.27	.12	.22	.19	.31	.34	.41	-			
11. Mother reported education	.18	.14	.28	.34	.39	.20	.30	.30	.34	-.01	-		
12. Child gender	.15	-.10	-.02	-.05	-.04	-.01	-.02	-.05	.07	-.01	.01	-	
13. Child race/ethnicity	-.21	-.11	-.07	.04	-.07	-.14	-.01	-.21	.07	-.09	.04	.07	-

The Development of Behavioral Self-regulation: Latent Growth Curve Analysis

Fit statistics for the five growth models are reported in Table 4. Both AIC and aBIC suggested that the changes and between person differences in behavioral self-regulation development are best described by the exponential curve, if no constraints are added. However, two of the models (including the exponential) required additional constraints. The initial quadratic model included a non-significant negative level variance, and the exponential model included two non-significant correlations that were estimated over 1 (between the level and the slope and between the level and the rate). Thus two additional models are included in Table 4 where these parameters are constrained to zero. With the inclusion of these constrained models, the constrained quadratic curve provides slightly better fit than the exponential curve (constrained and not constrained) based on the AIC and aBIC. Notably, the differences in fit based on the AIC and aBIC were small between these models, thus I graphed both the constrained quadratic and the constrained exponential models. As can be seen in the graph of the exponential model in Figure 2 (the constrained quadratic graph can be viewed in Appendix A), part of the reason both of these models fit similarly is because the trajectory of these data could be described equivalently by either a constrained quadratic or an exponential function. That said, theoretically, the typical u-shaped shape of a quadratic implies higher HTKS out of the range of the data (i.e., if we could adequately measure scores with the HTKS before age 3), whereas an exponential trajectory may fit this data better in reality given both age related measurement constraints of the HTKS, as well as the theory that early behavioral self-regulation emerges at or around age three and grows rapidly over the next few years. Thus based both on the fit statistics as well as theory, I concluded that the exponential curve best described the development of behavioral self-regulation across the preschool time period; that is, changes in behavioral self-regulation were best described by a curve in which children began with an initial low level of behavioral self-regulation followed by a period of accelerating gains throughout the preschool time period.

Table 4

Fit statistics for latent growth curve models

Models	Linear	Quadratic	Constrained Quadratic	Modified Logistic	Exponential	Constrained Exponential	Latent Basis
Fixed Effects							
- g_{0n} (μ_{g0})	1.19	3.28*	3.49*	15.83*	2.98*	3.02*	2.40*
- g_{1n} (μ_{g1})	2.91*	1.20*	1.08*	3.52*	-11.40*	-10.89*	22.49*
- g_{2n} (μ_{g2})	-	.88*	.93*	-	-.14*	-0.15*	-
- α (μ_{α})	-	-	-	6.09*	-	-	-
- λ (μ_{λ})	-	-	-	2.33*	-	-	-
Random Effects							
- g_{0n} (σ^2_{g0})	24.85*	-6.18	0.00	90.19*	2.83	13.34	32.87*
- g_{1n} (σ^2_{g1})	1.42*	9.06	19.24*	2.09*	1555.99	2245.17	84.33*
- g_{2n} ($\sigma2_{g2}$)	-	2.04	4.18*	-	.08*	0.13*	
- g_{0n}/g_1 covariance	2.90	12.15*	0.00	11.62*	-119.93	0.00	23.27*
- g_{0n}/g_2 covariance	-	-6.23*	0.00	-	0.93	0.00	-
- g_{1n}/g_2 covariance	-	-3.68	-8.41	-	-11.21*	-17.09	-
- e (σ^2_e)	85.14*	76.34*	75.32*	83.93*	74.93*	74.35*	83.20*
Fit Stats							
- -2LL	6827.82	6800.59	6802.98	6823.89	6800.27	6801.57	6819.75
- Parameters	6	10	7	8	10	9	13
- AIC	13667.63	13621.17	13619.96	13663.79	13620.53	13619.97	13665.50
- aBIC	13675.46	13634.22	13629.10	13674.23	13633.58	13630.41	13682.46

