Self-regulation and Academic Learning in Preschoolers with Autism Spectrum Disorder: Individual Differences and Links to Executive Function, Effortful Control, Reward Sensitivity, School Engagement, and Adaptive Behavior

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ABSTRACT

Self-regulation and Academic Learning in Preschoolers with Autism Spectrum Disorder: Individual Differences and Links to Executive Function, Effortful Control, Reward Sensitivity, School Engagement, and Adaptive Behavior

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Children's self-regulation has shown to be related to the trajectories across various domains of adaptive functioning and school success. Delay in self-regulation development represents an area of major challenge for children with autism spectrum disorder (ASD) (e.g., Jahromi, 2017), a neurodevelopmental disorder characterized by persistent deficits in social communication and interaction as well as restricted and repetitive behaviors (American Psychiatric Association, 2013). Children with ASD are often reported academic difficulties and underachievement compared to their typically developing peers (e.g., Nation et al., 2006). It has been well-documented that typically developing children with greater self-regulation had better academic achievement (e.g., Blair & Razza, 2007). However, few studies have extended the examination of the association between self-regulation and academic learning to the populations with special needs, especially to those with ASD. Moreover, the majority of previous studies solely relied on standardized assessments to reflect children's temporary learning *outcomes* rather than their dynamic learning *process*. Little is known about how children's self-regulatory skills are related to the way they learn and how various child characteristics moderate this association. Therefore, the goal of this study was to examine how the self-regulatory capacities of children with ASD, including executive function and effortful control, were linked to their dynamic academic learning process and to investigate the moderating effects of various child characteristics on this association, including ASD-related symptoms severity, school engagement, reward sensitivity, and adaptive behavior, all of which represent areas of challenge for children with

ASD. Additionally, children with ASD often receive many different types of reinforcement at school. Their ability to wait for delayed reinforcement and their responsiveness to different reinforcers seem crucial for how successful they could adapt to school lives. Thus, another goal of this study was to investigate children with ASD's responses to delayed reinforcement as well as token and social reinforcers in the natural classroom environment and to identify strategies that can facilitate their tolerance to delayed reinforcement and responsiveness to different types of reinforcers.

Thirty-two preschoolers aged 36 to 68 months from two specialized applied behavior analysis schools in the greater New York City area participated in the study. Each participant had an Individualized Education Program with a classification of Preschooler with Disability and had a current diagnosis of autism confirmed with the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012). Children with ASD received direct measures on their executive function in a laboratory setting and assessments on their responses to delayed reinforcement as well as token and social reinforcers in the natural classroom environment. Parents filled out reports regarding children with ASD's executive function, effortful control, and reward sensitivity. Teachers completed scales on these children's school engagement and adaptive behavior. Regarding the participants' academic learning, instead of using one-time standardized assessments, this study derived school data of multiple literacy and mathematics programs over a period of time to investigate the number of learning opportunities and additional one-to-one educational interventions a child required to achieve an academic objective in the learning process.

Findings in this study showed that children with ASD with better self-regulation engaged in school activities to a greater extent, demonstrated better adaptive behavior at school, and were reported to have stronger social communication skills. Children with ASD with better emotional control, attention, and inhibitory control achieved academic objectives in literacy faster, especially in the domains of word recognition and reading comprehension. Also, children with ASD with a better overall EF level learned math concepts and problem-solving skills faster in both trial-based and script-based mathematics curricula, and those with better working memory demonstrated a higher learning rate in the trial-based mathematics programs. Further analyses showed that the relationship between self-regulation and academic learning in children with ASD was influenced by their behavior school engagement and reward sensitivity. These results inform future interventions to focus on the school engagement behaviors and sensitivity to reward in children with ASD when developing their self-regulation and academic learning skills. Moreover, three socially-oriented strategies, including using language, gestures, and eye contact, were found to help children with ASD respond better to delayed reinforcement, above and beyond their self-regulation level. Also, these children responded better in a task that they already mastered under a situation in which tokens could be earned for exchanging preferred items or activities contingent on their performance rather than in a situation where only social attention was available.

Overall, self-regulation emerged as a potential protective factor for young children with ASD in their school success in terms of engagement and adaptive level as well as academic learning rates. Self-regulation development is recommended to be included as an essential component in future academic and social-emotional interventions for children with ASD. Meanwhile, developing the ability to use language, gestures, or eye contact to communicate needs and emotions may help children with ASD have a better response to delayed reinforcement in the natural classroom environment. Considering the majority of them demonstrated altered reward sensitivity characterized by nonsocial stimuli hypersensitivity and social rewards hyposensitivity, it is important to enhance their responsiveness and sensitivity to social reinforcers to promote their school adjustment and success.

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Chapter I

Introduction

Early childhood is a critical period for young children to learn and acquire new knowledge, skills, and behaviors. Children's cognitive and social development in this period has a long-lasting impact on their school success and psychosocial wellbeing (Mann et al., 2017). Research has highlighted the rapid development of self-regulation (e.g., Montroy et al., 2016) and its significant role in children's learning during this vital developmental period (e.g., Nesbitt et al., 2015). Self-regulation has been conceived as a multidimensional construct that functions to modulate various processes and responses, including executive function and temperamental effortful control (Jahromi, 2017; McClelland & Cameron, 2011). Executive function (EF) refers to the cognitive self-regulatory process. It is a complex integration of cognitive abilities involved in problem-solving, which mainly encompasses working memory, inhibition, cognitive flexibility, and attention (Carlson, Zelazo, & Faja, 2013; Geurts, de Vries, & van den Bergh, 2014; Müller & Kerns, 2015). Temperamental effortful control (EC) refers to children's "ability to inhibit a dominant response to perform a subdominant response" (Rothbart & Bates, 2006, p. 137). It also includes the abilities to voluntarily modulate attention and approach or withdrawal behaviors as needed to adapt (Eisenberg, 2012). Early childhood is a critical period for the emergence of EF and EC, which serves as the roots for the future growth of self-regulation. Although almost all children improve greatly in their self-regulation capabilities across the first five years of life, there are various individual differences in the developmental course of EF (Carlson, Mandell, & Williams, 2004) and EC (Eisenberg, 2012).

Considering the critical role of self-regulation in children's developmental trajectories, it is particularly imperative to examine the development of EF and EC among children with

Autism Spectrum Disorder (ASD), who often demonstrate delays in self-regulation (e.g., Geurts, de Vries, & van den Bergh, 2014). Individuals with ASD are characterized by persistent challenges in social communication and interaction as well as restricted, repetitive, and/or stereotyped behaviors (American Psychiatric Association, 2013). They also demonstrate prevalent deficits in EF as measured by direct assessments and parental reports (e.g., Geurts, de Vries, & van den Bergh, 2014). For example, children with ASD were reported to have more inhibitory control deficits by their parents than their typically developing peers (Boyd et al., 2009). They were found to have poorer performance in the direct measures that required various executive function skills, such as shifting and attention (Rumsey, 1985; Shu et al., 2001). Previous studies also suggested delays in EC in children with ASD. Jahromi, Bryce, and Swanson (2013) found that children with high functioning ASD were reported to have significantly delayed EC by their parents compared to their typically developing peers. Jahromi et al. (2019) also found that young children with ASD were rated significantly lower by their parents on EC measures than their typically developing peers.

Children's self-regulation has shown to be related to the trajectories across various domains of adaptive functioning and school success. For example, it has been well-documented that there is a positive association between self-regulation, including EF and EC, and academic achievement in typically developing children (e.g., Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; Fuhs et al., 2014). Research has found that young children's EF skills are significantly related to their literacy, language, and mathematics achievement (e.g., Allan & Lonigan, 2011; Clark, Pritchard, & Woodward, 2010). Robust relations between EF and academic outcomes were still apparent when controlling for intelligence (Blair & Razza, 2007; Bull et al., 2011) and prior academic achievement (Fuhs et al., 2014; Welsh et al., 2010). Similarly, the relation between EC and academic achievement has been established, such that higher EC is predictive of higher academic achievement (e.g., Coplan, Barber, & Lagace-Seguin, 1999; Valiente et al., 2010).

Overall, the work to date suggests the importance of self-regulatory processes for the academic learning outcomes of young children. However, much of the work has been on predominantly typically developing samples. Relatively little is known about the relationships between EF deficits or EC delays and individual differences in academic outcomes of children with ASD. One of the very few studies on this topic involved twice-exceptional students with ASD, whose cognitive abilities were well above the norm, and found that the executive function skills were related to their academic outcomes (e.g., Assouline, Foley Nicpon, & Dockery, 2012). There is a critical need for this line of work to be extended to children with ASD across a wide range of cognitive abilities, for whom both self-regulatory challenges and academic underachievement have been reported (e.g., Boutot, 2017; Geurts, de Vries, & van den Bergh, 2014). Compared to students in different disability categories, students with ASD have experienced some of the lowest rates of postsecondary success (Shattuck et al., 2012). It is argued that the reading and mathematics difficulties of individuals with ASD contribute to these poor outcomes. Wei, Blackorby, and Schiller (2011) examined the reading achievement of students with disabilities via the national data of the Special Education Elementary Longitudinal Study (SRI International, 2002) of 3,421 students with disabilities between 7 and 17 years old and found that students with ASD often demonstrated slower literacy growth curves compared to those with learning disabilities. Also, students with ASD were found to demonstrate improvements in word identification and comprehension between age 7 and 17 and achieved word reading skills and comprehension ability that resemble those of typically developing 10-year-olds at the age of 17 (Wei, Blackorby, & Schiller, 2011). Mathematics growth statistics also demonstrated that students with ASD have slower growth in math calculation compared to students with learning disabilities (Wei, Lenz, & Blackorby, 2013). Moreover, students with ASD often exhibit uneven learning profiles as they may function at or above age level in some subject areas but well below age level in others (Boutot, 2017). This pattern requires teachers to pay closer attention to the learning progress of students with ASD in different subject areas and to explore potential factors that may facilitate learning and long-term success for them.

Moreover, the majority of existing studies adopted standardized assessments to measure young children's academic performance when investigating the association between EF/ EC and academic achievement (e.g., Blair & Razza, 2007). Even though norm-referenced standardized tests are the most commonly used assessments to demonstrate and compare students' academic achievement (Boutot, 2017), these assessments can only reflect the learning *outcomes* rather than the dynamic learning *process* of young children. Less information exists about the association between self-regulation and how a child proceeds to learn in early childhood, the relation of which can help us understand the specific mechanism underlying the associations with academic achievement outcomes. Children go through rapid development during the preschool years. Previous research showed that the skills acquired in preschool served as essential foundations to later development of reading and writing (Lonigan, 2006; Snow, Burns, & Griffin, 1998). Children with stronger emergent literacy and numeracy skills demonstrated more advanced reading levels and better school adjustment when transiting to kindergarten (Lonigan et al., 2000). Therefore, understanding the learning process of children, especially those with ASD who have evident academic difficulties, seems to be particularly important during the preschool years.

A few studies attempted to explore children's learning processes more deeply through observing their learning-related behaviors and to examine the mediating effect of these behaviors on the association between EF/ EC and academic achievement. For instance, Nesbitt, Farran, and Fuhs (2015) found that children with greater EF skills in the prekindergarten programs were more likely to be observed as having higher levels of involvement, more sequential learning behaviors, more participation in social-learning interactions, and fewer demonstrations of unoccupied and disruptive behaviors. Among these learning-related behaviors, children's level of involvement, sequential learning behaviors, and engagement in the classroom mediated the association between EF skills and literacy and mathematics gains. Thus, EF skills are significant for understanding how young children engage in learning opportunities in a pre-K classroom setting and ultimately impact their pre-K literacy and math improvement. In contrast, Brock and colleagues (2009) found that young children's EF skills significantly predicted their math achievement, learning-related behaviors, and school engagement. However, learning-related behaviors did not account for, or mediate, the association between EF skills and math achievement. The contradictory findings on the role of learning-related behaviors in the relation between EF and academic achievement suggest that more studies would be needed to further examine how EF may be related to children's learning processes and what child characteristics may contribute to this association.

Autism is a spectrum disorder with various types and severity levels of symptoms. The heterogeneity of ASD is manifested by its phenotypic variations (American Psychiatric Association, 2013) and is supported by neuroimaging (Martinez-Murcia et al., 2017) and etiology studies (Jeste & Geschwind, 2014). There may be wide variation in the self-regulatory challenges and academic difficulties of children with ASD with different levels of symptoms. Therefore, it is significant to consider the symptom severity of children with ASD when investigating the association between their self-regulation abilities and academic learning, which has not yet been examined.

School engagement may be another important contributor to the variability in academic achievement observed in children with ASD. Research on academic achievement in typically developing children suggest a strong relationship between school engagement and academic achievement (e.g., Ladd et al, 1999). Students who like the school setting and engage in classroom activities actively were found to be more likely to achieve academic goals and have better academic achievements (Alexander & Entwisle, 1988). In contrast, students who had disruptive or inattentive behaviors were found to have lower scores on all achievement tests (Finn et al., 1995). However, the relationship between school engagement and academic achievement in children with ASD is not currently well understood. Children with ASD often demonstrated poorer school engagement compared to their typically developing peers, which was linked to their self-regulation skills (Jahromi et al., 2013). Therefore, it is important to consider how school engagement contributes to the association between self-regulation and academic learning in children with ASD.

Adaptive behavior is another important factor correlated with the academic achievement in children with ASD. Adaptive behavior refers to an individual's ability to function independently (Tassé et al., 2012). Academic achievement has been shown to correlate with different domains of adaptive functioning. For example, children with ASD with greater levels of social skills at age 6 demonstrate better word reading later at age 9 (Estes et al., 2011). The communication skills of children with ASD were found to be positively associated with their reading accuracy and comprehension performance (Arciuli et al., 2013). Meanwhile, adaptive behaviors were associated with self-regulation in individuals with ASD above and beyond IQ, age, and the severity of ASD symptoms (Gilotty et al., 2002; McLean et al., 2014). Thus, it requires us to examine the role of adaptive behavior in the association between self-regulation and academic learning in children with ASD.

Reward sensitivity refers to the extent to which goal-directed behavior is affected by the availability of reinforcement and familiarity with reward incentives (Pankert et al., 2014; Reed et al., 2012). Clinical observation and empirical studies suggest that preschool-aged children with ASD demonstrated altered reward sensitivity (e.g., Dawson et al., 2001). Particularly, they showed enhanced motivation to pursue non-social stimuli based on personal interests but had impaired motivation for social interactions (Dawson, Webb, & McPartland, 2005). Additionally, difficulties in understanding rules about stimulus-rewarding associations have also been found in young children with ASD (Dawson et al., 2001). Studies in typically developing adults suggest that there is an association between reward sensitivity and self-regulation. For example, Carver and White (1994) found that college students with higher sensitivity to punishment had less self-control than those who were less sensitive to punishment. However, there are very few studies that examined the relationship between reward sensitivity and self-regulation in children with ASD, for whom atypical development appears in both domains. Also, relatively little is known regarding the association between reward sensitivity and academic outcomes in this population. Considering the clinical evidence that altered reward sensitivity begins to show in children with ASD from preschool, it is important to examine the extent to which reward sensitivity relates to self-regulation and academic outcomes in this atypical population during early childhood, an important period during which self-regulation skills also develop rapidly.

During the early childhood period, children begin to learn in a formal educational setting. The concurrence of self-regulation development and transition to a formal learning environment makes early childhood a critical period for investigating how a child's EF and EC contribute to his or her academic learning progress. Young children with ASD often receive applied behavior analysis services to foster their development. It is important to understand the role of self-regulation in such learning settings. Thus, this study attempts to examine self-regulation capacities and the learning process of preschool-aged children with ASD in specialized applied behavior analysis schools in the suburbs of New York City, which adopt the Comprehensive Application of Behavior Analysis to Schooling (CABAS®)

instructional model (Greer, 2002). Particularly, the CABAS® schools access individual prerequisites of each student through the CABAS® Developmental Inventory: Early Learner Curriculum and Achievement Record (ELCAR; Greer, 2020) and design individualized instructional program and curriculum objectives based on each student's current verbal behavior development. It is believed that the monitoring of individualized learning progress in the CABAS® model can provide a more in-depth inspection of how children with ASD proceed to learn and the opportunity to examine associations between individual differences in young children's self-regulation and learning process.

Statement of the Problem and Study Rationale

It has been well documented that a significantly positive association exists between EF, EC, and academic achievement in typically developing children. However, few studies have extended the examination of this association to populations with special needs, especially to those with ASD. For individuals with ASD who often demonstrate profound deficits in EF and delays in EC, and slower growth in academic progress compared to their typically developing peers, it is particularly imperative to investigate whether deficits in self-regulation may hinder their academic learning. Therefore, this study focused on children with ASD to examine how assessments of their EF and EC relate to individual differences in academic learning in early childhood.