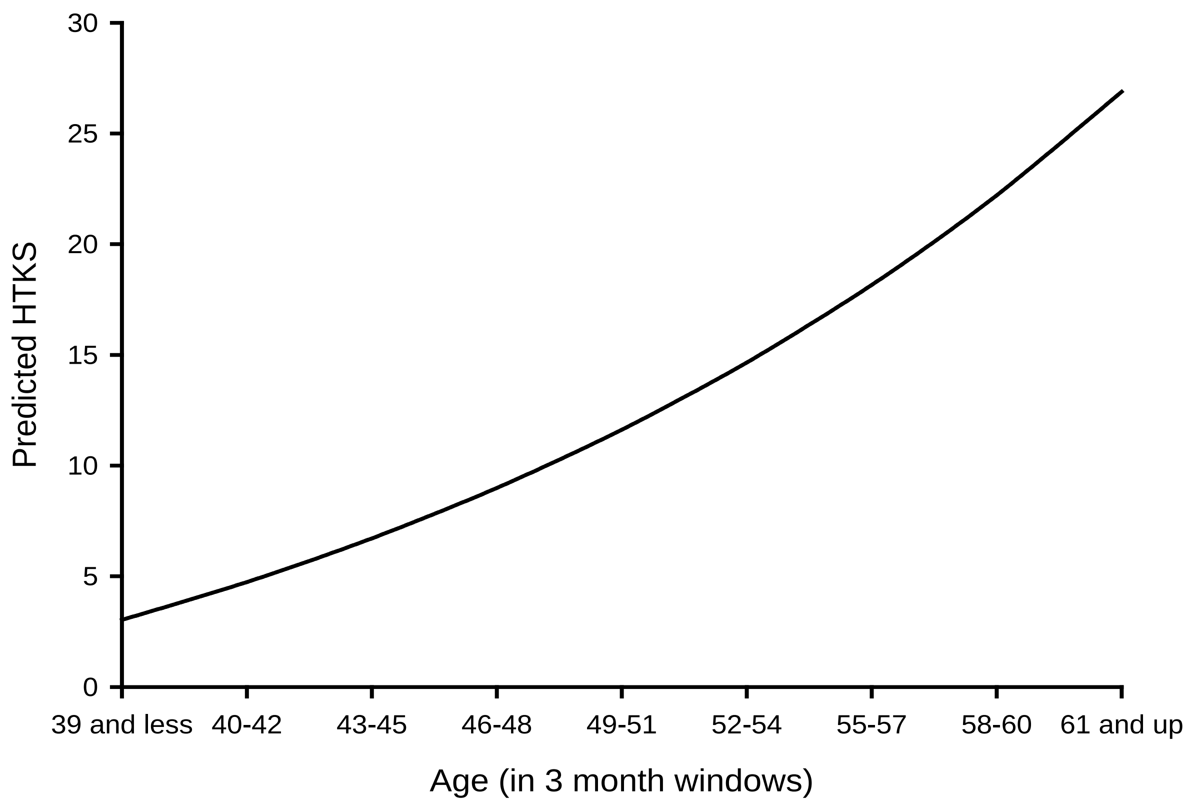

Figure 2. Exponential mean predicted developmental pattern for behavioral self-regulation across the preschool time period.

Heterogeneity in Behavioral Self-regulation: Growth Mixture Analysis

Growth mixture modeling allows for the estimation of different trajectories with the possibility of every estimated parameter differing across groups (e.g., means, variances, covariances, and basis coefficients; Grimm et al., 2007; McArdle & Bell, 2000; McArdle & Nesselroade, 2003). Currently, there is no generally accepted strategy for how growth mixture models should be evaluated in terms of which constraints to relax first (Grimm et al., 2007). However, past research utilizing growth mixture models generally has stuck to the principles of factorial invariance studies (e.g., Grimm et al., 2007), and I followed this strategy as well. Thus, in the subsequent analyses, I first constructed a two class model, based on the original constrained exponential model described above, where only the means (i.e., level, slope, and rate parameters) were allowed to vary. I then progressively relaxed constraints so that the basis coefficients (i.e., the shape of the model across classes) were allowed to vary and finally the variances and covariances were allowed to vary. This represents a top down approach beginning with the assumption that there is a single population trajectory, and then investigating the data for classes that differ in certain aspects of this overall population model including possibly different trajectories. These models were then fit with an increasing number of latent classes, until the fit (AIC, aBIC, and interpretability) did not improve (Grimm et al., 2007) or convergence problems occurred indicating very poor fit (Connell & Frye, 2006).

The two class means only model (AIC = 13541.98, aBIC = 13556.26) fit better than the original constrained exponential model (AIC = 13619.97, aBIC = 13630.41), and moving to a three class means model also improved fit (AIC = 13486.12, aBIC = 13517.89). The four class model would not converge suggesting poor fit, thus I moved to a means plus basis model. The two class means plus basis model (AIC = 13409.52, aBIC = 13425.18) fit better than the means only two class and three class model. However, the three class means plus basis model (AIC = 13347.50, aBIC = 13367.07) fit better than the means plus basis two class model. Finally, the means plus basis plus variance/covariances two class model and three class model did not converge suggesting poor fit. Please see Table 5 for a summary of fit across the different models, as well as interpretability. Based both on fit and interpretability, the three class means + basis model was retained.

Table 5

Fit statistics for growth mixture models

Models			
1 class (latent growth curve model)			
-AIC	13619.97	-	-
-aBIC	13630.41	-	-
-Interpretation	-Accelerating exponential	-	-
	Means Only Free	Means + Basis	Means + Basis + Var./Covar.
2 class			
-AIC	13541.98	13409.52	No convergence
-aBIC	13556.26	13425.18	-
-Interpretation	Class 1: (73%), linear class 2: (27%), decelerating exponential, way out of data range	Class 1: (31%), decelerating exponential class 2 (69%) accelerating exponential	- -
3 class			
-AIC	13486.12	13347.49	No convergence
-aBIC	13517.89	13367.07	-
-Interpretation	Class 1: (22%), high linear, class 2: (11%), accelerating exponential class 3: (67%), decelerating exponential both out or range	Class 1: (24%), low nearly flat line, class 2: (27%), decelerating exponential, class 3: (49%), accelerating exponential	- -

note. var. is an abbreviation for variance and covar. is an abbreviation for covariance. AIC refers to the Akaike Information Criterion and aBIC refers to the Adjusted Bayesian Information Criterion.

This suggests that children generally followed three behavioral self-regulation trajectories. Notably, upon inspection, one of these trajectories subsisted of children who appeared to make few to no gains in behavioral self-regulation across preschool. Based on the results for this trajectory, I fit a no growth model for this particular group rather than an exponential model (while adding no constraints to the other two classes). This final model fit better than all previous models (AIC = 13297.18, aBIC = 13324.58) and is graphed in Figure 3.

Findings based on this model suggested that most children (N = 360) demonstrated exponential growth in behavioral self-regulation that is similar to the general curve described by the latent growth curve analysis. Specifically, these children began with lower levels of behavioral self-regulation (compared to other children in other groups) and made accelerating gains across preschool. A second group of children (N = 170) also demonstrated exponential growth in behavioral self-regulation across preschool. However these children began with higher levels of behavioral self-regulation than children in any other group and rapidly gained early in the preschool time period, with these gains decelerating across preschool. Finally a smaller subset of children (N = 122) began preschool with relatively low levels of behavioral self-regulation, particularly compared to children in the decelerating exponential group, and maintained these low levels throughout the preschool time period.

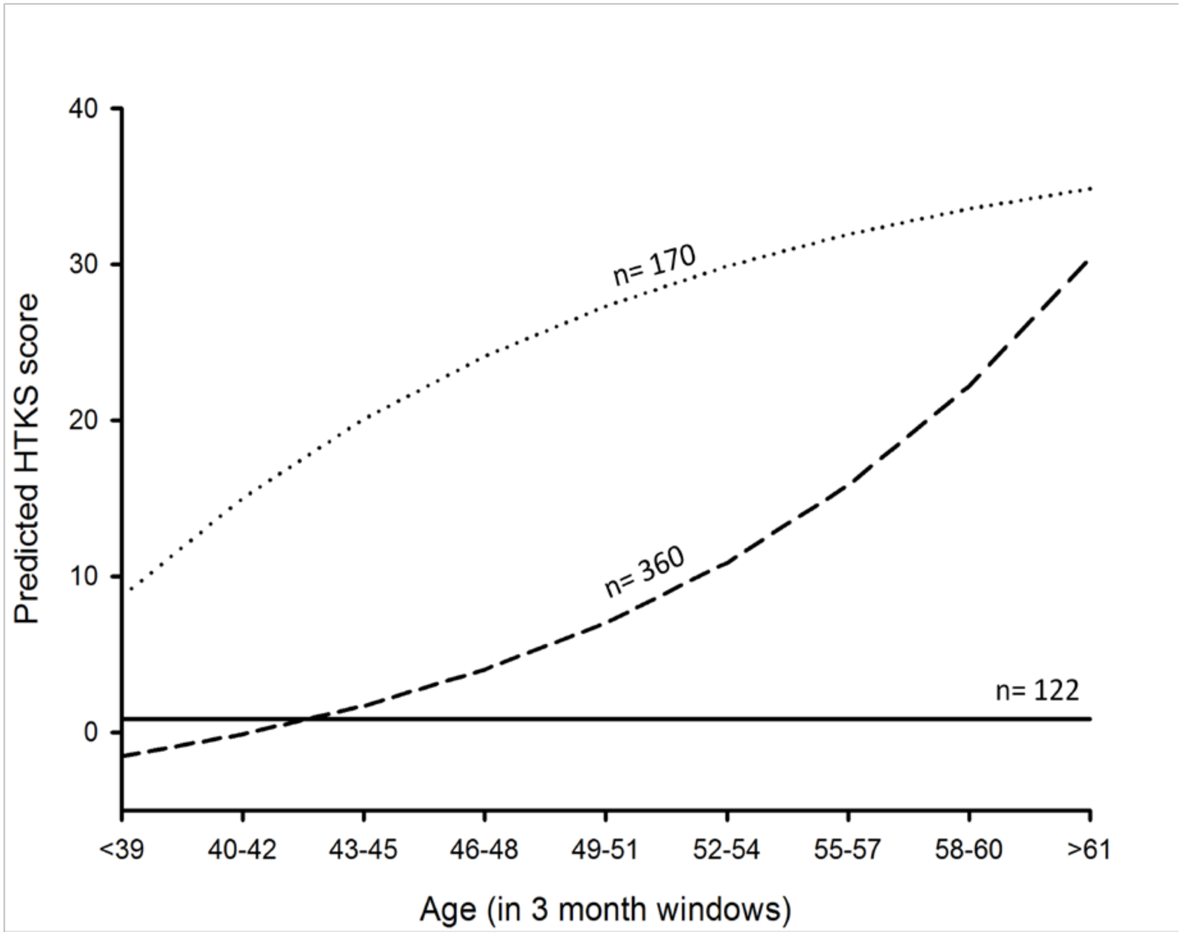

Figure 3. Mean predicted developmental trajectories of the latent classes for behavioral self-regulation across the preschool time period.

Descriptives of group differences across trajectories. In this section I evaluated the background characteristics of children by predicted group/trajectory membership. Given that a subset of children demonstrated a no growth behavioral self-regulation trajectory, I tested whether these children differed from children who globally demonstrated growth in behavioral self-regulation (both accelerating and decelerating exponential trajectories) in terms of age, gender, race/ethnicity, level of parent reported effortful control, and mother reported maternal education level. I then tested for differences in background characteristics between children who demonstrated either accelerating exponential growth, henceforth named the later developers or decelerating exponential growth, henceforth called the early developers.

Results indicated that the children who demonstrated a no growth trajectory of behavioral self-regulation tended to have lower levels of parent reported effortful control, (M = 61.00, SD = 8.19), compared to both of the groups of children, considered together, that demonstrated growth (M = 65.70, SD = 7.62, $p < .05$, d = -.59). They were more likely to come from families where mother's reported lower levels of education (M = 5.78, SD = 1.99), compared to children who demonstrated growth (M = 6.86, SD = 2.06, $p < .01$, d = -.53). Additionally these children also tended to be older in the fall of their first year of preschool (M = 50.88, SD = 6.21) compared to children who demonstrated either pattern of growth (M = 47.07, SD = 7.31, $p < .01$, d =.56). Likewise children in the no growth group were 1.49 times more likely to be identified as a boy (57% male) compared to the other groups combined (47% male, $p = .05$, CI_{95} = [1.00, 2.22], d = .20). Reported race/ethnicity did not statistically vary between the no growth (White/non-Hispanic = 79.5%, African-American = 0.0%, Hispanic/Latino = 5.7%, Asian = 5.7%, multi-racial = 4.5%, or reported race/ethnicity as other = 4.5%) and the growth groups, (White/non-Hispanic = 81.5%, African-American = 2.5%, Hispanic/Latino = 1.8%, Asian = 7.6%, multi-racial = 3.8%, or reported race/ethnicity as other = 2.8%, $p = .40$).