Moreover, previous studies solely relied on standardized assessments to assess children's learning *outcomes* rather than examining their learning *process*. As a result, the specific mechanism underlying the association between self-regulation and academic achievement in early childhood remains unclear, especially for children with ASD. Thus, this study attempted to understand more deeply the dynamic learning process of children with ASD when investigating how self-regulation relates to academic improvements in the school context where instructions were used based on the principles of applied behavior analysis.

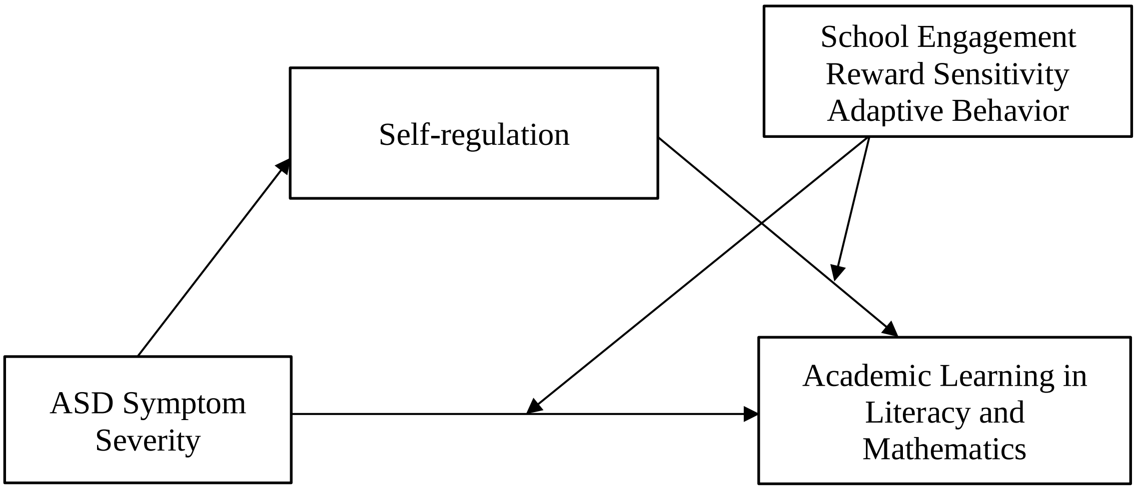
Furthermore, the results of the few studies that explored the mediating roles of learning-related behaviors in the association between self-regulation and academic achievement have been mixed. Thus, more studies need to be conducted to further investigate the mechanisms underlying the relationships between self-regulation skills and the dynamic learning process by investigating the roles of various child characteristics.

The Purpose of the Study

The overall purpose of the study was to examine the associations between self-regulation, the severity of ASD-related symptoms, school engagement, reward sensitivity, adaptive behavior, and academic learning in children with ASD in a preschool setting that adopts teaching instructions based on the principles of applied behavior analysis. The first goal of the study was to examine whether self-regulation skills and other essential child characteristics measured by direct assessments and parental reports were related to one another in children with ASD during the preschool years. Specifically, self-regulation was measured in two main perspectives in the study: executive function and temperamental effortful control. In line with previous literature, other child characteristics examined in the study included: the severity of ASD-related symptoms measured by observations of children's behaviors in a diagnostics assessment, behavioral and emotional school engagement reported by teachers, reward sensitivity reported by parents based on children's behaviors in everyday life, and adaptive behavior reported by teachers with diverse focuses from communication skills, daily living skills, social skills, to motor skills. The second goal of the study was to examine the associations between self-regulation, child characteristics, and academic learning in children with ASD at school. Instead of using a one-time standardized assessment, academic learning was examined through a closer investigation of the number of learning opportunities and additional one-to-one education interventions a child required over a period of time to achieve an objective in the literacy and mathematics programs that of various academic purposes and under different teaching approaches. The academic programs covered alphabetic knowledge, phonemic awareness, word recognition, reading comprehension, basic number skills, and mathematics problem-solving skills. This way may gain insights into the dynamic learning process in children with ASD rather than solely focusing on their academic achievement reflected on standardized measures. The third goal of this study aimed to examine the specific mechanism underlying the association between self-regulation and academic learning in early childhood. Specifically, the moderating effects of the severity of ASD traits, school engagement, and reward sensitivity were investigated. Also, the study investigated whether EF or EC serves as a mediator between the relationship between the severity of ASD-related symptoms and the academic learning process of young children with ASD. Furthermore, young children with ASD often receive different types of reinforcement in the applied behavior analysis schools, and thereby their reward sensitivity seems to be particularly important for their school success. Thus, the fourth goal of this study was to understand more deeply self-regulation and reward sensitivity of young children with ASD by mimicking some frustrating situations they often encountered in the classroom setting (e.g., delayed reinforcement delivery, delayed turn-taking activities) and examining how children with ASD perform differently with social and non-social stimuli. Specifically, three behavioral tasks (delayed delivery of edibles, delayed delivery of tokens, and delayed turn-taking with an adult) were implemented to examine how children with ASD adopt different strategies in response to delayed reinforcement and to investigate how EF, EC, and other child characteristics were associated with children's ability to wait. A post-hoc test was conducted using the A-B-A-B reversal design to examine the performance of children with ASD between token and social reinforcement. The study then investigated how performance difference of children with ASD under the two conditions was associated with their academic learning, self-regulation, and other child characteristics. See Figure 1 for the Conceptual Model.

Figure 1

Proposed Conceptual Model for Associations among Study Variables



Chapter II

Literature Review

The purpose of this chapter is to review the literature and background of academic learning of young children with ASD and the child characteristics related to it, including executive function (EF), effortful control (EC), school engagement, and reward sensitivity. The review begins with the theoretical framework guiding the current study, including Social Cognitive Theory (Bandura, 1986), Operant Learning (Skinner, 1938), and Cumulative Learning Theory (Gagné, 1968). It then describes the core components of EF and EC along with their developmental courses. This review continues to provide evidence of EF deficits and delayed EC development in children with ASD. This chapter then reviews the empirical evidence about academic underachievement in individuals with ASD and its associations with EF deficits and EC delays. The relation between school engagement, reward sensitivity, adaptive behavior, and learning are then examined. The learning methodology used in schools providing applied behavior analysis is introduced. Finally, research questions and hypotheses are presented.

Autism Spectrum Disorder (ASD) is a neurodevelopmental disability that characterized by persistent deficits in social communication and social interactions and restricted, repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). According to the Centers for Disease Control and Prevention (CDC), there is about 1 in 59 children that have been identified with ASD in the United States (CDC, 2018). The significant increasing prevalence of ASD globally urges us to focus on the special needs of this population to increase their wellbeing.

Academic learning and school success have a long-lasting impact on individuals' wellbeing. Children with ASD often reported significant academic difficulties and slower learning compared to their typically developing peers. Students with ASD have lower reading and math abilities, on average, compared to their typically developing peers (Boutot, 2017). Even compared to students with other disabilities, students with ASD also experienced some of the lowest rates of academic success related to reading and mathematics difficulties (Shattuck et al., 2012). Also, the ability levels of individuals with ASD are often diverse and heterogeneous. They often have uneven learning profile with excelled performance in an area of interest but well below age level in others (Boutot, 2017). The academic underachievement and special educational needs experienced by individuals with ASD require our attention to provide remediation of their academic risks in school settings and strive to explore potential factors that may facilitate learning for them.

There has been increasing research attention to a broader array of factors that affect children's performance in school. Findings that self-regulation predicts academic achievement beyond cognitive abilities (Blair & Razza, 2007; Bull et al., 2011) highlight the importance of examining individual differences in self-regulatory skills when considering children's academic learning. Self-regulation has been conceived as a multidimensional construct that functions to modulate various processes and responses, including EF and temperamentally based EC, which are central to understanding self-regulation in early childhood (Jahromi, 2017; McClelland & Cameron, 2011). Specifically, EF is a complex cognitive self-regulatory process involved in problem solving, which mainly encompasses inhibition, working memory, cognitive flexibility, and attention (Geurts, de Vries, & van den Bergh, 2014; Jones et al., 2016; Miyake et al., 2000). Temperamental EC refers to children's ability to voluntarily modulate attention and to inhibit prepotent but inappropriate responses or behaviors and to perform a subdominant response (Eisenberg, 2012; Rothbart & Bates, 2006). Self-regulation is crucial for the quality of children's social interactions and their learning capabilities (Eisenberg, 2012). Young children are increasingly expected to self-regulate their behaviors, emotions, and thoughts as they mature. Particularly during early childhood, young children begin to learn to apply their self-regulatory skills to manage their thoughts, behaviors, and emotions in their daily performance at school. However, individuals with ASD demonstrate prevalent deficits in EF (e.g., Geurts, de Vries, & van den Bergh, 2014) and developmental delays in EC (e.g., Jahromi, Bryce, and Swanson, 2013; Konstantareas and Stewart, 2006). Research shows that one of the risk factors of academic underachievement in individuals with ASD relates to their self-regulation deficits or delays (e.g., Assouline et al., 2012). Considering the tight association between self-regulation and academic outcomes, it is imperative to examine how individual differences in EF and EC are related to academic learning process of young children with ASD, and to investigate the child characteristics that influence this association.

Theoretical Framework

Social Cognitive Theory

Social Cognitive Theory proposed by Albert Bandura explains human learning through the continuous reciprocal relationship between cognitive, behavioral, and environmental influences (Bandura, 1986). According to this theory, personal factors (e.g., cognition or perceptions), behaviors, and the environment are interrelated with and influential to each other, all of which contribute to the complex learning process together. It is argued that mastery of any skill often requires repeated learning opportunities to coordinate personal, behavioral, and environmental components (Zimmerman & Schunk, 2004). Specifically, in the person-environment interaction, personal factors including cognitive competencies are modified by external factors, such as parent and environment. In the person-behavior interaction, the cognitive processes can affect an individual's behavior. Likewise, behavioral performance can modify the way an individual think. In the environment-behavior interaction, external factors can change the way an individual emits a behavior. Also, one's behavior can also modify and affect the environment (Bandura, 1986). This model of triadic reciprocal determinism guides the current study to focus on various factors contributing to the academic learning process directly and indirectly, including personal factors, such as self-regulation and ASD traits; its effects on behavior, such as school engaging behaviors; and its effects on environment, for instance, the role of temperamental EC in establishing peer and teacher interaction at school, which in turn affect one's academic performance.

Social Cognitive Theory particularly emphasizes the central role of cognition in the learning process between responding to external stimuli and emitting an individual behavior. Self-regulation is one of the core concepts of this theory, which highlights the importance of controlling one's behaviors and thoughts on learning. It is believed that self-regulation accounts for individual differences in achievement, and the improvements in self-regulatory skills can lead to better academic performance (Schunk & Zimmerman, 2012). Students with better self-regulatory skills often actively contribute and exercise control over their academic learning behaviors and endeavors, for example, focusing effort on the learning goal and inhibiting distractions (Schunk, Pintrich, & Meece, 2008).

Finally, Social Cognitive Theory also emphasizes the significant role of reinforcement or punishment in the future occurrence of a behavior. It argues that new experiences are to be evaluated by the learner through analyzing his or her past experiences with the same determinants under similar conditions (Bandura, 1986). In this perspective, social cognitive theory helps to explain how individuals regulate their behaviors through self-regulation as well as previous consequences of such behaviors (reinforcement or punishment) to achieve learning goals. This construct of Social Cognitive Theory guides the current study to focus on the reciprocal relationship between behavior and environment during the learning process, for example, the learn unit approach, which demonstrates the three-term contingencies of antecedent, behavior, and consequence, and children's reward sensitivity, a personal factor of which may affect the reciprocal interaction of learning behavior and consequence delivered by teachers.

Operant Learning

Based on the law of effect proposed by Edward Thorndike (1898), which suggests the behaviors followed by pleasant consequences have increased future occurrence whereas behaviors followed by unpleasant outcome have decreased future occurrence, Skinner (1938) introduced the principle of operant conditioning, which is also a method of learning that occurs through reinforcement and punishment for a behavior. Through operant conditioning, an association between a specific behavior and a consequence can be established. Specifically, behavior which is reinforced tends to be more likely to repeated, whereas behavior which is punished tends to have decreased likelihood to occur in the future under similar condition (Skinner, 1938). In terms of this principle, operant behaviors are shaped by consequences. It highlights the importance of consequences delivered by teachers on students' behaviors during learning process. Therefore, the principle of operant conditioning guides this study to adopt the learn unit approach to measure students' rate of learning and its dynamic process as the three-term contingency trial of learn unit integrates an antecedent, a student's behavior, and an immediate or delayed consequence by the teacher (Greer, 1994).

Cumulative Learning Theory

Cumulative learning theory proposed by Robert M. Gagné (Gagné, 1968) argues that there are different types of learning based on individual differences in intellectual skills and emphasizes that learning and development accrue cumulatively and incrementally as successive capabilities are attained (Gagné, 1970). Gagné (1970) argued against the stage construct and presumed that there are no particular points in life that determine when a person is ready to learn or to develop any particular capability. Instead, the present capabilities of individuals are the determinants or prerequisites of what they can start to learn or develop next (Gagné, 1970). According to Gagné (1968), various characteristics of the learner must be taken into consideration during the learning process, including intellectual skills, repertoires of skills, and current knowledge states. It highlights that it is crucial to consider the individual differences in children's cognitive ability and prerequisites capability when developing instructional approaches and academic objectives for them. This viewpoint guides the current study to examine young children's EF, EC, school engagement, and reward sensitivity when investigating their learning process.

Moreover, the Cumulative Learning Theory proposes that there are Nine Essential Steps of Instruction: 1) Gain students' attention by presenting stimulus to ensure reception of instruction; 2) State a learning objective; 3) Stimulate recalling of prior learning; 4) Present the stimulus of a new content; 5) Provide learning guidance; 6) Elicit learning performance responding to teachers' stimulus; 7) Teacher provides feedback based on the learner's performance; 8); Assess students' performance; 9) Enhance retention and generalization to other contexts (Gagné, 1970). This instructional approach highlights that it is important to obtain students' attention before any other teaching step. Student's internal learning processes can lead to various learning outcomes when the events of instruction occur. Therefore, it is believed that students' better attentional control abilities can facilitate this instructional step. In addition, this instructional approach also recognizes the importance of providing appropriate antecedent stimulus and consequence in between the students' learning behaviors to aid the learning process of them, which are in accordance with the principle of operant learning. In this perspective, Cumulative Learning Theory guides the current study to focus on students' attention, which is one of the core skills of EF, during their learning process and the operant conditioning procedure used by the teacher.

Self-regulation in Young Children

The emergence of self-regulation in early childhood plays a significant role in young children's developmental trajectories. It broadly refers to the abilities to modulate affective, cognitive, and behavioral responses (Blair & Diamond, 2008; Posner & Rothbart, 2007). As a multidimensional construct, self-regulation continuously obtains scholars' attention to examine its various components and the coalescence across its different dimensions (e.g., McClelland & Cameron, 2011). For instance, in the comprehensive review of self-regulation with a focus on children with ASD conducted by Jahromi (2017), self-regulation has been considered as a multidimensional construct that functions to modulate various processes and responses, including emotional regulation, EF, and temperamental EC. The increased examination of the constructs of self-regulation is crucial to understand young children's adaption to and learning in school settings (Blair, 2002; Howse et al., 2003), especially for those who experience self-regulatory challenges, particularly, those with ASD (Jahromi, 2017). Therefore, this study will first review the key components of self-regulatory repertoires of young children.

Mainly, EF is a complex cognitive process involved in problem-solving, whereas EC is temperamentally based self-regulation tendency towards behavioral and emotional reactivity under social or emotional situations (Blair & Diamond, 2008; Posner & Rothbart, 2007). EF and EC are two distinct constructs that share similar core components, which are inhibition of dominant responses, shifting and attention control (Carlson, Zelazo, & Faja, 2013; Diamond, 2013; Eisenberg, 2012). Together, EF and EC comprise key components of self-regulation, and the examination of these two constructs will provide a comprehensive investigation of children's modulation of thoughts, behaviors, and emotions in the school settings. Even though EF and EC both develop rapidly during early childhood and are the foundations of more complex self-regulatory skills, it is imperative to note their differences before examining their roles on the academic learning of young children. By examining both roles of cognitively-oriented EF in conjunction with temperament-based EC in emotionally-driven situations, this study provides a comprehensive understanding of how key features of self-regulation contribute to young children's academic learning during early childhood.

Executive Function

Executive function underlies individuals' ability to manipulate and monitor thoughts and actions, which is generated in the prefrontal cortex of the brain (Geurts, de Vries, & van den Bergh, 2014; Lehto et al., 2003; Miyake et al., 2000). It refers to a complex integration of top-down mental processes involved in problem-solving, the cores of which are generally believed to encompass inhibition, working memory, cognitive flexibility, planning and attention control (Carlson, Zelazo, & Faja, 2013; Diamond, 2013; Geurts, de Vries, & van den Bergh, 2014; Müller & Kerns, 2015). Based on these core components, higher-order EF skills are developed such as planning, reasoning, and goal-setting, which may integrate other knowledge above and beyond the core-component processes (Collins & Koechlin, 2012; Geurts, de Vries, & van den Bergh, 2014; Lunt et al., 2012). These more sophisticated skills of EF are typically investigated among older children or adults, whereas the core domains of EF are usually presented as the keys to examine self-regulation during early childhood (Diamond, 2013). The measures of EF skills are primarily through cognitively-oriented tasks, which are often assessed through computer or highly structured activities in a controlled lab environment without involving social situations or emotions (Jones et al., 2016). In order to investigate the contributory role of EF on learning during early childhood, it is important to first review the core domains of this cognitive control process.

Core Domains of Executive Function.

Inhibition**.** Inhibition, which is also called inhibitory control, refers to the ability to generate appropriate responses in social interactions while inhibiting inappropriate impulses

(Geurts, de Vries, & van den Bergh, 2014). Inhibition includes controlling one's attention, behavior, emotions, and/or thoughts, therefore, this core EF skill makes it possible for us to alter our behaviors or cognitive reactions that have been conditioned by environmental stimuli (Diamond, 2013). Specifically, inhibitory control over one's behaviors and emotions is also called self-control, which is about resisting inappropriate impulses and temptations (Diamond, 2013). Cognitive inhibition refers to the capacity to restrain predominant mental representations and resisting nonpreferred thoughts (Anderson & Levy, 2009; Diamond, 2013). Overall, inhibitory control enables us to stay on task despite distractions or temptations and to suppress inappropriate impulses or premature prepotent responses while generating appropriate responses.

***Working Memory*.** Working memory refers to the ability to temporarily and mentally store, process, and manipulate information. It is crucial for tasks that require holding information about what happens earlier in mind and relating that to what comes afterward. Thereby, working memory plays an important role in academic tasks including those involves written or spoken language, arithmetical operation, or reasoning (Diamond, 2013). Working memory and inhibitory control support one another in the majority of events. Holding the key information in mind through working memory increases the likelihood that a prepotent but inappropriate response is inhibited while an appropriate one emits. Inhibiting internal and external distractions can also help an individual concentrate on manipulating the key information in mind while suppressing irrelevant thoughts and behaviors (Diamond, 2013).

Cognitive Flexibility. Cognitive flexibility, which is also called shifting or mental flexibility, refers to the ability to change strategies and to rapidly switch from tasks to tasks (Diamond, 2013; Geurts, de Vries, & van den Bergh, 2014). It also relates to the ability to change perspectives spatially or interpersonally, update our previous thoughts about something, and adjust our behaviors due to changing demands (Diamond, 2013).

Planning. Planning refers to the capacity to anticipate future events and to develop effective approach or steps in a timely manner to achieve a goal or to carry out a task (Gioia, Espy, & Isquith, 2003).

Attention Control. Attention control, which is also called executive attention or attentional inhibition, allows us to selectively attend to what we prefer and to voluntarily suppress attention to other stimuli, in contrast to stimulus-driven involuntary attention (Diamond, 2013; Posner & DiGirolamo, 1998; Theeuwes, 2010). Factor analyses have demonstrated that attentional inhibition and inhibition of behavior are significantly correlated (Friedman & Miyake, 2004). Research also shows developmental improvement in working memory can support improvement in attention control (Stedron, Sahni, & Munakata, 2005).

Developmental Course. Children's EF capacities emerge in infancy, experience the greatest development growth between 3 and 6 years old, and continue to develop more gradually throughout middle childhood and adolescence (Garon, Bryson, & Smith, 2008; Diamond et al., 1997; Zelazo et al., 2003). The emergence of individual differences in EF has been found in the third year of life (Carlson, Mandell, & Williams, 2004). Specifically, during early childhood, children develop inhibitory control of suppressing inappropriate behavioral and emotional impulses or ignoring interfering stimuli (Carlson & Moses, 2001; Diamond, 1990), sustained attention to ignore distractions (Klenberg, Korkman, & Lahti-Nuuttila, 2001), working memory ability to hold and manipulate information in mind (Baddeley & Hitch, 1974; Bell & Cuevas, 2012), shifting in response to different sets of tasks or changing situational demands (Zelazo, Frye, & Rapus, 1996; Zelazo et al., 2003), and then integrate these skills together to solve more complex problems (Asato, Sweeney, & Luna, 2006; Bull, Espy, & Senn, 2004). These EF skills are found to be more distinct and differentiated in adults but are far less distinct in early childhood. Therefore, assessments of EF tend to be represented by a unitary factor during early childhood (Hughes et al., 2009;

Wiebe, Espy, & Charak, 2008; Willoughby et al., 2010). Considering that early childhood from age 3 to 6 years old is particularly salient to self-regulation research because the core EF skills grow dramatically during this preschool period (Best & Miller, 2010; Garon, Bryson, & Smith, 2008), and the fact that the majority of EF measures are not developmentally appropriate before three years of age (Jones et al., 2016), this study will primarily focus on the EF skills of 3- to 6-year-old preschool-aged children.

Temperamental Effortful Control

Effortful control refers to an innate temperamental predisposition related to self-regulation, which involves the abilities to voluntarily manage attention, behavior, and emotions (Diamond, 2013; Lengua, 2009; Rothbart & Bates, 2006). The key components of EC comprise inhibitory control of behaviors, attention control, and attention shifting. Particularly, temperamental effortful control emphasizes children's "ability to inhibit a dominant response to perform a subdominant response" (Rothbart & Bates, 2006, p. 137) and includes the abilities to modulate attention voluntarily and to activate or inhibit behaviors as needed (Eisenberg, 2012). As an important dimension of temperament, EC is constitutionally based self-regulatory tendencies that emerge early in life and influenced overtime by genes, environment, and experience but relatively stable throughout the life (Caspi & Shiner, 2006; DePauw et al., 2009; McCrae et al., 2000; Posner & Rothbart, 2007; Rothbart, Derryberry, & Hershey, 2000). Early childhood is a critical period for the growth of temperamental EC, which serves as the roots for future growth of self-regulatory skills (Eisenberg, 2012). Research shows that the majority of children improve rapidly in their temperamentally based EC through the first five years of life while there are still some individual differences in its developmental course due to both biological factors, such as genes and prenatal environment, and external environmental influences during early childhood, such as parenting (Eisenberg, 2012). For those who have delays in the development of EC, it is more likely for them to fail to inhibit inappropriate behaviors or emotions to peers and adults in social interactions and to have poorer attention for academic tasks. Studies have demonstrated that developmental differences in EC during early childhood has been associated with problem behaviors, negative emotions, and social competence concurrently and at older ages (Eisenberg et al., 2009; Eisenberg, Valiente, & Eggum, 2010; Kochanska & Knaack, 2003). Unlike the measures of EF, the investigations of EC typically involve managing strong emotions such as frustration, desire, or motivation, besides cognitive-demanding tasks and are often conducted within the context of social interactions or through observations of behaviors reported by parents or teachers (Eisenberg, 2012; Jones et al., 2016).

Delays in Self-regulation in Individuals with ASD

Executive Function Deficits in Individuals with ASD

Individuals with ASD have been found to prevalently manifest deficits across various dimensions of EF (Geurts, de Vries, & van den Bergh, 2014; Hill, 2004). The first account of executive dysfunction in ASD was Damasio and Maurer (1978), who described the similarities of specific behaviors between individuals with ASD and those with frontal lobe damages, the brain region of which determines the capacity of EF. Brain imaging studies showed that individuals with ASD performed abnormal activation in the frontostriatal circuitry when taking EF-related tasks as they often recruited more brain areas as compared to typically developing people (Gilbert et al., 2008; Kana et al., 2007; Luna et al., 2002; Schmitz et al., 2006). Many studies revealed that the executive dysfunction manifested by individuals with ASD are often demonstrated by their higher proportion of performance impairments in various EF tasks than those of typically developing peers. For example, Rumsey (1985) found that, compared to typically developing peers, children with ASD had much poorer performance in the Wisconsin Card Sorting Test, a task aimed at testing most of the significant executive control capacities, including shifting, inhibitory control, working memory and attention. Shu et al. (2001) also found that children with ASD had more difficulties in shifting their behaviors in the Wisconsin Card Sorting Task than their typical peers. EF deficits in individuals with ASD are also demonstrated by parental reports, particularly the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). For instance, Boyd et al. (2009) found that school-aged children with ASD aged 6 to 17 years had been rated significantly more issues of inhibitory control by their parents on the BRIEF than their typically developing peers. Meta-analysis studies also show that executive dysfunction exist in individuals with ASD across development (Demetriou et al., 2018).

EF deficits have been reported in individuals with ASD starting from the preschool age. Sinzig et al. (2014) reported that preschool and elementary school children with ASD showed clear deficits in inhibitory control on the direct EF measure Go/No-Go task and sustained attention impairments compared to typically developing peers. Jahromi, Bryce, and Swanson (2013) found that preschool-aged children with ASD were reported significantly more inhibitory control and emotional control problems on the Behavior Rating Inventory of Executive Function, Preschool version (BRIEF-P; Gioia, Isquith, Guy, & Kenworthy, 2000) than their typically developing peers. Children with ASD at a very young age between 2.7 and 3.5 years were also reported by their parents significantly more inhibition and shifting deficits on the BRIEF-P (Carotenuto et al., 2019). Overall, EF deficits begin to demonstrate in children with ASD during early childhood, when most of them begin to learn in a formal educational setting and start to receive special education services. There is a need for more work to better understand how variances in EF levels of children with ASD relate to their academic achievement and school success from preschool.

It should be noted that, even though executive dysfunctions are not rare in individuals with ASD, they are not specific for this population. Various other disorders also perform EF deficits, such as ADHD (Antonini et al., 2015). Considering the prevalence of executive dysfunction in individuals with ASD and its relation with poor self-regulation and impaired learning ability, it is particularly important to examine how individual differences in EF are related to academic learning progress in children with ASD.

Effortful Control Delays in Individuals with ASD

Delayed EC has been repeatedly reported in individuals with ASD, which are demonstrated by measures across a variety of settings. For example, Jahromi, Bryce, and Swanson (2013) examined EC of young children with high functioning ASD, on average, aged around 55 months, and their matched typically developing peers through a parental report of temperament measure. Results showed that children with high functioning ASD demonstrated significantly delayed EC reported by their parents compared to their typically developing peers. Jahromi, Chen, Dakopolos, & Chroneue (2019) also found that young children with ASD were rated significantly lower by their parents on temperamental EC measures than their typically developing peers. Similarly, Faja and Dawson (2015) examined the level of temperamental EC among 6- to 7-year-old young children with ASD without intellectual disabilities and found lower EC in them compared to their typically developing peers based on the parental reported questionnaire, representing by lower scores for maintaining attention on tasks and inhibiting inappropriate responses when directed. The significant difference in EC between children with ASD and their comparative group of peers remains apparent for older age groups and in larger sample size. For instances, Konstantareas and Stewart (2006) found that children aged 3 to 10 years old with ASD demonstrated lower EC than their typically developing peers. De Pauw et al. (2011) also found prevalent delayed EC in a larger group of 175 children with ASD averagely aged 10 relative to their typically developing peers based on the parental reports. Overall, it has been well reported through temperament questionnaires that children with ASD exhibit delays in EC compared to their typically developing peers. Many researchers suggest that the examination of temperamental

EC can significantly advance our understandings of the heterogeneity of symptoms presented in ASD. It is believed that individual differences in temperamental EC may help to explain the fact that behavioral or emotional issues appear not to exist in all but some children with ASD (Garon et al., 2009; Hepburn & Stone, 2006; Konstantareas & Stewart, 2006; Schwartz et al., 2009; Samyn, Roeyers, & Bijttebier, 2011).

Academic Underachievement in Individuals with ASD

Considering the heterogeneity of the ability level of individuals with ASD, it is believed that patterns of academic underachievement in this population can be varied, and the factors associated with positive academic outcomes of them may be diverse. In general, literacy and mathematics are the two main areas of challenge for children with ASD (e.g., Grigorenko et al., 2003; Nation et al., 2006; Wei, Lenz, & Blackorby, 2013). It has long been reported that students with ASD have poorer academic achievements compared to their typically developing peers represented by their lower reading and math abilities on average (Boutot, 2017). Reading comprehension has repeatedly been reported as one of the academic challenges of individuals with ASD (e.g., O'Connor & Klein, 2004; Grigorenko et al., 2003; Nation et al., 2006). For example, Wei, Blackorby, and Schiller (2011) examined the reading achievement of students with disabilities via the national data of the Special Education Elementary Longitudinal Study (SRI International, 2002) of 3,421 students with disabilities between 7 and 17 years old. It found that students with ASD often demonstrated slower literacy growth curves compared to students with learning disabilities. Students with ASD typically improve in word identification and comprehension between age 7 and 17 and achieve word reading skills and comprehension ability that resemble those of typically developing 10-year-olds at the age of 17 (Wei, Blackorby, & Schiller, 2011).

Mathematics difficulty is another academic challenge of students with ASD. Wei, Lenz, and Blackorby (2013) investigated math growth trajectories of students with disabilities via a national representative sample between 7 and 17 years old. Results showed that students with ASD demonstrated lower mathematics achievement compared to typically developing peers and grew significantly slower in mathematics calculation and applied problems compared to students with learning disabilities.

A discrepancy between cognitive ability and academic achievement has also been found in children with ASD. Estes et al (2011) conducted a study with thirty children with ASD aged 9, whose nonverbal intellectual quotient was over 70, and found that the majority of the participants showed a significant discrepancy between their academic outcomes and the predicted achievement based on their intellectual ability in at least one academic domain, such as spelling, word reading, or number skills. Particularly, a total of 60% of the participants had a significantly lower academic performance in at least one domain than the expected achievement predicted from their cognitive ability. Such discrepancy between academic achievement and cognitive ability has also been reported in adolescents with ASD (e.g., Jones et al., 2009)

Moreover, students with ASD often exhibit uneven learning profiles as they may function at or above age level in a specific subject area of interest but well below age level in others (Boutot, 2017). This pattern requires teachers to pay closer attention to the learning progress of students with ASD in different subject areas due to their special educational needs. While these adverse academic outcomes may not impact all students with ASD, it is imperative for researcher and educator to be aware of these potential academic deficits in this population in order to provide remediation of their academic risks in school settings and strive to explore potential predictors or mediators that may facilitate learning and long-term success for them.

Self-regulation and Academic Achievement

There has been growing evidence that EF and EC appear to be significant factors contributing to young children's academic achievement in reading and mathematics (e.g., Blair & Diamond, 2008; McClelland et al., 2007). In general, the extant literature showed that EF was associated with growth in young children's development in language, mathematics, and literacy during preschool and kindergarten (Blair & Razza, 2007; Duncan et al., 2007; Fuhs et al., 2014; McClelland et al., 2007). EC represents the essential skills to guide students to avoid negative emotions that disturb the learning experience and to promote high-quality social and emotional interactions with peers and teachers in the classroom, which contribute to academic success significantly (Fabes, Martin, & Hanish, 1999). One of the key components of EC, attentional control, is believed to be a crucial cognitive skill for children to maintain attention when engaged in learning (Posner & Rothbart, 2007). It is also believed that students with the better development of EC tend to regulate goal-directed behaviors well and to have higher levels of school engagement, which are important for academic achievement (Zhou et al., 2007; Zimmerman, 1998).

Brock et al (2009) examined a link between EF and academic achievement on 173 typically developing kindergartener. The construct of EF was divided into two components in this study: cool EF, which coordinates cognitive processing, and hot EF, which facilitates emotion regulation. These EF skills were measured through direct assessments adapted from the Preschool Self-regulation Assessment (Smith et al., 2007). Particularly, hot EF tasks had emotional components that children needed to negotiate for successful problem solving, whereas cool EF tasks did not generate any emotional consequence. Mathematics and reading achievements were measured by the Woodcock-Johnson III Test of Achievement applied problems and letter-word identification subtests respectively (Woodcock, McGrew, & Mather, 2001). The achievement tasks were measured twice in the fall and spring of kindergarten. Results showed that cool EF, cognitive ability, and fall math scores accounted for variances in the participants' spring math scores. Small associations between cool EF and math achievement still presented after controlling for fall math performance. In contrast, cool EF was not a significant predictor of reading achievement, and hot EF did not predict any achievement outcome when examined together with cool EF. These findings enriched the empirical evidence that cool EF, including inhibitory control, cognitive flexibility, and working memory, are crucial precursors to mathematical learning.