Additionally, comparing the later developing children group to the groups of children who demonstrated early development suggested that children who demonstrated early growth were older (M = 48.10, SD = 7.52) in the fall of their first year of preschool compared to children with later growth (M = 46.58, SD = 7.16, $p < .05$, d = .21). These children also had higher levels of parent reported effortful control, (M = 67.03, SD = 6.99) compared to their peers with later growth (M = 64.41, SD = 8.03, $p < .05$, d = .35), and were more likely to come from families where mother's reported higher levels of education (M = 7.65, SD = 1.97) compared to children with later growth (M = 6.46, SD = 2.00, p < .01, d = .60). However, children in the early growth group were 1.01 as likely to be identified as a boy (47% male) as children in the later growth group (48% male, p = .95, CI_{95} = [0.70, 1.46], d = -.02). Likewise reported race/ethnicity did not significantly vary between the early growth group, (White/non-Hispanic = 86.0%, African-American = 0.8%, Hispanic/Latino = 0.0%, Asian = 6.2%, multi-racial = 1.6%, or reported race/ethnicity as other = 5.4%) and the later growth group, (White/non-Hispanic = 79.2%, African-American = 3.4%, Hispanic/Latino = 2.6%, Asian = 8.3%, multi-racial = 4.9%, or reported race/ethnicity as other = 1.5%, p = .91).

Behavioral Self-regulation and Academic Achievement

Means and standard deviations for spring early literacy and mathematics achievement are listed in Table 2. For the general exponential trajectory described via the latent growth curve analysis, the rate of change across the preschool time period was related to both early literacy, β = -4.04, p < .01, and early math, β = -2.62, p < .05, achievement such that a more rapid rate of change was related to higher levels of spring early literacy and math achievement. Initial level, or put another way, the level of behavioral self-regulation at 39 months or less, was not indicative of either spring early literacy, β = .24, p = .165, or math achievement, β = 0.36, p=.145.Although the slope parameter was a statistically significant predictor for early literacy, β = -4.15, p < .01, and math achievement, β = -2.87, p < .01, this parameter describes the distance between the initial level (set at 39 months or less), and the point where the exponential asymptotes which, in this case, is outside of the range of the data and thus should be interpreted with caution. However, tentatively these findings suggest that children who begin to make gains in behavioral self-regulation earlier (i.e., the more negative the asymptote is) have higher levels of early literacy and mathematics achievement in the spring compared to children who begin to make gains later.

Heterogeneity in behavioral self-regulation trajectories and academic achievement. Next, I predicted early literacy and math achievement in the spring based on children's predicted group membership from the final three class model. Similar to the analyses evaluating background characteristics of children by group, I tested whether children who demonstrated no growth differed from children who demonstrated growth in behavioral self-regulation (both early and later growth). I then tested whether children's spring early literacy and math achievement differed between children who demonstrated either early rapid growth or later rapid growth.

Results indicated that children who demonstrated growth in behavioral self-regulation (including both early and later growth) had higher levels of spring early literacy, $\beta = .25$, $p < .001$, as well as higher levels of early math, $\beta = .32$, $p < .001$, achievement compared to children who demonstrated no growth. Additionally, children who demonstrated early rapid growth of behavioral self-regulation had higher levels of early literacy, $\beta = .21$, $p < .001$, and higher levels of early math, $\beta = .33$, $p < .001$, achievement compared to children who demonstrated later rapid growth of behavioral self-regulation development. This suggests that although gains of any sort across preschool are linked with higher levels of academic achievement at the end of preschool compared to little or no behavioral self-regulatory gains, gains that are made rapidly and early on during the preschool time period are associated with the highest levels of early literacy and math achievement overall across the different patterns of behavioral self-regulation trajectories during the preschool time period.

CHAPTER 4: DISCUSSION

The development of effective self-regulation is recognized across multiple fields, perspectives and studies as fundamental to an individual's successful functioning (Blair, 2002; Bronson, 2000; Calkins, 2007; Diamond, 2002; Gross & Thompson, 2007; Kopp, 1982; Moffit et al, 2011; McClelland & Cameron, 2012; Mischel et al, 2011; Ochsner & Gross, 2005; Vohs & Baumeister, 2011; Zelazo et al., 2003). Specifically research in the past two decades suggests that the first five years of life represent a critical period in the development of self-regulation, with a major developmental shift from more reactive early forms of self-regulation to more reflective cognitive/behavioral self-regulation between the ages of three to five (i.e., the preschool time period) (Best & Miller, 2010; Blair & Raver, 2012; Blair, 2010; Calkins, 2007; Diamond 2002; Diamond et al., 1997; Garon et al., 2008; Mischel et al., 2011). Despite this, very little research has focused upon describing the longitudinal trajectory of behavioral self-regulation across the preschool time period and whether there is heterogeneity in this trajectory across children. This is a substantial oversight as adequately describing and understanding the development of self-regulation is crucial both in terms of better understanding and supporting self-regulatory processes for all children and the relationships between self-regulation processes and other complex skills such as early academic achievement skills. Thus the primary goal of this dissertation was two-fold: (1) to evaluate the trajectory of behavioral self-regulation across preschool and whether there was heterogeneity in this trajectory across children, and (2) to investigate the relationship between growth in behavioral self-regulation and early literacy and math achievement at the end of preschool with particular emphasis on whether heterogeneity in behavioral self-regulation trajectories predicted different patterns of academic achievement.

The Development of Behavioral Self-regulation

The general growth trajectory of behavioral self-regulation across preschool was best represented by an accelerating exponential function. Put another way, behavioral self-regulation develops early in preschool, with gains increasing across the preschool time period. This result is consistent with previous findings suggesting that behavioral self-regulation (and the top down control skills that support behavioral self-regulation) develop(s) in a non-linear fashion with early, rapid gains during the preschool years (e.g., Cameron-Ponitz et al., 2008; Diamond, 2002; Rueda et al., 2006; Willoughby et al, 2012). Also consistent with past cross sectional findings, results indicated more rapid development just after age four (Diamond & Taylor, 1996; Gerstadt, et al., 1994; Zelazo et al., 2003).

Heterogeneity in Behavioral Self-regulation Trajectories

The growth mixture modeling results indicated heterogeneity across children in the developmental trajectories of behavioral self-regulation. Specifically, although most children (55%) demonstrated an accelerating exponential pattern of gains in behavioral self-regulation with lower initial levels of behavioral self-regulation and rapid gains across preschool(later growth), a subset of children (26%) demonstrated a decelerating exponential trajectory with higher initial levels of behavioral self-regulation as compared to the other trajectories, rapid gains early in behavioral self-regulation (early growth), with decreased gains throughout the preschool time period. Another smaller subset of children (19%) demonstrated a no growth pattern of development such that they began preschool with lower levels of behavioral self-regulation compared to early growth group, and made few to no gains across the preschool time period. Although there is heterogeneity across groups of children, there are also some important similarities. For example, for the majority of children (81%) across both growth groups, there is a period of rapid development of behavioral self-regulation with differences in when this rapid growth occurs and what level of behavioral self-regulation children demonstrated at about age three. Near the end of the preschool time period, these two trajectories began to converge. These findings are consistent with previous research suggesting that children's self-regulation skills "leap" during preschool and suggests that similar behavioral self-regulation developmental processes are occurring across children, but with clearly identifiable variations in timing (Diamond, 2002; Ponitz et al., 2008). Notably, and consistent with previous research, the current results also indicated that children who demonstrated early growth tended to be older at preschool entry (Diamond, 2002; McClelland et al., 2007) than children demonstrating later growth and demonstrated higher levels of parent reported effortful control at the beginning of preschool (Rothbart et al., 2006). One can speculate at this point that some of the timing differences are related to maturation, as indicated by age, and biological traits as indicated by effortful control which is often considered to be based in part on biologically based aspects of temperament (Aksan, & Kochanska, 2004; Calkins & Fox, 2002; Calkins & Leerkes, 2011; Kochanska et al., 2000; Rothbart et al., 2006). Specifically, in regards to effortful control, Calkins and colleagues (2002) suggest that in terms of biological variation in temperament, on one end of the spectrum some children are more subject to over-stimulation and negative emotion, while on the other end of the spectrum some children are more extroverted, surgent and thrill seeking. In both of these cases, these children have to overcome a more intense, biologically determined, dominant response in order to demonstrate an appropriate level of effortful control/self-regulation. Due to this, these children generally show lower levels of effortful control at younger ages when compared to same aged peers (Calkins, 2007). Thus, it is possible that timing differences between the observed early growth and later growth groups may be driven by both the child's inherent biological traits and maturational timing of the biological system.

However, it can also be speculated at this point that some of the differences in background characteristics between the early growth and the later growth group may be related to the child's environmental context. Specifically, although effortful control and subsequently behavioral self-regulation relies in part on children's biological reactivity, it also relies in part on caregiver socialization of children and what tools children have been given in order to help them assert regulated behavior (Rothbart et al., 2006). For instance, warm and supportive parenting and maternal responsiveness are linked to higher levels of regulated behavior (Gilliom et al., 2002; Kochanska et al, 2000) whereas maternal power assertions, particularly during discipline, are linked to lower levels of self-regulation (Kochanska et al., 2000). Past theory and research suggest that the way that caregivers respond to children's needs scaffolds and supports the strategies that children themselves later espouse in order to self-regulate (Eisenberg et al., 1993; Grolnick and Farkas, 2002). Put another way, the environment provided to the child by the caregivers can give the child resources that ultimately help the child to self-regulate. Related to this notion, reported maternal education was also higher for children demonstrating early growth as opposed to later growth. Maternal education is considered an important indicator of the family's socio-economic status. Specifically families where the mother is more highly educated generally have more resources available to spend on their child/children than families where mothers are less highly educated (Bradley & Corwyn, 2002). These resources include physical resources such as toys, games, learning materials, and books that support child learning, but also abstract resources such that more highly educated mothers often hold very different beliefs compared to their lower educated counterparts that affect their parenting behavior towards their children (see Bradley & Corwyn, 2002 for review). For instance, more highly educated mothers tend to read to children more, engage them more in conversation, and provide more direct instruction/ learning experiences that include more scaffolding of child skills (Borduin & Henggeler 1981; Shonkoff & Phillips, 2000). More direct instruction and engagement in particular would be expected to support developing self-regulation (Kopp, 1982; Vygotsky, 1977). Thus, contextual elements related to the emotional climate of the home such as parent warmth, responsiveness and expressivity as well as the resources that higher levels of education allow parents to give to their children (both physical and in terms of parenting beliefs and practices) may play a role in group differences between the early growth and later growth groups as well; although research evaluating the multiple levels of child characteristics in greater depth as they relate to self-regulation, as well as potential predictors of group differences, is needed to truly confirm these assertions.