Other empirical evidence also showed similar findings of the link between cool EF and children's math outcomes. Blair and Razza (2007) found that inhibition measured in both preschool and kindergarten predicted mathematics achievement in kindergarten in a sample of low-income children, independent of cognitive ability. Attention shifting in kindergarten also showed moderate associations with math ability. However, the role of EF in emerging literacy was less substantial than in math. Results showed that inhibitory control was the only skill that was independently positively associated with all three measures of academic abilities, and this association was particularly stronger in mathematics ability than literacy skills, including letter identification and phonemic awareness. Additionally, this study found that parent-reported EC through the Children's Behavior Questionnaire (Putnam & Rothbart, 2006) was unrelated to all measures of academic abilities, whereas teacher-reported EC through the same scale in preschool was associated with participants' letter knowledge and mathematics skills in kindergarten. In another study conducted by Valiente, Lemery-Chalfant, and Castro (2007), it found that parent- and participant self-rated EC of through another scale, the Early Adolescent Temperament Questionnaire (Capaldi & Rothbart, 1992), were significantly positively associated with older children's academic competence among 240 typically developing children between 7 and 12 years old. Particularly, school liking mediated the association between EC and academic competence.

In another set of comprehensive analyses by Duncan et al. (2007) using six large-scale longitudinal data sets, the authors showed that cool EF were consistently predictive of children's later math and literacy academic achievements, even after controlling for the academic level at school entry and cognitive abilities. Cool EF still showed strong associations with math achievement in elementary school. It is argued that the weaker association between cool EF and reading achievement may be due to the fact that kindergarten classroom often has a higher proportion of literacy instruction making the majority of children receive sufficient opportunities to improve reading skills regardless of their EF skills at school entry. Even though there is a lack of strong associations between young children's hot EF skills and their academic achievement in current empirical studies, it is still imperative for young children to regulate their emotions spontaneously beyond kindergarten under increasingly intellectual demanding situations and towards academic tasks that may be well above their current academic capacities.

Similarly, Mann et al. (2016) examined the predictive roles of cool EF and hot EF on kindergarten academic outcomes respectively. A total of 93 typically developing children aged 3 to 6 years old participated in this study. It found that the single-factor model including the four EF components of working memory, sustained attention, inhibitory control, and delay of gratification was a poor fit for the data. By separating the cool and hot components of EF, it found that the cool skills, working memory and inhibitory control, predicted children's math and literacy performance represented by the composited scores of the applied problems and letter-word identification subtests in the Woodcock-Johnson III Test of Achievement (Woodcock, McGrew, & Mather, 2001). These findings are consistent with previous empirical results showing that cool EF has a significant impact on academic achievement compared to hot EF. A further multivariate structural equation modeling showed that working memory and inhibitory control predicted the delay of gratification, the hot EF capacity, which predicted social-emotional readiness representing these young children's understanding of emotions and social interactions. The social-emotion readiness was found to predict academic achievement. Overall, cool EF skills, working memory and inhibitory control, had indirect effects on academic achievement mediating by their effects on delay of gratification, which in turn affected social-emotional readiness, which then influenced academic achievement.

One of the limitations of the extant literature is that the majority of studies adopted standardized assessments to measure young children's academic outcomes to investigate the association between EF skills and academic achievement. For example, in Blair and Razza (2007), standardized assessments were adapted to measure three areas of academic outcomes, including mathematics knowledge, phonemic awareness, and letter knowledge. Specifically, mathematics and letter knowledge were measured by adapting the math battery and the letter knowledge test developed for the Head Start National Reporting System Direct Child Assessment, and phonemic awareness was assessed through the Elision subtest of the Preschool Comprehensive Test of Phonological and Print Processing (Pre-CTOPPP) (Lonigan, Wagner, Torgessen, & Rashotte, 2002). Even though norm-referenced standardized tests are the most commonly used assessments to demonstrate and compare students' academic achievement (Boutot, 2017), this way of assessing only can reflect the learning *outcomes* rather than the dynamic learning *process* of young children. Without getting to know how a child proceeds to learn step by step, the specific mechanism underlies the association between a child's EF skills and his or her academic achievement in early childhood remain unclear.

A few studies tried to explore children's learning process more deeply through observing their learning-related behaviors and to examine the potential impact of these behaviors as mediators within the association between EF and academic achievement. For instance, Nesbitt, Farran, and Fuhs (2015) examined young children's learning-related behaviors in prekindergarten (pre-K) classrooms and its relations with EF skills and pre-K literacy, language, and math gains. A total of 1,054 children with an average age of 54.5 months participated in this study. Four domains of EF skills were measured, including shifting, attention, inhibitory control, and working memory. A child's learning-related behaviors were assessed in four ways, including levels of involvement, sequential learning behaviors, social-learning interactions, and unoccupied or disruptive behaviors, through a well-designed observation protocol. Results showed that EF skills at the beginning of pre-K were significantly associated with young children's end of pre-K literacy and mathematics gains and all dimensions of learning-related behaviors. Specifically, children with greater EF skills were more likely to be observed as having higher levels of involvement, more sequential learning behaviors, more participation in social-learning interactions, and fewer demonstrations of unoccupied and disruptive behaviors. Among these learning-related behaviors, children's level of involvement, sequential learning behaviors, and engagement in the classroom mediated the association between EF skills and literacy and mathematics gains. Thus, this study further specified that young children's EF skills contributed to their literacy and mathematics achievement through learning-related behaviors in the classroom environment. It highlighted that EF skills were significant for understanding how young children responded to learning opportunities in a pre-K classroom setting and therefore affected their pre-K literacy and math improvement.

Similarly, Brock et al (2009) also investigated the mediator role of learning-related behaviors in the association between EF and young children's academic achievement. The learning-related behaviors of a total of 173 participants in kindergarten were represented by four behavior constructs through standardized tests rated by the teachers: a) self-directed learning style and b) hyperactive-distractibility from the Social Competence and Adjustment

Scale (Ladd, Profilet, & Muth, 1996); c) work habits from the Mock Report Card (Pierce, Hamm, & Vandell, 1999); and d) self-control from the Teacher's Self-Control Rating Scale (Humphrey, 1982). Moreover, a research assistant observed a child for 15 minutes of academic classroom time and rated five classroom behaviors, including self-reliance, attention, disruptive behavior, compliance, and engagement. Results showed that young children's cool EF skills significantly predicted math achievement, learning-related classroom behaviors, and observed engagement. In contrast to the finding in Nesbitt, Farran, & Fuhs (2015), children's learning-related classroom behaviors did not account for or mediate the association between cool EF skills and math achievement in this study. The contradictory finding on the role of learning-related behaviors in the association between EF and academic achievement revealed that more studies would be needed to examine how EF skills contribute to a child's academic achievement, and the impacts of potential mediators, including children's learning-related behaviors, are needed to be explored.

Additionally, research has demonstrated that children with higher EC are likely to have better skills than those with lower EC to accurately manipulate their behaviors that aid in learning, such as paying attention to the teacher for extended periods and sitting still in class (Coplan, Barber, & Lagace Seguin, 1999; Lemerise and Arsenio, 2000). Children with higher EC adapt to the school environment more effectively than those with lower EC (Valiente, Lemery-Chalfant, & Castro, 2007). In contrast, for those who have poorer self-regulatory skills, they generally have worse academic performance, even when controlling for family incomes and cognitive skills (Ladd, Birch, & Buhs, 1999; Shores & Wehby, 1999). Delayed EC leads to less effective attention control and lower inhibitory control (Faja and Dawson, 2015), and can put children at risk for emotional distress and alienation from school activities that resulted in poorer school engagement and worse academic achievement (Birch & Ladd, 1997; Murray & Greenberg, 2000).

Another limitation of the current literature is that much of the work to date has been on predominantly typically developing samples. Relatively little is known about the relation between EF deficits or EC delays and individual differences in academic outcomes of children with ASD. Given the strong association between self-regulation and academic achievement in typically developing children, there is a critical need for this work to be extended to populations with special needs, especially to children with ASD, for whom both self-regulatory challenges and academic underachievement have been reported (e.g., Boutot, 2017; Geurts, de Vries, & van den Bergh, 2014).

School Engagement and Learning

School engagement broadly refers to children's level of participation in, and commitment to activities in school settings (Fredricks, Blumenfield, & Paris, 2004). There are three forms of school engagement that have been studied among school-aged children, including behavioral, emotional, and cognitive engagement (e.g., Fredricks et al., 2004). *Behavioral engagement* includes cooperative or independent participation in classroom activities and the absence of disruptive behaviors (Buhs & Ladd, 2001; Finn et al., 1995). It also refers to effort, persistence, and attention during participation in classroom activities (Birch & Ladd, 1997). Students who had disruptive or inattentive behaviors were found to have lower scores on all achievement tests (Finn et al., 1995). Connell (1990) also reported that behavioral engagement in school activities predicted positive academic achievement and lower dropout rates of school. The second dimension of school engagement, *emotional engagement*, refers to children's affective reactions to peers, teachers, academic work, or the larger school environment (Finn, 1989; Ladd, Buhs, & Seid, 2000). It also includes children's sense of identification with school and the degree to which children value academic work (Voelkl, 1997). Students who like the school setting and engage in classroom activities actively are more likely to be motivated to pursue academic goals and have better academic achievements (Alexander & Entwisle, 1988). For example, Ladd et al. (1999) found that typically developing children who liked school performed more appropriate behaviors in the school setting and had positive academic performance. In contrast, students who dislike school or avoid participating in school activities often demonstrate decreased attention and have academic disadvantages beyond risks related to language, socio-economic status, or ethnicity (Finn, 1993). The third dimension of school engagement, *cognitive engagement*, refers to children's intellectual efforts on learning academic tasks (Newmann, Wehlage, & Lamborn, 1992). Mainly, it includes the use of cognitive learning strategies (Lee & Anderson, 1993), task-specific thinking (Helme & Clarke, 2001), flexible problem-solving, and a preference for challenging tasks (Connell & Wellborn, 1991). Overall, school engagement reflects motivation for learning, guides behaviors linked to school success, and serves as a proximal contributor to the academic abilities for children from all levels of socio-economic background (Finn, 1993). The link between school engagement and academic outcomes holds true not only when children enter school but also over the entire course of their school years (Fredricks, Blumenfield, Friedel, & Paris, 2005).

Empirical evidence also highlights that children's school engagement is related to their self-regulatory skills. For example, Jahromi, Bryce, and Swanson (2013) found that young children with high functioning autism demonstrated deficits in EF, delays in EC, poorer behavioral engagement, and less school liking compared to their typically developing peers. Results showed that there were strong associations between EC/ EF and behavioral and emotional engagement of the participants. Particularly, EF was the only self-regulatory skill that predicted both emotional and behavioral engagement in school activities. Additionally, it has been found that EC was positively related to children's school liking and participation among typically developing children (Valiente, Lemery-Chalfant, & Castro, 2007; Valiente et al., 2008).

The important role of school engagement has also been demonstrated in the association between young children's self-regulation and their academic performance. Valiente, Lemery-Chalfant, and Castro (2007) found that school liking mediated the association between EC and academic ability after controlling for parents' education and family income. It has been found that high levels of school liking predict low levels of school avoidance and attendance (Berndt & Keefe, 1995; Ladd et al., 1996), and students' school liking predicts their participation, academic progress, and academic competence (Ladd et al., 2000; Ladd & Burgess, 2001; Ladd, Kochenderfer, & Coleman, 1996). Moreover, students with a better development of EC tend to regulate goal-directed behaviors well and to have higher levels of school engagement, which are important for academic achievement (Zhou et al., 2007; Zimmerman, 1998).

Considering the fact that children with ASD often display difficulties in managing their behaviors in the school setting (Ashburner, Ziviani, & Rodger, 2010) and the challenges faced by them to effectively regulate their emotions towards stressful academic tasks (Ladd et al., 2000), it is imperative to examine how their self-regulation skills relate to their school engagement and contribute to their academic success.

Reward Sensitivity and Learning

Reward sensitivity refers to the extent to which goal-directed behavior is affected by the availability of reinforcement and familiarity with reward incentives (Pankert et al., 2014; Reed et al., 2012). Obtaining rewards through competent efforts is essential for goal-directed behaviors and learning (Damiano et al., 2012). However, abnormal reward sensitivity has been reported in individuals with ASD. Neuroimaging studies showed that individuals with ASD demonstrated abnormal activation in the brain regions related to reward processing and nonsocial rewards, such as the amygdala (Bachavalier & Loveland, 2006; Schmitz et al., 2008). Clinical observation and empirical studies also suggested that individuals with ASD showed altered reward sensitivity compared to their typically developing peers. For example, Dawson et al., (2004) reported that individuals with ASD had enhanced motivation to pursue non-social stimuli based on personal interests, whereas demonstrated reduced motivation to request social interactions. Geurts, Luman, and van Mell (2008) also found that there was reduced responsiveness to social reward and motivation in children with ASD. Additionally, difficulties in understanding rules from stimulus-rewarding associations have been found in individuals with ASD (Dawson et al., 2001; Jones et al., 2013).

Reward sensitivity is often measured through the behavioral inhibition system (BIS) and behavioral activation system (BAS) scale developed by Carver and White (1994). Specifically, the BAS scale includes three subdomains: Drive, Reward Responsiveness, and Fun Seeking. Research has shown that the BAS Drive and BAS Reward Responsiveness subscales reliably reflect individual differences in reward sensitivity (Carver & White, 1994; Hickey et al., 2010). An adapted parent-reported reward sensitivity scale developed by (Colder & O' Connor, 2004) can be used to assess young children's sensitivity to punishment and reward.

Altered reward sensitivity of individuals with ASD may have an adverse impact on their social skills and learning abilities. Some argued that individuals with ASD may have difficulty in processing and representing social stimuli, including gestures and facial expression, and thereby their attention often fails to draw on these social stimuli (Dawson et al., 2004). This issue may be due to their failure to assign reward values to social interactions, which easily leads to social reward hyposensitivity and results in social skills difficulties and language abilities delays (Damiano et al., 2012; Mundy & Neal, 2001). Even though many studies focused on the abnormal reward sensitivity of individuals with ASD, there is limited evidence regarding the association between reward sensitivity and self-regulation or academic achievement in children with ASD. De Vries et al. (2018) is one of the very few existing studies which examined the association between EF deficits and reward sensitivity of children with ASD. The study found that children who demonstrated more severe EF deficits had enhanced reward sensitivity and more severe ASD traits and behaviors. Also, Faja, Murias, Beauchaine, and Dawson (2013) conducted a study to examine the reward sensitivity of young children with ASD aged 6 to 7 through a reward-based decision-making gambling task and its relation to children's EF skills. It is believed that individual differences in sensitive responses to rewards and working memory can be reflected through this children's gambling task as early as preschool (Crone, Bunge, Latenstein, & van der Molen, 2005; Kerr & Zelazo, 2004). Results showed that there was an enhanced reactivity to nonsocial rewards in children with ASD compared to matched typically developing peers, and an association between increased electrodermal responding for wins in the game, which was believed to reflect expectancy of reward contingencies (Amiez et al., 2003), and worse overall executive function. It is argued that the altered reward sensitivity to nonsocial stimuli in children with ASD may explain their repetitive behaviors because their behavioral patterns with certain nonsocial stimuli may be excessively rewarding to them, and their deficits in EF may limit their ability to flexibly shift between various stimuli in real life (Faja, Murias, Beauchaine, and Dawson, 2013).

In the natural environment, reinforcement may not always be delivered immediately. Tolerance to delay of reinforcement is essential to sharing, cooperation, social interaction, and learning (Whiting & Dixon, 2015). From a behavioral perspective, self-regulation is often conceptualized as the behaviors that result in larger, delayed reinforcers rather than smaller, more immediate ones (Ainslie, 1974; Odum, 2011; Whiting & Dixon, 2015). Behavioral scholars argued for the importance of understanding tolerance for delayed reinforcers and delayed discounting, a process by which the value of a reward depreciates as a function of the time and is often used as a measure of impulsive behaviors (e.g., da Matta et al., 2012). Individuals with ASD often demonstrate impulsive behaviors, which prevent them from waiting for larger, delayed reinforcers compared to smaller, immediate reinforcers (Whiting & Dixon, 2015). Studies on delay of gratification also suggest that children with ASD waited for significantly shorter durations in getting larger, delayed reinforcers than their typically developing peers (Jahromi et al., 2019) and were less likely to pass the task (Faja & Dawson, 2015). Children with ASD's ability to wait was found to be associated with their self-regulation skills (Faja & Dawson, 2015; Jahromi et al., 2019).

Children with ASD in the study has been receiving reinforcement on their desirable behaviors and academic performance throughout the day at the CABAS® schools. Reinforcement sometimes may be delayed in the classroom for various reasons. It is important for children with ASD to tolerate delays in reinforcement, which is believed to be related to their school success and social interactions (Whiting & Dixon, 2015). Given that individuals with ASD often show altered reward sensitivity, which is related to deficits in social skills and learning ability, and difficulties in tolerating delays in reinforcement, it is important to examine the relationship between reward sensitivity and academic learning in young children with ASD and how self-regulation is associated with the ability to tolerate delays in reinforcement.