It must also be noted with some concern that nearly 20% of children did not display a rapid growth trajectory, but rather demonstrated little or no growth in behavioral self-regulation across preschool and were clearly behind their peers in level of behavioral self-regulation at the end of preschool. While this could represent an alternative trajectory and by proxy an alternative process, more likely these children represent a group of late developers of behavioral self-regulation (e.g., Cameron Ponitz et al., 2008; Diamond & Taylor, 1996; Gestalt et al., 1994; Zelazo et al., 2003). Although beyond the scope of the current study to assess, it is likely these children will eventually exhibit gains in behavioral self-regulation, and at this point, there is no reason to suspect that these gains will not proceed in a similar fashion to the gains other children demonstrated during preschool, just at a later time period (Bronson, 2000). However, quite consistent with cross sectional findings, this suggests that not only are most children in general still developing behavioral self-regulation skills as they leave preschool and enter kindergarten, but for a subset of children they are just beginning this process and thus will need additional supports in order to carry out regulatory tasks such as following directions in kindergarten classrooms, and to not fall further behind both in terms of regulatory processes and in relation to other skills such as academic skills which I will discuss shortly (Blair, 2010; Rimm-Kaufman et al., 2000).

Children who demonstrated little to no growth in behavioral self-regulation also demonstrated important differences across background characteristics when compared to their peers who demonstrated growth. In particular, and consistent with the literature, children who demonstrated little to no growth also demonstrated the lowest levels of effortful control across groups and the lowest levels of mother reported maternal education (Blair, 2010; Calkins, 2007; Rothbart et al., 2006). Likewise, and also consistent with some (Matthews et al., 2009), though not all (Montroy et al., 2014) past studies, children in the no growth group were more likely to be identified as male than children in the growth groups. This may, in part, be linked to the lower levels of maternal education associated with this group as past findings suggest that gender differences related both to self-regulation and academic achievement generally are more manifest in lower socio-economic status brackets (Entwisle, Alexander, & Olson, 2007).

Surprisingly, children in the no growth group were also the oldest compared to the other groups at preschool entry, despite past findings indicating that younger children generally struggle more with behavioral self-regulation (Cameron Ponitz et al., 2008; Diamond, 2002; Diamond et al, 1997; Zelazo et al., 2003). It is difficult to determine why this would be the case, but given past evidence, this finding is likely linked to a third, unobserved factor, such as parent beliefs about when children should enter school. For example, past findings indicate that parents are increasingly delaying formal school entry for their children (especially their boys; Deming & Dynarski, 2008) due in part to beliefs about child readiness for school (Lewit & Baker. 1995, although see Bassok & Reardon, 2012 for alternative motivations). Surprisingly some studies suggest that despite parent intentions, red-shirted children appear to be at no advantage and are possibly (still) behind in relation to social emotional skills such as self-regulation when they begin school (Byrd, Weitzman, & Auinger, 1997). This could potentially explain the current finding, though past research has yet to assess if this parent practice of "red-shirting" extends to the preschool time period. Nevertheless, more research is certainly necessary to determine why age was related in this unexpected way to little to no growth in behavioral self-regulation.

The Development of Self-regulation and Academic Achievement

Finally, based on the results of the latent growth curve analyses, the rate of development of behavioral self-regulation was associated with spring early literacy and mathematics achievement in preschool, although not the initial level of behavioral self-regulation children demonstrated. Consistent with these findings and with my hypotheses, when I examined differences in the patterns of spring early literacy and math achievement in relation to the different behavioral self-regulation trajectories obtained via the growth mixture analyses, children who demonstrated early rapid growth of behavioral self-regulation development had higher levels of spring early literacy and math achievement than children who demonstrated later rapid growth. However, as expected given past findings (McClelland et al, 2007; McClelland et al, 2006), children who made gains demonstrated higher levels of spring early literacy and math achievement compared to children who made few to no gains in behavioral self-regulation. Importantly, this finding suggests that these children who made few to no gains are at risk of entering kindergarten unprepared for the demands of formal education and may require additional supports or intervention before or near the beginning of kindergarten to help them handle school demands, and possibly allow them to catch up developmentally to their peers. Without intervention or support, previous research suggests that the academic gap, both in literacy and mathematics achievement, widens throughout early elementary school between children who have higher levels of behavioral self-regulation and those who have lower levels of behavioral self-regulation at the beginning of kindergarten (McClelland et al, 2006).

The Measurement of Behavioral Self-regulation: Process and Development

The current dissertation evaluated the development of behavioral self-regulation via the HTKS task, which purports to require that children integrate multiple top down skills such as attention, working memory, and inhibition into a behavioral response (McClelland & Cameron, 2012; McClellend et al., 2007; Ponitz et al., 2008). Results suggest that gains in behavioral self-regulation during this time period (as measured by HTKS) are non linear in nature with rapid gains for majority of children. This offers tentative evidence in support of the hypothesis that the process that may be occurring during this developmental time span is an integration of multiple skills into a regulated behavioral response, as rapid non linear gains or a quantitative shift in the ability to regulate, would be expected if this was the case (Best & Miller, 2010; Diamond, 2002; Fjell et al., 2012; Garon et al., 2008; Rueda et al., 2005). This is also consistent with findings evaluating the longitudinal development of top down processes during this time span, as well as cross sectional research suggesting that although majority of children struggle with behavioral self-regulation tasks that require integration, such as the HTKS, at age 3; they are successful at these tasks by age five (Diamond et al., 1997; Diamond & Taylor, 1996; Gerstadt et al., 1994; Zelazo et al., 2003). However, each of these tasks, including the HTKS, have measurement constraints in the form of floors and ceilings. Although fitting non-linear models allows researchers the ability to account for the effects of floors and ceilings, it makes it difficult to interpret whether non-linear gains reflect true developmental changes or are an artifact of imperfect measurement. Thus caution must be taken in interpreting these results to imply a process without further evaluation of self-regulation and how skills integrate to support self-regulation over this time period. Despite this caution, it is clear based on the current findings that, during preschool, children do fall into different, distinct classes or groups based on differences in initial levels of behavioral self-regulation and how quickly they develop behavioral self-regulation skills.