Adaptive Behavior and Learning

Adaptive behavior refers to an individual's capability to function independently as expected based on chronological age (Sparrow, Balla, & Cicchetti, 1984; Tasse et al., 2012). Compared with typically developing peers, individuals with ASD were found to have limited gains in adaptive behavior from early childhood (Kanne et al., 2011; Klin et al., 2007; McGovern & Sigman, 2005). Impairments in adaptive behavior limit one's ability to complete essential tasks in daily life, such as personal hygiene and travel, and initiate and maintain proper social interaction (e.g., Dawson et al., 1998). Three domains have been highlighted in the adaptive behavior profile of individuals with ASD: impairments in communication, delays in daily living skills, and significant deficits in socialization (Bolte and Poustka, 2002; Carter et al., 1998). Many factors have been shown to relate to the adaptive behavior profile in individuals with ASD. Research showed that slower gains in adaptive behavior in individuals with ASD were associated with higher levels of ASD symptoms and lower IQ scores. For example, Freeman et al. (1999) found that children and young adults with ASD without intellectual disability showed greater gains in adaptive skills over time compared to those with intellectual disability. Perry et al. (2009) found that the severity of ASD symptoms was moderately to strongly negatively related to adaptive behavior. EF is another important factor that has been found to be associated with adaptive behavior development in children with ASD. Executive dysfunction behaviors were associated with difficulty with adaptive behavior above and beyond the severity of ASD symptoms and IQ (Gilotty et al., 2002). EF deficits reported by parents were linked to age-related decreases in standardized scores on measures of adaptive behavior after accounting for IQ, age, and the severity of ASD symptoms (McLean et al., 2014). Longitudinal analyses also showed that EF predicted later gains in adaptive behaviors in the domains of socialization and daily living skills after accounting for IQ and age (Pugliese et al., 2016).

Adaptive behavior has been shown to relate to children's academic learning. Hall and Segarra (2007) found that the adaptive behavior of children with language impairments was a strong predictor of their later achievement in reading, writing, and math. Similarly, Arciuli et al. (2012) found positive associations between communication skills on adaptive behavior measures and reading accuracy and comprehension performance in children with ASD. Social skill was also found to be predictive of word reading ability in children with ASD from early to middle childhood (Estes et al., 2011). Social skill deficits in individuals with ASD were associated with their underachievement in reading comprehension, even after controlling for vocabulary, oral language, and nonverbal IQ (Åsberg, Kopp, Berg-Kelly, & Gillberg, 2010; Ricketts et al., 2013). Miller et al. (2016) also found that adaptive and social functioning in children with ASD is associated with academic achievement in both reading and math. Given the significant associations among EF, adaptive behavior, and academic learning shown in previous studies, it is important to examine the association between self-regulation and adaptive behavior in children with ASD in the study and to investigate the role of adaptive behavior in the relationship between self-regulation and academic learning.

Summary and Rationale

Given the relations between self-regulation and academic outcomes (e.g., Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Valiente, Lemery-Chalfant, & Castro, 2007), it is proposed that self-regulation may be related to academic achievement directly and indirectly. It is possible that EF and EC are positively correlated with young children's academic learning and partially mediate the relation between ASD traits and academic achievement. School engagement, reward sensitivity, and adaptive behavior may serve as potential moderators within the association between self-regulation and academic learning (e.g., Nesbitt, Farran, & Fuhs, 2015). Therefore, the present study aims to examine these processes in a study of preschool-aged children with ASD who are educated in an applied behavior analysis learning environment.

Research Questions and Hypotheses

Research Question 1. Is There an Association between Self-regulation, Including EF and EC, in Children with ASD, as Measured by Direct Assessments and Parental Reports?

In line with research (e.g., Jahromi, Bryce, & Swanson, 2013), it is hypothesized that there is a significant positive association between young children's EF and EC.

Research Question 2. How is Self-regulation Related to Other Characteristics and Behaviors in Children with ASD, Including ASD Symptoms Severity, Reward Sensitivity, School Engagement, and Adaptive Behavior?

Based on past research (e.g., Faja and Dawson, 2015; Faja, Murias, Beauchaine, & Dawson, 2013; Jahromi, Bryce, & Swanson, 2013), it is hypothesized that self-regulation in children with ASD is negatively related to ASD symptoms severity and reward sensitivity. It is also hypothesized that self-regulation in children with ASD is positively related to school engagement and adaptive behavior.

Research Question 3. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning in the Literacy Programs?

In line with research (e.g., Blair and Diamond, 2008; McClelland et al., 2017), it is hypothesized that there is a positive association between self-regulation in children with ASD and their academic learning in the literacy programs.

Research Question 4. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning in the Mathematics Programs?

Based on existing research (e.g., Blair and Diamond, 2008; McClelland et al., 2017), it is hypothesized that there is a positive association between self-regulation in children with ASD and their academic learning in the mathematics programs.

Research Question 5. Are There any Associations Between Self-regulation in Children with ASD and the Total Number of Tactics Needed in Literacy and Mathematics Learning?

Though this research question was not answered directly in previous studies, based on the research suggesting a positive association between self-regulation and academic achievement (e.g., Blair and Diamond, 2008), it is hypothesized that there is a significant negative association between self-regulation in children with ASD and the total number of tactics needed in literacy and mathematics learning.

Research Question 6. Are There any Associations Between Child Characteristics and Academic Learning in Literacy and Mathematics in Children with ASD?

In line with research (e.g., Damiano et al., 2012; Grigorenko et al., 2003; Mundy & Neal, 2001; Nation, Clarke, Wright, & Williams, 2006; Valiente, Lemery-Chalfant, and Castro, 2007; Wei, Lenz, & Blackorby, 2013), it is hypothesized that there is a negative association between the ASD symptom severity and reward sensitivity and academic learning in children with ASD; there is a positive relationship between school engagement and adaptive behavior and academic learning in children with ASD.

Research Question 7. Does Self-regulation Mediate the Relationship Between the ASD-related Symptoms Severity and Academic Learning in Children with ASD?

It is hypothesized that self-regulation mediates the relationship between the ASD symptoms severity and academic learning in children with ASD.

Research Question 8. Do any Child Characteristics Moderate the Relationship Between Self-regulation and Academic Learning in Children with ASD?

Based on previous research (e.g., Murias, Beauchaine, and Dawson, 2013; Valiente, Lemery-Chalfant, and Castro, 2007), it is hypothesized that reward sensitivity and school engagement moderate the relationship between self-regulation and academic learning in children with ASD.

Research Question 9. What Are the Distraction Strategies Used by Children with ASD in Response to Delayed Reinforcement? How Are the Wait During Delay in Reinforcement Associated with Self-regulation and Other Child Characteristics in Children with ASD?

The former part of this research question is exploratory in nature, so no specific hypotheses are proposed. In line with previous research (e.g., Odum, 2011), it is hypothesized that there is a positive relationship between self-regulation and the length of wait to delay in reinforcement in children with ASD.

Research Question 10. Do Children with ASD Respond Better Under Token or Social Attention Condition in the Classroom Setting? How is the Reinforcement Preference Related to Self-regulation and Other Child Characteristics in Children with ASD?

This research question is exploratory in nature, so no specific hypotheses are proposed.

Chapter III

Method

Participants

The study included a total of 32 preschoolers with ASD (25 males) aged 36 months to 68 months (*M*= 51.35 months, *SD* = 7.59) from two specialized applied behavior analysis schools in the greater New York City area. Each participant had an Individualized Education Program with a classification of Preschooler with Disability and had a current diagnosis of autism confirmed with the ADOS-2 (Lord et al., 2012). Inclusion criteria for the study were that a) children aged between 3 and 6 years old; b) children had a diagnosis of ASD, which was confirmed with an Autism Diagnostic Observation Schedule- Second Edition (ADOS-2; Lord, Rutter, DiLavore, Risi, Gotham, & Bishop, 2012); and c) children had at least one literacy or math program at school. The participants demonstrated low (*n* = 1) to moderate (*n* = 23) to high (*n* = 8) level of ASD-related symptoms during the ADOS-2 assessment. With respect to ethnicity, 48.3% of the participants were White, 24.1% were Hispanic, Latino, or of Spanish origin, 10.3% were African American or Black, 6.9% were of Asian origin, and 10.3% were identified as other ethnicities. The majority of the participants (86.2%) had siblings, 44% of whom also identified as having developmental delays. On average, there were 2.24 children living in the house (*SD* = 1.06). Most of the participants (75.9%) spoke only English (75.9%), while 24.1% were reported to speak another language. Participants represented a variety of classroom types and were drawn from four self-contained classrooms (n = 15) and three integrated classrooms (n = 17). The classrooms implemented the Comprehensive Application of Behavior Analysis to Schooling (CABAS®) model of education (Greer, 1996, 2002), which individualized all instructional programs and curricular objectives based on each student's needs and current academic levels. This system of instruction is rooted in the principles of applied behavior analysis applied to pedagogy, curriculum, classroom management, and training for teachers.

Parents of the children filled out a questionnaire about demographic information and three parental measures about the child's executive function, temperamental effortful control, and reward sensitivity. Of the 29 parents who returned the questionnaire, 27 were a mother (93.1%), and 2 were a father (6.9%). The mean age of mothers in the study was 37.36 years (*SD* = 5.73), and that of fathers was 37.5 years (*SD* = 10.61). The majority of the parents in the study (86.2%) were married or in a committed partnership, while 10.3% indicated that they had never been married or partnered, and 3.4% identified as divorced. More than half of the parents (58.6%) indicated that they were not born in the United States and moved to this country at some point in life. Regarding the highest level of education, 41.3% of mothers earned a master's, professional, or doctoral degree, while 24.1% had a bachelor's degree, 24.1% had an associate degree, and 10.3% had a high school diploma or GED. Fathers of the child participants earned relatively lower levels of educational degrees compared to mothers as a whole, with 24.1% earned a master's, professional, or doctoral degree, 31% had a bachelor's degree, 20.7% had an associate degree, 17.2% had a high school diploma or GED, and 6.9% received less than high school education. The majority of the parents (70.3%) reported a household income of $100,000 or higher. On average, there were 2.07 adults living in the house (*SD* = .37). Using the reported zip codes to estimate the percentage of populations in the community living below the federal poverty level based on the United States Census Bureau data, it showed that 62% of the families lived in a relatively wealthy community, where less than 10% of the community population living below the federal poverty level, while 6.9% lived in a more impoverished community with more than 20% of neighbors living below the poverty level. Demographic information of the child participants and their parents were summarized in Table 1.

Table 1

Demographic Characteristics of Child Participants and Parents (N = 32)

Demographic Characteristics	n	%
Child Age (Years – Months, *n* = 32)		
3-0 to 3-11	9	28.1
4-0 to 4-11	21	65.6
5-0 to 5-11	2	6.3
Child Gender (*n* = 32)		
Female	7	21.9
Male	25	78.1
Child Ethnicity (*n* = 29 reported)		
Caucasian/ White	14	48.3
Asian American/ Asian	2	6.9
Hispanic, Latino or Spanish origin	7	24.1
African American/ Black	3	10.3
Biracial or Other	3	10.3
Child Who Speaks Another Language (*n* = 29 reported)		
Yes	7	24.1
No	22	75.9
Child Sibling Status (*n* = 29 reported)		
Yes	25	86.2
No	4	13.8
Child Sibling with Developmental Delays		
Yes	11	44
No	14	56
ASD Symptoms Severity- ADOS-2 Comparison Score (*n* = 32)		
Low (3-4)	1	3.1
Moderate (5-7)	23	71.9
High (8-10)	8	25

Mother Highest Education Level (*n* = 29 reported)		
High School Diploma or GED	3	10.3
Associate Degree	7	24.1
Bachelor’s Degree	7	24.1
Master’s, Professional, or Doctoral Degree	12	41.3
Father Highest Education Level (*n* = 29 reported)		
Less than High School	2	6.9
High School Diploma or GED	5	17.2
Associate Degree	6	20.7
Bachelor’s Degree	9	31
Master’s, Professional, or Doctoral Degree	7	24.1
Parent Marital Status (*n* = 29 reported)		
Currently Married/ Committed Partnership	25	86.2
Divorced	1	3.4
Never Married/ Partnered	3	10.3
Parent Nativity Status (*n* = 29 reported)		
Non-U.S.	17	58.6
U.S.	12	41.4
Household Income (*n* = 27 reported)		
$10,000 – $24,999	2	7.4
$25,000 – $49,999	2	7.4
$50,000 – $74,999	3	11.1
$75,000 – $99,999	1	3.7
$100,000 – $149,999	8	29.6
$150,000 – $199,999	8	29.6
$200,000 or More	3	11.1
Community Poverty Level (*n* = 29 reported)		
Less than 5%	7	24.1
5.1% – 10%	11	37.9
10.1% – 15%	4	13.8
15.1% – 20%	5	17.2
More than 20%	2	6.9

Classroom teachers of the participants filled out three teacher measures about the children's adaptive behavior and school engagement. All classroom teachers of the participants provided applied behavior analysis instructions to preschoolers with developmental disabilities. The majority of the classroom teachers (57.14%) were doctoral students in the Applied Behavior Analysis program at Teachers College, Columbia University. They have been teaching at a CABAS® school for at least two years since their master's training. All of them hold New York State teaching certificates in general and special education (birth to grade 6).

Procedures

Institutional Review Board approval was obtained from both Teachers College, Columbia University, and the participating schools before the onset of the study. Parents signed the informed consent before children's involvement in the study, and classroom teachers subsequently provided consent for using data on the teachers' reports.

Direct measures were conducted on the child participants to obtain data on their executive function level, autism-related symptoms severity, as well as self-regulation performance and strategies used in three frustrating tasks. A validated executive function measure, the NIH Toolbox Early Childhood Cognition Battery (the NIHTB-ECB), was implemented on an iPad to all participants in a quiet assessment room at the schools. The measure lasted for a maximum of 20 minutes. All participants were administered the ADOS-2 (Lord et al., 2012) to confirm their diagnosis of autism by the author, who has established research reliability of the measure. The ADOS-2 was also conducted in a quiet assessment room at school, which lasted between 40 and 60 minutes. Three behavioral measures were designed to assess the participants' self-regulation performance and strategies used under frustrating situations where the demands for self-regulation increased incrementally: *delayed delivery of edibles, delayed delivery of tokens, and delayed turn-taking with an adult.* All three tasks were implemented at a corner in the child's classroom, while other students and teaching staff were engaged in other activities simultaneously in the same room.

Participant's parent filled out a questionnaire about the family's demographic information (see Appendix B for a complete list of questions) and reported the child's executive function levels through the Behavior Rating Inventory of Executive Function, Preschool Version (BRIEF-P; Gioia, Isquith, Guy, & Kenworthy, 2000), temperamental effortful control through the Child Behavior Questionnaire-Short Form (CBQ-SF; Putnam & Rothbart, 2006), and reward sensitivity through the Sensitivity to Punishment and Sensitivity to Reward Questionnaire for Children (SPSRQ-C; Colder and O'Connor, 2004; Luman et al., 2012). Classroom teachers reported the child participants' adaptive behavior through the Vineland Adaptive Behavior Scales, Third Edition, Comprehensive Teacher Form (Vineland-3; Sparrow, Cicchetti, & Saulnier, 2016) and their school engagement performance via the Teacher Rating Scale of School Adjustment (TRSSA; Birch and Ladd, 1997) and the School Liking and Avoidance Questionnaire (SLAQ; Ladd & Price, 1987).

Measures

Demographic Information

A researcher-designed questionnaire was used to collect demographic information from the parents for assessing the extent to which demographic variables were associated with other study variables. Demographic information included the child's age, ethnicity, sibling's information, second language status, mother or father's age depending on who filled out the questionnaire, marital status, parent's nativity, annual household income, zip code, number of adults living in the household, mother's and father's highest educational level, and their occupations. See *Appendix D* for a complete list of questions.

Executive Function

Children's EF was assessed through both direct measures and a parental report. The NIH Toolbox Early Childhood Cognition Battery (NIHTB-ECB) Ages 3-6 provides a comprehensive assessment for young children aged 3 to 6 and has demonstrated excellent reliability, convergent validity, and developmental sensitivity across childhood (Zelazo et al., 2013). The battery lasted for a maximum of 20 minutes, depending on the child's performance. This battery was implemented on an iPad and included four measures: The Picture Vocabulary Test Age 3+ (the Vocabulary test), the Flanker Inhibitory Control and Attention Test Ages 3-7 (the Flanker test), the Dimensional Change Card Sort Test Ages 3-7 (the DCCS test), and the Picture Sequence Memory Test Ages 3-4 (the Memory test). The Vocabulary test attempts to measure receptive vocabulary in a computer-adaptive format. The Flanker test aims to measure one's attention and inhibitory control. The DCCS test measures the capacity of planning, cognitive flexibility, and attention. The Memory test assesses episodic memory involved in the acquisition, storage, and retrieval of information. A Cognition Early Childhood composite score was generated based on children's performance on the above four measures. Higher scores indicate greater levels of EF.

Additionally, parents reported children's EF through the Behavior Rating Inventory of Executive Function, Preschool Version (BRIEF-P; Gioia, Isquith, Guy, & Kenworthy, 2000). It is a standardized parental questionnaire to assess EF in preschoolers aged 2 to 5 years in the everyday environment. Parents were asked to rate their children's behaviors (e.g., "During the past 6 months, how often has the following behaviors been a problem? Becomes upset with new situations") on a 3-point Likert-type scale ranging from Never to Often. The BRIEF-P measures five aspects of executive function: Inhibit, Shift, Emotional Control, Working Memory, and Plan/ Organize. These scales form three broader indexes of Inhibitory Self-Control (Inhibit + Emotional Control), Flexibility (Shift + Emotional Control), and

Emergent Metacognition (Working Memory + Plan/ Organize). The measure yielded an overall composite score, the Global Executive Composite. These scores have a mean of 50 and a standard deviation of 10. All scores on the BRIEF-P in this study were reversed so that higher scores indicate greater levels of EF. Cronbach's alphas for the parent version of the BRIEF-P scales are reported as .80 to .90 (Sherman & Brooks, 2010). In the study, internal consistencies of all the BRIEF-P scales and indexes were: Inhibit (.94), Shift (.87), Emotional Control (.88), Working Memory (.94), Plan/ Organize (.91), the Inhibitory Self-Control Index (.96), the Flexibility Index (.93), the Emergent Metacognition Index (.96), and the Global Executive Composite (.98).

Temperamental Effortful Control

Effortful control was assessed through the Children's Behavior Questionnaire-Short Form (CBQ-SF; Putnam & Rothbart, 2006; Rothbart, Ahadi, Hershey, & Fisher, 2001). This questionnaire is a parent-report measure of temperament for 3- to 7-year-olds. It uses a 7-point Likert-type scale from 1 (*extremely untrue of my child*) to 7 (*extremely true of my child*) for the parents to report how true particular statements are about their child's behaviors (e.g., "takes a long time in approaching new situations"). The Cronbach's alphas for the short-form scales range from 0.65 to 0.85 (Putnam & Rothbart, 2006). As per the factor structure proposed by Putnam & Rothbart (2006), EC was computed as an average of four subscales: Inhibitory Control (Cronbach's alpha in the present study = .729), Attentional Focusing (Cronbach's alpha = .613), Low Intensity Pleasure (Cronbach's alpha = .556), and Perceptual Sensitivity (Cronbach's alpha = .681). Higher scores indicate higher levels of EC. The internal consistency of Low Intensity Pleasure was relatively low. Even though similar results were reported in Putnam & Rothbart (2006), this value should be interpreted with caution.

Autism-Related Symptoms Severity

The Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012) was used to confirm the participants' diagnosis of autism and to examine the severity of their autism-related symptoms. The ADOS-2 is a semi-structured, standardized individual observational assessment of communication, social interaction, play/imaginative use of materials, and restricted and repetitive behaviors for individuals who have possible ASD traits. This measure can be used with individuals at a wide range of developmental and language levels from 12 months through adulthood via four different modules. The participants in the study were administered either Module 2 or Module 3 based on their language ability and ages. Behaviors of the participants were observed and coded to either 3-point (0 to 2) or 4-point (0 to 3) scale for the test items. A score of zero indicates a presence of a typical behavior or an absence of an atypical behavior. The ADOS-2 algorithm generates scores in two domains: Social Affect and Restricted and Repetitive Behavior. The total score of these two subscales is converted to the ADOS-2 comparison score depending on the age of the child. This score reflects the severity of an individual's autism traits across the spectrum compared to others with ASD with comparative developmental and language levels: no evidence (1-2), low (3-4), moderate (5-7), or high (8-10), with a higher comparison score yields more severe autism-related symptoms. The ADOS-2 demonstrated high internal consistency for the Social Affect subscale in Modules 1 to 3 (Cronbach's alpha = .87 - .92) and moderate for the Restricted and Repetitive Behavior subscale (Cronbach's alpha = .51- .66) (Lord et al., 2012). Its test-retest reliability for Module 1 to 3 ranged from .68 to .92, and interrater reliability for item coding goes from .79 to .98 across the five modules and achieves agreement in diagnostic classification from 92% to 98% in Module 1 to 3 (Lord et al., 2012). All participants in the study met the inclusion criteria by getting an ADOS-2 comparison score of 3 or higher, indicating some levels of autism-related symptoms. All participants were assessed by an experimenter who had established research reliability of the ADOS-2.

Adaptive Behavior

The Vineland Adaptive Behavior Scales, Third Edition, Comprehensive Teacher Form (Vineland-3; Sparrow, Cicchetti, & Saulnier, 2016) was used to measure the participants' adaptive behavior in the study. This measure is a teacher report providing information on the examinee's adaptive functioning at school and may be used for those ages 3 through 21 who go to school. The teacher who responds to this form should have had frequent contact with the examinee for at least two months. The Vineland-3 targets the following domains: Communication (receptive, expressive, and written); Daily Living Skills (personal, domestic, and community); Socialization (interpersonal relationships, play and leisure, and coping skills); and Motor Skills (fine and gross motor). For the purpose of this study, teachers completed all four domains. The domains of Communication, Daily Living Skills, and Socialization yields the Adaptive Behavior Composite score. This standard score has a mean of 100 and a standard deviation of 15. In the study, the participants had an average Adaptive Behavior Composite score of 85.56 (SD = 9.61, ranged from 67 to 118), indicating an overall moderately low to adequate adaptive level. For preschool-age children, the Vineland-3 has reported excellent internal consistency reliability: Communication domain (α =.93), Daily Living Skills (α= .95), and Socialization (α = .93), and Motor Skills (α = .89) (Goldberg, 2009). In the study, internal consistency reliability was reported as .72 for the Communication domain, .69 for the Daily Living Skills domain, .84 for the Socialization domain, and .77 for the Motor Skills domain.

School Engagement

Children's school engagement was measured in two aspects: behavioral school engagement and emotional school engagement. Behavioral school engagement was measured through a teacher report, the Teacher Rating Scale of School Adjustment (TRSSA; Birch and Ladd, 1997). This measure is a teacher-reported questionnaire using a 3-point Likert-type scale from 1 (*doesn't apply*) to 3 (*certainly applies)* to investigate student's behavioral and relational adjustment to school. Two dimensions of behavioral school engagement were assessed: cooperative participation, which indicates the degree to which children are cooperative and responsible to the teacher and classroom demands (e.g., "uses classroom materials responsibly"), and independent participation, which reflects the degree to which the child is autonomous and self-reliant toward academic activities and in the classroom setting (e.g., "is a self-directed child"). A mean composite score of *behavioral school engagement* was created to be used in subsequent analyses that reflected both cooperative and independent participation in the classroom (Cronbach's alpha = .77). Higher scores indicate greater levels of behavioral school engagement.

Emotional school engagement was assessed using the School Liking and Avoidance Questionnaire (SLAQ; Ladd & Price, 1987). It is a teacher-reported questionnaire using a 3-point Likert-type scale from 1 (*doesn't apply*) to 3 (*certainly applies)* to examine children's expressed desire to like or avoid school in the two subscales of School Liking (e.g., "likes to come to school") and School Avoidance (e.g., "makes up reasons to go home from school"). Items on the School Avoidance subscale were reverse-coded, such that higher scores indicated higher school liking. A mean composite score of *emotional school engagement* was created for subsequent analyses that reflected children's affective reactions to school (Cronbach's alpha = .90). Higher scores indicate greater levels of emotional school engagement.

Reward Sensitivity

Children's reward sensitivity was assessed using the Sensitivity to Punishment and Sensitivity to Reward Questionnaire for Children (SPSRQ-C; Colder and O'Connor, 2004).

This measure is a parent-reported questionnaire using a 5-point Likert-type scale from 1 (*strongly disagree)* to 5 (*strongly agree*) to report how true particular statements are about the child's reactions to reward (e.g., "The good prospect of obtaining a reward motivates your child strongly to do some things") and punishment (e.g., "Your child prefers not to ask for something when they are not sure they will obtain it"). This measure includes one Punishment Sensitivity scale (SP) corresponding to the behavioral inhibition system (BIS) functioning and three Reward Sensitivity scales (SR; Drive; Reward Responsivity; Impulsivity/Fun-Seeking) corresponding to the behavioral approach system (BAS) functioning. These subscales generated by factor analysis were consistent with the adult BIS/BAS scales developed by Carver and White (1994). The Drive subscale measures one's persistent pursuit of rewards (e.g., "Your child likes to compete and do everything they can to win"). The Reward Responsivity subscale reveals children's response to the anticipation or occurrence of reward (e.g., "Your child often does things to be praised"). The Impulsivity/ Fun Seeking scale reflects how children's impulsive behaviors (e.g., "Your child has a lot of difficulty ending a fun activity"). For the purpose of the study, reward sensitivity was of primary interest. Scores in the three SR scales were averaged respectively to create a composite score representing children's sensitivity to reward in the subsequent analyses. Higher the score indicates higher sensitivity to reward. Internal consistency reliability was reported as .76 for the Impulsivity/ Fun-Seeking scale, .73 for the Drive scale, and .69 for the Reward Responsivity scale (Colder and O'Connor, 2004). In the study, Cronbach's alpha for the reward sensitivity subscale was .75.

School Academic Programs

Data on the literacy and mathematics programs at school were used to reflect academic learning in children with ASD in the study. At the CABAS® schools, literacy and mathematics programs were tailored to individual students' developmental needs and academic levels. Of the 32 participants, school data of four literacy programs and three mathematics programs were collected. The literacy programs included Letter Names and Sounds, 100 Easy Lessons reading program, Textual Responding to Dolch Words, the Reading A-Z curriculum, and the Reading A-Z curriculum Comprehension quizzes. These five academic programs targeted different foundational literacy components, including alphabetic knowledge, phonemic awareness, word recognition, and reading comprehension. The three mathematics programs included Number Skills, the STEM Math curriculum, and the Connecting Math Concepts curriculum. These three programs cover the development of fundamental number skills and mathematic problem-solving skills, including recognizing numbers, quantities, and numeric relationships, performing simple arithmetical operations, and identifying different money values.

Letter Names and Sounds. The Letter Names and Sounds program aims to teach children with ASD names and sounds of the 26 letters of alphabets. This literacy program utilizes a teaching approach called Multiple Exemplar Instruction. It is a type of instruction that provides practices with various response topographies to help ensure the acquisition of desired response forms and to promote response generalization of the untrained topographies (Cooper, Heron, & Heward, 2007). The Letter Names and Sounds program rotates response topographies and provides multiple exemplars of letter names and sounds. Learning behaviors in this program included matching, pointing to, textually responding, and intraverbally tacting letter names and sounds. The criterion in this program was set as an accuracy rate of 100% in a session or 90% in two consecutive sessions. Once a student reached a criterion, he/ she was considered to achieve a learning objective, except for the situation in which a learning tactic was introduced, which was explained later in this section. Composite scores were generated in this program to represent participants' learning in alphabetic knowledge in the study.

The 100 Easy Lessons. This literacy program is based on the *Teach Your Child to Read in 100 Easy Lessons* program developed by Engelmann, Haddox, and Bruner (1983) for preschool-aged struggling readers. It includes 100 twenty-minute lessons with detailed scripts for teachers to use. This program provides direct instruction on phonemic awareness, including rhyming, blending, and segmenting. Children with ASD at the CABAS® schools followed teachers' direction instruction on this book to learn phonics and to practice blending sounds into words. The criterion in this program was set as an accuracy rate of 90% in a session. Composite scores were generated in this program to represent learning in phonemic awareness in children with ASD in the study.

Textual Responding to Dolch Words. This literacy program uses a list of 104 high-frequency Dolch words to teach children with ASD word recognition. This list was first published by Edward Dolch in 1936, which included sight words and high-frequency words, and aimed to improve children's word recognition and reading fluency. In this program, students were asked to say word by word when teachers presented the printed words. The criterion was set as an accuracy rate of 90% in a session.

The Reading A-Z Curriculum. The Reading A-Z curriculum is designed to improve phonological awareness, phonics, vocabulary, fluency, and reading comprehension of students from pre-Kindergarten to the sixth grade matching the literacy Common Core Standards (https://www.readinga-z.com). It includes approximate 1000 fiction and nonfiction books across 29 levels of reading difficulty. The literacy program based on the Reading A-Z curriculum at the CABAS® schools mainly targets students' phonological awareness and sight words recognition in a one-to-one setting. Students were asked to read words by words on leveled books with progressively increased reading difficulty. This program reported data on the percentage of correct words read by the students in each session. The criterion was set as an accuracy rate of 100% in a session or 90% in two consecutive sessions. Once a student reaches a criterion in a leveled book, he/ she was considered to achieve a learning objective and was assigned the next book on the same reading level or a book on the next reading level depending on the individual student's progress. Considering the similar learning goals of sight word recognitions in both of the Textual Responding Dolch Words program and the Reading A-Z curriculum program, composite scores were generated from the two programs to represent participants' learning progress in word recognition.

The Reading A-Z Curriculum Comprehension Quizzes. The reading comprehension program at the CABAS® school focuses on students' performance in answering the text-dependent questions on each book of the Reading A-Z curriculum. Several multiple-choice and short-answer questions were designed for each book. For example, for the fiction book *The Three Little Pigs,* multiple-choice comprehension questions included, "What happened before the pigs built their houses? Why did the third pig build a brick house? Why did the wolf likely want to get into the pigs' houses?", and a short answer question was asked, "Why was the wolf lying down at the end of the story?" This literacy program reported students' percentage of accurate responses to the reading comprehension questions on the Reading A-Z curriculum. The criterion was set as an accuracy rate of 90% in a book. Composite scores were derived from this program to reflect participants' learning progress in reading comprehension.

Number Skills. The Number Skills program aims to teach Arabic numbers and the concepts of quantities using the Multiple Exemplar Instruction. It includes pointing, matching, tacting, and intraverbal responses to numbers and corresponding quantities through printed materials. The criterion was set as an accuracy rate of 100% in a session or 90% in two consecutive sessions. Composite scores were generated in this program to represent students' learning progress in basic knowledge of numbers and quantities.

The Curriculum for Early Academic Success (STEM Math Curriculum). This mathematics curriculum was developed and used by the CABAS® schools (Greer & Weber, 2017), which adopts the Multiple Exemplar Instruction to teach the functions of math. It requires to continually rotate all the response topographies and to provide multiple exemplars of each target stimuli. Through this instruction, the curriculum ensures students' acquisition of the basic knowledge of numbers and quantities and the functions of math. The learning objectives in this program include knowledge of numbers and quantities, understanding relationships between numbers, making simple calculations, recognition of shapes, positions, and patterns. The criterion was set as an accuracy rate of 90% in a session. Considering similar learning goals and types of instructions used in both the Number Skills program and the STEM Math curriculum, composite scores were derived from these two programs to reflect students' learning progress of basic numeric knowledge and mathematics problem-solving skills in trial-based mathematics programs.

Connecting Math Concepts Curriculum. This mathematics curriculum provides explicit and intensive teacher-directed instruction to students who are at risk of falling behind on learning math from grade levels of kindergarten to the 8th grade (Science Research Associates, 2012). Its learning objectives match the Common Core State Standards. It facilitates students' mastery of math skills and understandings of key concepts through making connections among math knowledge, problem-solving skills, and applications. The mathematics program at the CABAS® schools based on the Connecting Math Concepts curriculum mainly focuses on the objectives set for Grade K, including counting numbers, mathematic symbols, equality, up to two-digit addition and subtraction, money knowledge, shapes, positions, sizes, and grouping. The criterion was set as an accuracy rate of 90% in a session. Composite scores were generated from this program to represent participants' acquisitions of mathematics problem-solving skills in script-based mathematics program.

Overall, two types of composite scores were generated from the literacy and mathematics programs to reflect academic learning in children with ASD in the study. The first composite score was the average sessions to criteria, which was calculated by averaging the number of learning sessions a child required to achieve an academic objective in literacy and mathematics programs. It is noted that the CABAS® schools adopt the Decision Tree Protocol developed by Keohane and Greer (2005) for deciding when to introduce necessary intervening tactics to facilitate students' learning through graph analysis. A new objective was created after introducing a learning tactic. For example, the Letter Names and Sounds program targets three letter names and sounds in a session originally. If a student shows an error pattern in recognizing the letter name "A", a learning tactic called Increased Opportunities to Respond is often introduced to provide additional opportunities for the student to learn just the letter name "A" without the other two letters so that he/she can acquire thus target response more quickly and more efficiently. In this case, the original learning objective, for example, "mastering letter name 'A, B, C'", was on hold while a new learning objective was created called "mastering letter name 'A'" following the introduction of a learning tactic. In the study, this new kind of learning objectives created due to a tactic was not counted into the number of objectives a student achieved in a program when calculating the average sessions to criteria, but the additional sessions under this new objective were included in the number of sessions required to achieve the original learning objective. Also, according to the Decision Tree Protocol (Greer, 2002; Keohane & Greer, 2005), if a student achieves an accuracy rate of 90% or more in the first session of a learning objective, he/she was considered to have mastered that objective in the repertoire, which was thereby not included in the number of objectives achieved by the participants when calculating the average sessions to criteria. The second composite score was the total number of tactics introduced in the literacy and mathematics programs, representing the level of intervention and scaffolding a student required in academic learning.