Practical Implications

These findings have several implications. First, given that growth in behavioral self-regulation is non-linear exponential, this research supports previous work emphasizing the importance of the preschool time period for the examination of growth in self-regulation, and possibly for increased support and focus as majority of children's skills develop rapidly during this time period (Blair, 2002; 2010; Diamond, et al.,, 2007; McClelland & Cameron, 2012; McClelland et al., 2007; Tominey & McClelland, 2011). In particular utilizing preschool curricula such as Tools of the Mind (Bodrova & Leong, 2007) that center on scaffolding children's early self-regulation skills may provide children the support they need to develop behavioral self-regulation skills early, which in turn positively affects children's early literacy and mathematics achievement and thus may represent an important step moving forward in helping all children develop the skills necessary to be ready for formal education.

In addition, to offering insights into the developmental trajectories of behavioral self-regulation, this dissertation also offers tentative evidence suggesting that which children will follow which trajectory may be somewhat predictable based on background characteristics.

Specifically, it may be possible to screen for children who are at risk of making few to no developmental gains in behavioral self-regulation across preschool, as there was clear stratification across groups based on child characteristics. If children can be identified early in the preschool time period, then possibly instructional practices can be tailored or direct interventions can be put in place to better support these children before they fall farther behind. For example, past research indicates that direct interventions targeted at increasing behavioral self-regulation skills result in significant behavioral self-regulatory gains as well as some academic gains, particularly for individuals who are have lower initial levels of behavioral self-regulation compared to peers (Tominey & McClelland, 2011). Importantly, as preschool has evolved in focus across the last few decades (and continues to evolve) from social-emotional skills to more academic skills (Kagan, Kauerz, & Tarrant, 2007; Stipek, 2011), it is critical for researchers and policy-makers alike to remember that social-emotional development such as self-regulation development can have long lasting impacts on children's school readiness and success, including academic success. Thus focusing on and targeting these skills early, particularly in identifiably at-risk children should be a crucial goal of preschool programs, as part of their overarching goals to help children get ready for school.

Limitations

Several limitations should be considered within the present work. The current study only includes one measure of behavioral self-regulation across multiple time points. Although the HTKS measure demonstrates excellent validity and reliability properties for preschool aged samples, because self-regulation is conceptually a multi-dimensional construct in nature, it is difficult to capture with a single measure. The inclusion of other measures of self-regulation that each focus on a different aspect of self-regulation such as emotional self-regulation and physiological regulation would certainly be informative in future studies for better understanding how these multiple skills come together to ultimately support behavioral self-regulation and its relation to academic achievement. They may also provide a greater specificity of information, particular related to the subset of children who demonstrated little to no development in behavioral self-regulation as the inclusion of additional measures of self-regulation that focus on other aspects of the construct could suggest that these children as still making gains during this time period, but perhaps in physiological or emotional aspects of self-regulation. For example, previous research has demonstrated different timing and patterns of development for self-regulation in different contexts that possibly draw on different aspects of self-regulation (Kochanska et al., 2001). Thus, more research is necessary to understand the timing of developmental trajectories of the multiple aspects of self-regulation and how and when these aspects come together across children with this dissertation representing the first step in the process of describing and mapping out the development of self-regulation across preschool.

Additionally, this study draws from a fairly homogenous sample of families, particularly in terms of maternal education, an important indicator of the family's socio-economic status. Past research has consistently suggested a relationship between behavioral self-regulation and socio-economic status (see Blair, 2010 for review). Thus it is possible results may have been different if a more heterogeneous population had been sampled. Although notably, despite sample characteristics, there was clear variation among children's levels as well as growth trajectories in behavioral self-regulation and this variation is similar to what has been reported in more diverse samples of cross-sectional and longitudinal data based on two time points. For instance across several studies there appears to be a subset of children who finish preschool and enter kindergarten with low levels of self-regulation compared to their peers (Blair & Ursache, 2011; Calkins, 2007; Carlson & Wang, 2007; McClelland et al., 2007; McClelland & Wanless, 2012). For example, Rimm-Kaufman and colleagues (2000) report that 46% of kindergarten teachers rate over half of their entering students as unprepared for kindergarten in relation to self-regulated behaviors. Within the current study nearly 20% of children potentially match this description; thus future work with more heterogeneous populations may find differences in the percentage of children demonstrating rapid growth in behavioral self-regulation versus children demonstrating little to no growth across the preschool time period, but the trajectories themselves may be similar.

Future Studies

Although this dissertation represents a first step in understanding and supporting the relationship between growth in behavioral self-regulation and academic achievement, only one time point of academic achievement was evaluated. Future work evaluating the role of self-regulation development on academic development didactically across time will likely give even more insights into how self-regulation affects academic achievement and how best to support this relationship. For example, previous research suggests that between preschool and second grade children also demonstrate rapid nonlinear growth in early literacy skills (Skibbe et al., 2008; Skibbe et al., 2012). Future research is necessary to more clearly ascertain the relationship between behavior self-regulation and this literacy development. One question that has yet to be answered is: are these leaps made somewhat concurrently, or do rapid self-regulatory gains proceed academic gains as past research suggest that high levels of behavioral self-regulation give children access to academic learning as it helps them to interact socially with peers and teachers, follow classroom rules, and attend to the necessary academic information (Birch & Ladd, 1998; Eisenberg, Valiente, & Eggum, 2010; Montroy et al., 2014, Williford, et al., 2013).