Delayed Behavioral Measures

Three delayed behavioral measures were designed in the study to assess children's response to delay of reinforcement in the natural classroom environment and to examine how these children's abilities to wait in these three tasks are related to their self-regulation and sensitivity to rewards measured by direct assessments and parental reports. The three tasks included *delayed turn-taking with an adult, delayed delivery of edibles, and delayed delivery of tokens*. These tasks examined children's ability to delay their receipts of reinforcement by progressively extending the lengths of delays they could get a reward. The cumulative durations in which the child waited and the distraction strategies they used during the procedures were coded for the subsequent analyses. The three delayed behavioral measures were implemented to a total of 29 participants in the study (90.63%), as the other three participants have graduated before the onset of these tasks.

Delayed Turn-taking with an Adult. On this task, the child and the experimenter took turns to push a toy car down a car ramp. At the beginning of the task, the child had a few trials to test placing and pushing the toy car on the ramp. Rules were explained to the child before the onset of the task that the experimenter and the child would take turns to play this game. No one should touch the car in the other's playing sessions. At the end of the experimenter's playing sessions, the child would need to request a turn by saying, "My turn, please," and wait for the experimenter to pass the toy car without touching it. The experimenter confirmed that the child understood the rules by asking a few test questions: "What should you say and do for getting the car? Can you get the car directly once it is down the car ramp? Can you touch the car or the car ramp during the other's turn?" During this task, the child and the experimenter took turns playing with the toy car by following a sequence of sessions alternately. The sequences of the child's turn were as follows: 1) Request: The child requested the toy car from the experimenter by saying, "My turn, please," and waited for the experimenter to pass the toy car without touching it. A session with immediate reinforcement was rotated with another session with delayed reinforcement. In the immediate reinforcement sessions, the experimenter gave the toy car to the child immediately after he/she requested it. In the delayed reinforcement sessions, the experimenter delayed passing the toy car from 2 to 16 s incrementally by pretending busy with documenting data; 2) Play: After getting the toy car, the child was expected to place it on the top of the ramp and to push it down without any stereotypy or passivity; 3) Pass: Once the toy car crossed the finish line on the bottom of the car ramp, the experimenter requested the car by saying, "My turn, please." The child was observed whether he/she passed back the toy car as requested without any delay; 4) Wait: After getting the toy car from the child, the experimenter put it on the top of the ramp. A session with an immediate play was rotated with another session with a delayed play. In the immediate play sessions, the experimenter pushed the car down the ramp immediately after placing it on the top of the ramp. In contrast, the experimenter delayed pushing the car from 2 to 16 s incrementally by pretending busy with documenting data in the delayed sessions. The child was observed whether he/she was able to wait for the experimenter to finish her work without touching the car or the car ramp. In sum, during the delayed reinforcement sessions, the child had to wait for his/her turn twice: First, he/she waited for the experimenter to pass the toy car after requesting it vocally in the Request session; Second, he/she waited for the experimenter to finish playing after passing back the toy car in the Wait session. There was a total of 16 turn-taking rounds, eight of which were with immediate reinforcement, and the other eight were delayed reinforcement. The lengths of the delays were increased incrementally from 2 to 16 s in both wait sessions. If the child did not follow the general rules, for example, he/she did not request a turn vocally and grabbed the car immediately after the experimenter's session, rules were reemphasized, and the experimenter corrected the child by providing vocal prompts. If the child did not wait, no correction was provided. However, rules were reemphasized when the experimenter requested the car from the child or waited for the child to finish her turn. For example, the experimenter would say, "I am not grabbing the car from you, even though I said, 'My turn, please.' But it is time to pass the car to me so I can play, too." Four kinds of data were collected in this task: 1) the number of delayed turn-taking sessions in which the child was able to wait for the teacher to pass the reinforcer car without touching it in a total of 16 opportunities (one Request session and one Wait session in a delayed round, and there was a total of eight delayed rounds). A plus (+) was recorded if the child followed the rules in a session, whereas a minus (-) was recorded; 2) the cumulative durations the child waited for the experimenter to pass the car without touching it during all the Request sessions. The maximum possible wait duration was 72 s; 3) the cumulative durations the child waited for the experimenter to play with the car without touching it during all the Wait sessions. The maximum possible wait duration was 72 s; 4) the behavioral strategies the child used to regulate him/herself during the waits, which were coded as a) using language; b) using gestures; c) having eye contacts with the experimenter. Using language was defined as the child said, sang, or yelled anything meaningful during the waits. The child can direct this behavior to either the experimenter, him/herself or any other people in the classroom. Using gestures was defined as the child used gestures to communicate during the waits. Gestures can be descriptive (e.g., grabbing gestures to request the car), conventional (e.g., clap hands), informational (e.g., holding up one finger to mean one round), or emotional (e.g., shaking fists to mean angry). Having eye contact with the experimenter was defined as the child initiated a clear and appropriate gaze towards the experimenter.

Delayed Delivery of Edibles. Before the onset of the task, a kind of small edible was chosen as the reinforcer based on each child's preference, such as M&Ms, Goldfish, or Chips. Children were seated at a table with the experimenter and were asked to complete a performance task that has been mastered in their repertoire, matching non-identical pictures with two non-exemplars. A plate of the chosen edibles was placed in the participants' visions. Rules were explained to the child before the onset of the task that the child could get an edible if he/she matched the pictures correctly, but the edible should not be taken until the experimenter signaled, "Take one," and only one edible was allowed to take each time. The experimenter confirmed that the child understood the rules by asking a few test questions: "When can you take a Goldfish? Can you take a Goldfish before I say, 'take it'? How many Goldfish can you take each time?" Every time when the child matched pictures correctly, the experimenter said, "That was correct," in a natural tone to confirm that the answer was received. A session with immediate reinforcement was rotated with another session with delayed delivery of edibles. The participants experienced a maximum of 12 immediate reinforcement sessions and 12 delayed reinforcement sessions to get edible reinforcers. In the sessions with immediate reinforcement, the experimenter prompted the child to get an edible reinforcer immediately after a correct answer was made by saying, "That was correct. Take one!" The child was thereby allowed to get an edible without any delay after giving a correct answer. After confirming the answer was received in the delayed sessions, the experimenter delayed the pick-up signals by pretending busy with documenting data. At the end of each waiting interval, the experimenter prompted the child to get the edible on his/her own by saying, "Take one." Overall, the delayed duration increased from 2 to 16 s. Instead of implementing the delayed sessions by extending the lengths of delay incrementally, the experimenter stratified the delayed durations into two levels: the basic level was among 2, 4, 6, and 8 s, and the advanced level was among 10, 12, 14, and 16 s. During each level of delayed sessions, the experimenter randomized the delayed durations for each participant in four opportunities. For example, under the basic level, the experimenter always started the waiting duration from 2 s for all participants and then randomized the intervals among 4, 6, and 8 s for different participants. The criterion was set as a 75% passing rate for the basic-level delayed sessions. If a participant achieved the criterion, the experimenter implemented the advanced-level delayed sessions twice by starting to ask the participant to wait for 10 s and then randomized the rest of the sessions with 12, 14, and 16 s delays. If a participant did not achieve a 75% passing rate on the basic-level delayed session, the experimenter continued to implement this level one more time. If the participant achieved a 75% passing rate on the second chance, the experimenter extended the waiting duration to the advanced level once. If the participant still did not achieve the 75% passing rate the second time, the experimenter stopped the whole task, as the basic-level delay was considered the ceiling. Rotating the immediate and delayed reinforcement sessions prevented the participants from learning to wait longer and longer in the task and made it difficult for them to predict how long the delay would be in each session. Meanwhile, it attempted to examine the children's self-regulation by mimicking the delayed reinforcement situations they may encounter in a natural classroom environment. On this task, if the participant waited for the experimenter's signal without touching the edible reinforcers during the whole duration, a plus (+) was recorded. Otherwise, a minus (-) was recorded, indicating that the participant failed to wait for that session. No correction was provided as this task was intended to assess whether the participants were able to wait for the reinforcers instead of teaching them how to wait. Three kinds of data were collected in this task: 1) the number of sessions in which the child was able to wait for the experimenter's signal to get the edibles without touching it for the whole duration in a total of 12 delayed delivery opportunities; 2) the cumulative durations the child waited for the experimenter's delayed delivery of edibles throughout all the sessions. Only the sessions in which the child waited for the whole duration counted. The maximum possible wait duration on this task was 124 s; 3) the frequencies of using different behavioral strategies during the waits. The behaviors were coded as a) using language; b) using gestures; c) having eye contact with the experimenter. Using language was defined as the child said, sang, or yelled anything meaningful during the waits. The child can direct this behavior to either the experimenter, him/herself or any other people in the classroom. Using gestures was defined as the child used gestures to communicate during the waits. Gestures can be descriptive (e.g., grabbing gestures to request the reinforcer), conventional (e.g., head nodding), informational (e.g., holding up one finger to mean one edible), or emotional (e.g., shaking fists to mean angry). Having eye contact with the experimenter was defined as the child initiated a clear and appropriate gaze towards the experimenter.

Delayed Delivery of Tokens. The procedure was identical to the delayed delivery of edibles task except that a token system was used as the reinforcer, which included tokens and a token tower to organize and show the number of tokens that had earned. Before the onset of the task, the experimenter explained the rules to the child and confirmed he/she understood by asking a few test questions. The experimenter also asked the child to choose a toy or a storybook in the classroom as a back-up reinforcer. It required a total of 24 tokens to get the back-up reinforcer for 3 minutes, and the participants had a maximum of 24 opportunities to earn the tokens, 12 of which were with immediate reinforcement and another 12 were with delayed reinforcement. A session with immediate reinforcement was rotated with another session with delayed delivery of tokens. Same criterion and delayed procedures were used in this task like the ones in the delayed delivery of edibles task. During the procedure, a bowl of tokens and a token tower were placed in the participants' visions. The participants were prompted to get one token from the bowl and put it into the token tower when the experimenter signaled, "Take one," after a correct answer was given. If a participant did not experience the advanced-level of delayed sessions due to a failure to achieve the criterion of the basic-level at a 75% passing rate, the experimenter provided additional opportunities for the participants to earn extra tokens quickly after the whole task so that he/ she still had the opportunities to get the back-up reinforcer. Similarly, three kinds of data were collected in this task: 1) the number of sessions in which the child was able to wait for the experimenter's signal to get the tokens without touching them in a total of 12 delayed delivery opportunities; A whole duration method was used, such that the child was considered failing to wait if he/she did not wait for the whole duration of the session; 2) the cumulative durations the child waited for the experimenter's signals in the task. The maximum possible wait duration was 124 s; 3) the frequencies of using different behavioral strategies during the waits. The behaviors were coded as a) using language; b) using gestures; c) having eye contact with the experimenter.

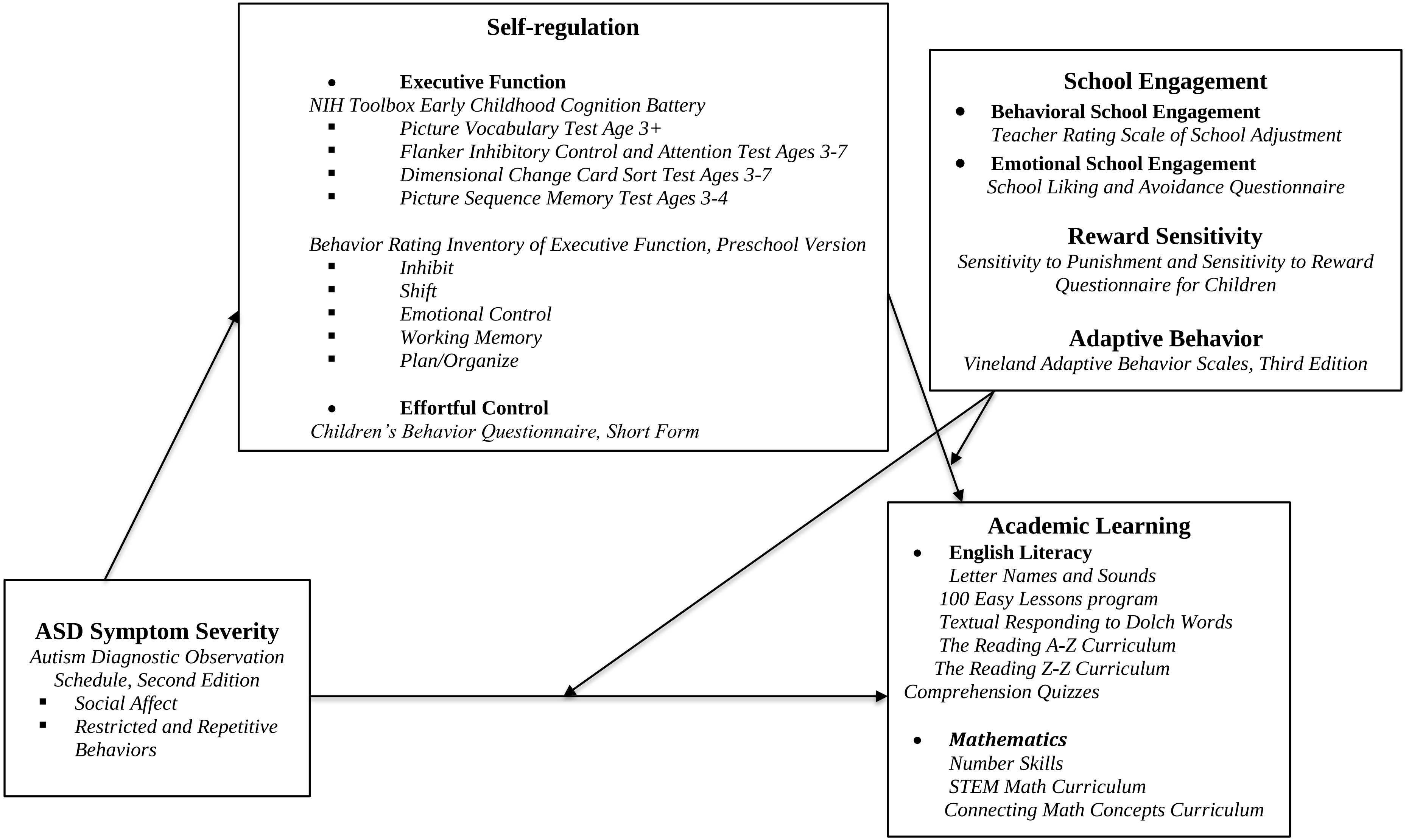
Reinforcing Efficacy of Token versus Social Reinforcement

Children with ASD receive reinforcement consistently at the schools using instructions based on the principles of applied behavior analysis. Two types of reinforcement are often delivered in such a school setting for preschoolers with ASD: token, a kind of generalized conditioned reinforcers that can be used to exchange for various back-up reinforcers, and social reinforcement, including but not limited to praise, eye contact, and attention. It has been well-documented that obtaining rewards through competent efforts is crucial for goal-directed behaviors and learning (e.g., Damiano et al., 2012). Understanding the reward sensitivity of children with ASD between token and social stimuli more deeply provides us insights into a more comprehensive picture of learning in this special group of students. Therefore, a post-hoc test was conducted in this study utilizing an A-B-A-B reversal design to examine the reinforcing efficacy of token versus social reinforcement in children with ASD in the natural classroom environment and investigate factors contributing to the reinforcer preference in this atypical population.