Additionally, this study capitalizes on a panel design with a large number of children with relatively few assessments (although more than any study to date) for the individual child. Thus, estimation in the current study relies both on individual and between child differences to estimate the development of behavioral self-regulation. Future work is still needed that more intensely focuses on the individual and their specific trajectory. Although traditionally inquiries in social sciences have focused on large cross sectional samples with an eye at generalizing results, findings from longitudinal research such as the current study increasing demonstrate that it is unreasonable to apply the same model in the same way to all individuals. Specifically Molenaar (2004) firmly asserts that to truly understand development and tailor services to the individual both a nomothetic, that is the study or formulation of general/universal laws, *and* an idiographic approach (study of individual cases) is necessary. With the increase in computational power and consequently the ability to estimate complicated models that properly consider the role of time and the many levels of functioning required for a complex construct such as self-regulation, it is increasingly possible to take both a nomothetic and an idiographic approach to development. This is also absolutely necessary in order to understand better when states across development that affect complex skills such as self-regulation (e.g., states related to stress physiology) become so commonplace that they become a part of the trait. The current study is a first step in beginning to bridge the gaps between traditional nomothetic, and idiographic approaches with a hope for the future that both will become common place.

Conclusions

In conclusion, this research is an important contribution to our understanding of how self-regulation develops during early childhood, particularly during the preschool time period, and how this development is linked to early literacy and mathematics achievement at the end of preschool. Specifically, findings indicate that the development of behavioral self-regulation is exponential in nature. Likewise, there are differences in this trajectory such that majority of children develop exponentially with gains accelerating across the preschool time period, while another group of children, although still demonstrating exponential growth, begin the preschool time period with comparatively higher levels of behavioral self-regulation and demonstrate rapid, but decelerating gains. In addition to these two exponential trajectories, a subset of children demonstrated low levels of initial behavioral self-regulation and little to no growth across preschool. These behavioral self-regulatory trajectories differences were linked both to different child background characteristics and, importantly, to different patterns of spring early literacy and math achievement. Specifically in relation to academic achievement children who began preschool with higher levels of behavioral self-regulation and gained rapidly had higher levels of spring early literacy and math achievement compared to individuals who began with lower levels and made accelerated gains later in the preschool time period. However, children who made gains, whether relatively early or later in preschool had higher levels of early literacy and math achievement in the spring than children who demonstrated little to no growth in behavioral self-regulation. Based on these findings researchers and educators alike should consider carefully how best to support individual children's development of behavioral self-regulation during the preschool time period, particularly for children who may be at-risk of making few gains during preschool as self-regulation development is key to successful school functioning both academically and socially.

APPENDIX

APPENDIX A

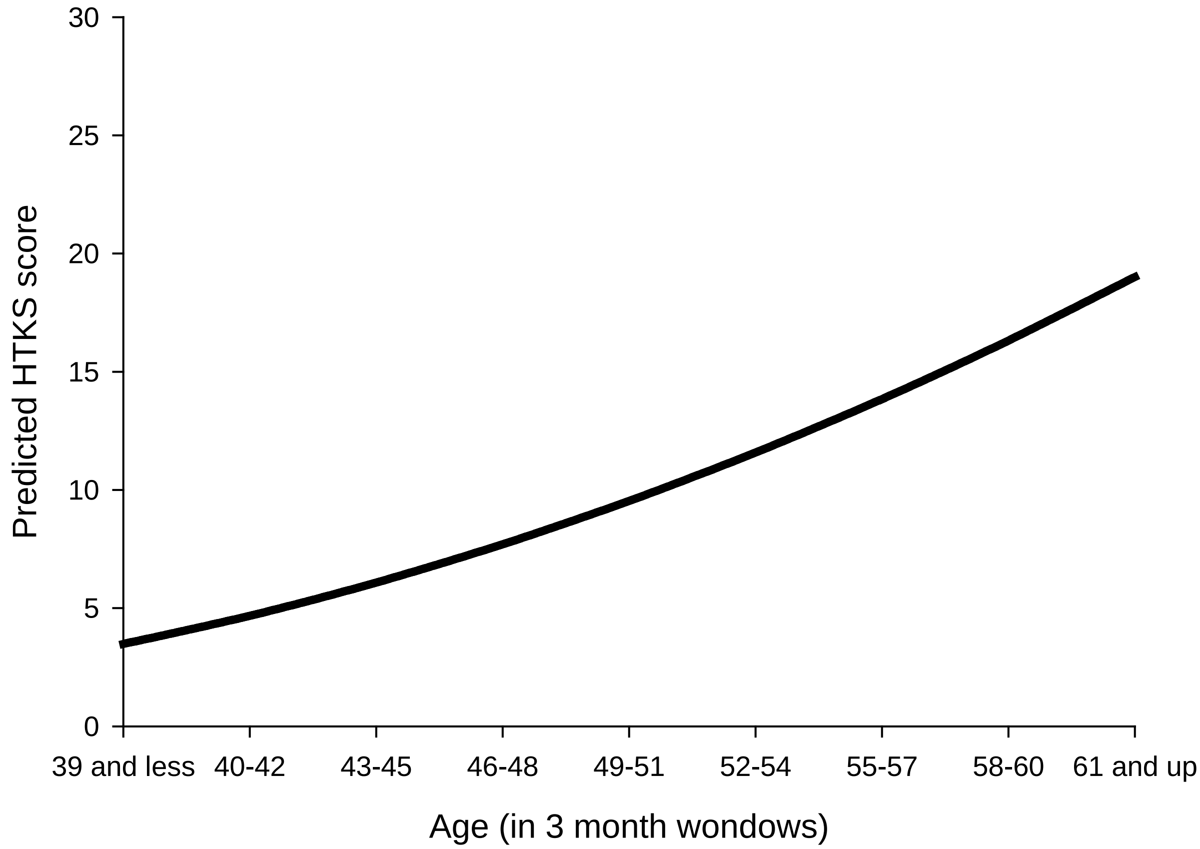

Figure A-4. Quadratic mean predicted developmental pattern for behavioral self-regulation across preschool.

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