In this test, the reinforcing efficacy of token versus social reinforcement in children with ASD was examined through a performance task, matching non-identical pictures or matching upper- and lower-case letters, depending on the participant's repertoire. The dependent variable was the number of correct responses given by the participant in the performance task in two minutes. The order of the procedure was as follows: 1) Phrase A1 Token Condition: the participants received tokens as a reinforcer by giving a correct response to the performance task. A token was delivered directly by the examiner into a token tower following each correct response. No social attention was given throughout the procedure. A back-up reinforcer in the classroom was allowed to be exchanged for 3 minutes after the whole session of the test; 2) Phrase B1 Social Condition: the participants received social reinforcement by giving a correct response to the performance task. The examiner delivered social praise and attention following each correct response; 3) Phrase A2 Token Condition: the procedure was the same as Phrase A1; 4) Phrase B2 Social Condition: the procedure was the same as Phrase B1. No correction was given throughout this test. The criteria were set as the differences in the correct responses in six consecutive sessions were less than three per minute. Materials in this test included a laptop for showing the stimuli on the performance task, a token tower with a clear display of the tokens, a bowl of tokens, and back-up reinforcers in the classroom, including toys, storybooks, and iPad videos. No edible reinforcers were allowed to be exchanged to control for their confounding reinforcing effects. This post-hoc test was conducted on a total of 25 participants in the study (78.13%), as the rest of the participants either had graduated before the onset of this test or had schedule conflicts to complete at least one Token condition and one Social condition. Interobserver agreement was obtained for a total of 62% of all sessions, yielding 100% agreement across all sessions for all participants.

Figure 2

Measures of Study Variables



Chapter IV

Results

This study investigated the association between self-regulation and academic learning in preschoolers with ASD and examined how child developmental characteristics moderated this relationship. First, descriptive statistics and data preparation are presented for the primary child characteristics variables, including self-regulation in two dimensions (EF and EC), ASD-related symptoms severity, reward sensitivity, school engagement (behavioral and emotional), and adaptive behavior. Second, correlations between demographic variables and child characteristics variables are reported for identifying covariates in the subsequent analyses. Third, descriptive statistics are presented for the academic learning variables, along with their correlations with the demographic factors. Findings are then presented for each research question.

Data Preparation

Prior to any main statistical analyses, all primary study variables were evaluated to see if they violated the assumptions of parametric tests, including representative samples, sample size, and normality of distributions of variables. Regarding a representative sample, all participants in the study had a current diagnosis of autism confirmed with an ADOS-2 assessment. It included 25 males and 7 males, the ratio of which approximated the gender ratio in the autism prevalence estimated by the Centers for Disease Control and Prevention (CDC, 2020). This sample included participants from diverse ethnic and family backgrounds (see Table 1) and thereby was believed to be a representative sample in the population. A sample size of 30 or more is considered to be sufficient for the majority of bivariate parametric tests (Abu-Bader, 2016). Therefore, the study's sample size (N = 32) met the requirements for using parametric tests for analyses. Both visual inspection and statistical tests were used to determine data's normality of distributions in the study. All primary continuous study variables were first examined visually through univariate histograms and the normal Q-Q plots. The Shapiro-Wilk test was used to determine the normality. Since the sample size in the study was relatively small, the Fisher's measure of skewness was used to re-examine the normality. To determine if a distribution is severely skewed by the Fisher's test, the skewness value was divided by its standard error to see if the outcome fell within the acceptable range of ± 1.96, and the Kurtosis coefficient was also divided by its standard error to see if the outcome again fell within the acceptable range of ± 1.96. When severe skewness happened, data transformation was conducted.

Descriptive Statistics of Child Characteristics Variables

Table 2 provides the descriptive statistics of the child characteristics variables in the study.

Self-regulation

In terms of EF, children with ASD had an average score of 98.59 (*SD* = 14.62, range = 69-126) on the direct measure, the NIHTB-ECB. For the data of two subscales on this measure, the DCCS test and the Memory test, the significance values of the Shapiro-Wilk test were less than 0.05. However, visual inspection and the Fisher's measure of skewness showed no significant skewness, so data were not transformed. For the parent-reported EF measure, the BRIEF-P, an average standardized composite score (reversed) of - 68.61 (*SD* = 16.82, range = - 99 to - 41) was reported on children's everyday executive functioning. The average standardized score of the normative samples is 50 (*SD* = 10) (Gioia, Espy, & Isquith, 2003). Accordingly, children with ASD in this study represented a sample with more severe executive dysfunction compared to their typically developing peers. Regarding temperamental EC, parents reported a mean score of 4.65 (*SD* = 0.70, range = 3.19- 5.69) on the CBQ-SF. A score of 4 indicates a neutral response to how true particular statements are about their child's behaviors. Scores closer to 7 indicated higher levels of EC. Compare to the average scores of the four EC subscales in the CBQ reported in 3 and 4 to 5-year-old typically developing children (Rothbart et al., 2001), children with ASD in the present study demonstrated lower levels of EC as reported by parents.

ASD Symptoms Severity

With regard to the severity of ASD-related symptoms, children received an average ADOS-2 Comparison score of 6.81 (*SD* = 1.56, range = 4-10), indicating a sample with an overall moderate level of ASD-related symptoms. Of the 32 participants, 3.1% demonstrated a low level of symptoms (*n* = 1), 71.9% had a moderate level (*n* = 23), and 25% showed a high level (*n* = 8). Based on the children's language ability and age, the majority (90.63%, *n* = 29) was administered a Module 2 assessment, whereas 9.38% (*n* = 3) had a Module 3. A significant group difference was found in the standard scores of the Communication domain in the teacher-reported Vineland-3 between children in the ADOS-2 Module 2 and Module 3, t (30) = - 2.72, p = .011. Children in Module 2 had a lower average score in their receptive, expressive, and written communication skills (*M* = 89.45, *SD* = 9.49) reported by their teachers than those in Module 3 (*M* = 104.67, *SD* = 4.04). This finding aligned with the language requirement of module selection in the ADOS-2 assessment: examinees in the Module 2 are able to use three-word phrases regularly but has not yet been verbally fluent, whereas those in the Module 3 should have more advanced language development demonstrated by their regular use of complex sentences.

Reward Sensitivity

In terms of children's reward sensitivity, parents reported an average score of 3.26 (*SD* = 0.54, range = 2.33-4.78) on the three sensitivity to reward subscales on the SPSRQ-C measure. A score of 3 indicates a neutral response to how true particular statements are about the child's reactions to rewards. This variable was positively skewed and was transformed using the square root of it (Tabachnick & Fidell, 2007). Data transformation effectively reduced the skewness.

School Engagement

Teachers reported children's school engagement in two perspectives: behavioral and relational adjustment to school (behavioral school engagement) and the expressed desire to like or avoid school (emotional school engagement). In terms of behavioral school engagement, teachers reported an average score of 2.2 *(SD* = 0.46, range = 1.13-3) on the TRSSA scale. Scores closer to 3 indicates better cooperative and independent participation in the school activities. In terms of emotional school engagement, on average, teachers reported a score of 2.8 (*SD* = 0.35, range = 1.66-3) on the SLAQ. A score closer to 3 indicates higher levels of school liking. This variable was found to be severely negatively skewed. To meet the assumption of normality, data transformation was conducted. The skewness reduced after a powerful inverse-normal transformation was used (Tabachnick & Fidell, 2007). However, it remained significant according to the Fisher's measure of skewness and the Shapiro-Wilk test. Therefore, any subsequent analysis involved the emotional school engagement variable used nonparametric tests instead.

Adaptive Behavior

Teachers reported an average score of 85.56 (*SD* = 9.61, range = 67-118) on the Vineland-3, indicating an overall moderately low to adequate adaptive level regarding children's adaptive behavior in the study. This variable was positively skewed and was thereby transformed using a base-ten log transformation method (Tabachnick & Fidell, 2007). As a result, the skewness was effectively reduced. Similarly, the variable of the Daily Living Skills subscale was also positively skewed and required data transformation. The skewness was reduced after a base-ten log transformation (Tabachnick & Fidell, 2007). However, it was still significant. Therefore, any subsequent analysis involved this variable

Table 2

Means and Standard Deviations of Child Characteristics Variables

Child Characteristics	*n*	*M*	*SD*	*Min*	*Max*	*Shapiro-Wilk Test*	*Skewness*	*Kurtosis*
EF – NIHTB-ECB	32	98.59	14.62	69	126	.97	-.36	.15
Vocabulary – the Vocabulary Test	32	93.28	11.74	62	112	.94	-.42	.19
Inhibitory Control & Attention –the Flanker Test	32	98.34	14.87	63	122	.94	-.45	-.44
Cognitive Flexibility & Attention – the DCCS Test	32	98.97	10.23	79	115	.93*	-.29	-.27
Episodic Memory –the Memory Test	32	106.97	25.56	60	142	.77**	-.73	-1.27
EF – BRIEF-P (reversed)	28	-68.61	16.82	-99	-41	.96	.04	-1.05
Inhibit	28	-63.5	15	-89	-38	.95	-.09	-1.25
Shift	28	-61.39	12.96	-87	-40	.96	.02	-.89
Emotional Control	28	-63.68	13.68	-96	-36	.98	.21	-.13
Working Memory	28	-68.68	16.05	-98	-40	.97	-.05	-1.01
Plan/ Organize	28	-64.79	15.96	-90	-38	.95	0	-1.02
Temperamental EC – CBQ-SF [a]	28	4.65	0.70	3.19	5.69	.95	-.18	-.60
ASD Severity – ADOS-2	32	6.81	1.60	4	10	--	--	--
Social Affect	32	10.91	3.32	6	19	--	--	--
Restricted and Repetitive Behavior	32	2.66	2.06	0	7	--	--	--
Sensitivity to Reward – SPSRQ-C [b, e]	28	3.26	0.54	2.33	4.78	.96	.56	1.22

Behavioral School Engagement – TRSSA [c]	32	2.20	0.46	1.13	3	.98	-.38	-.33
Emotional School Engagement – SLAQ [d, f]	32	2.80	0.35	1.66	3	.64***	-2.05	3.63
Adaptive Behavior – Vineland-3 [e]	32	85.56	9.61	67	118	.96	.69	1.98
Communication	32	90.88	10.13	71	109	.97	.06	-.70
Daily Living Skills [f]	32	87.31	10.77	60	124	.90**	.91	4.13
Socialization [e]	32	83.31	12.78	62	117	.94	.59	.52
Motor Skills [e]	32	81.22	15.11	29	105	.94	-.24	.97

Note. [a] Parent-reported EC coded as 1= Extremely untrue 7= Extremely true, such that higher scores indicated higher levels of EC; [b] Parent-reported reward sensitivity coded as 1= Strongly disagree 5= Strongly agree, such that higher scores indicated greater sensitivity to reward; [c] Teacher-reported behavioral school engagement coded as 1 = Doesn't apply 3 = Certainly applies, such that higher scores indicated higher behavioral participation; [d] Teacher-reported emotional school engagement coded as 1 = Doesn't apply 3 = Certainly applies, such that higher scores indicated higher school liking;
[e] For the reward sensitivity composite score reported on the SPSRQ-C, the adaptive behavior composite score on the Vineland-3, and the standard scores of two Vineland-3 subscales (Socialization, and Motor Skills), the Skewness and Kurtosis after transformation are reported; [f] Normality of distribution did not achieve after data transformation. Nonparametric tests were used in subsequent analyses involved this variable.
* $p < .05$. ** $p < .01$. *** $p < .001$

used nonparametric tests instead. Another subscale, Socialization, was also positively skewed. A base-ten log transformation effectively reduced the skewness (Tabachnick & Fidell, 2007). Last, scores on the Motor Skills subscale were negatively skewed. This variable was first reversed-coded, making the distribution positively skewed. Subsequently, the interpretation of the scores changed, such that lower scores indicated more advanced development of motor skills. Values were then transformed using the square root of the variable (Tabachnick & Fidell, 2007). The data transformation significantly reduced the skewness.

Relations between Demographic Factors and Child Characteristics Variables

Before conducting the main study analyses, correlations between demographic factors and child characteristics variables were tested. Table 3 provides the correlations between child demographic and child characteristics variables. Table 4 presents the correlations between family demographic and child characteristics variables.

Pearson's r correlation test (r) was used to test the associations between the child's age and the continuous child characteristics variables. Spearman's *rho* correlation test (r_s) was used to test the correlations between child age and other child characteristics variables that require a nonparametric test, such as the ADOS-2 comparison score and children's emotional school engagement reported on the SLAQ, due to the level of measurement or a violation to the normality of distribution. Point-biserial correlation test (r_{pb}) was used to test the relations between dichotomous variables, such as the child's gender, and other continuous child characteristics variables. Rank-biserial correlation test (r_{rb}) was used to test the associations between dichotomous variables and other ordinal child characteristics variables. All tests' assumptions were met. Similar approaches were applied to the tests of the correlations between family demographic and child characteristics variables.

Regarding self-regulation in children with ASD, a significant correlation was found between their ethnicity (White vs. not) and the scores on the NIHTB-ECB, r_{pb} (28) = .44, p = .018, with Caucasian/ White students had higher average scores in the measure (M = 106.46, SD = 10.41) than those with other ethnical backgrounds (M = 94.40, SD = 14.22). Similarly, a significant correlation was found between the ethnicity of young children with ASD (Hispanic vs. not) and the overall scores parent reported on the BRIEF-P, r_{pb} (27) = .52, p = .005. Specifically, Hispanic students with ASD were reported to have an average higher score on the parent-reported BRIEF-P (M = - 52.33, SD = 11.02) than their non-Hispanic peers (M = - 73.05, SD = 15.44), indicating that Hispanic children with ASD were reported by parents to have less executive dysfunction behaviors in accordance with parents' expectations. There was also a significant correlation between the ethnicity of young children with ASD (Hispanic vs. not) and the EC score reported by parents on the CBQ-SF, r_{pb} (27) = .40, p = .038, with Hispanic students with ASD reported to have an average higher score (M = 5.16, SD = .53) than their non-Hispanic peers (M = 4.50, SD = .68). In other words, Hispanic children with ASD were reported higher levels of EC by their parents than peers from other ethnical backgrounds. Together, these findings show that White students with ASD demonstrated better EF performance on direct measures than their peers from other ethnical backgrounds, while Hispanic students were reported by their parents to have fewer executive dysfunction behaviors and fewer delays in EC compared to non-Hispanic students by their parents. Therefore, children's ethnicity was tested as a covariate in the subsequent analyses related to self-regulation variables. Specifically, considering the different correlation patterns that emerged, children's ethnicity (White vs. not) was controlled in the analyses of direct EF measures on the NIHTB-ECB, and children's ethnicity (Hispanic vs. not) served as a covariate in the tests of parent-reported BRIEF-P.

In terms of family demographic variables, there was a significant positive association between mother's educational level and the composite scores children with ASD got on the

Table 3

Means and Standard Deviations of Child Demographic Variables and Their Correlations with Child Characteristics Variables

	n	*M*	*SD*	NIHEF	ADOS	BRIEF-P	EC	SR	ABC	BSE	ESE
Child age [a]	32	51.35	7.59	.12	.19	.06	-.00	-.16	-.09	.32	-.01
Child gender [b]	32	0.22	0.42	.10	-.19	-.42*	.41*	-.04	.25	.02	.09
Child Ethnicity (White vs. not) [c]	29	0.48	0.51	.44*	-.22	.26	-.23	.19	-.14	-.07	-.01
Child Ethnicity (Hispanic vs. not) [c]	29	0.24	0.44	-.16	-.01	-.52**	.40*	-.42*	-.06	-.17	-.11
Second language status [c]	29	1.76	0.44	-.35	.03	-.25	.22	-.50**	-.22	-.18	-.11
Sibling status [c]	29	1.14	0.35	.22	-.18	-.22	.13	-.19	.25	-.09	-.20
Sibling with DD [c]	25	1.56	0.51	.14	-.10	.14	.05	.22	.35	-.04	-.33

Note. NIHEF = NIH Toolbox Early Childhood Cognition Composite Score; ADOS = the ADOS-2 Comparison Score; BRIEF-P (reverse-scored) = the BRIEF-P Global Executive Composite Score; EC = temperamental effortful control on the CBQ-SF; SR = sensitivity to reward composite score on SPSRQ-C; ABC = the Vineland-3 Adaptive Behavior Composite Score; BSE = behavioral school engagement on TRSSA; ESE = emotional school engagement on SLAQ; DD = developmental delay.

[a] Child age coded in months; [b] Child gender coded as 0 = Male and 1 = Female; [c] Child ethnicity (White vs. not), Child ethnicity (Hispanic vs. not), Second language status, Sibling status, and Sibling with DD coded as 0 = No and 1 = Yes.

* $p < .05$. ** $p < .01$. *** $p < .001$

Table 4

Means and Standard Deviations of Family Demographic Variables and Their Correlations with Child Characteristics Variables

	n	*M*	*SD*	NIHEF	BRIEF-P	ADOS	EC	SR	ABC	BSE	ESE
Mother's education level [a, e]	32	--	--	.58**	.15	-.05	-.21	.02	.01	.08	-.14
Father's education level [a, e]	32	--	--	.39*	.19	-.11	-.14	.06	.07	-.13	.18
Marital status [b]	29	0.86	0.35	.02	-.07	.10	-.02	.06	-.18	.05	-.09
Nativity status [c]	29	0.59	0.50	-.22	-.50**	.25	.27	-.44*	-.07	-.32	-.20
Number of adults in household	29	2.07	0.37	.05	-.09	-.12	.09	-.20	.23	-.03	-.18
Number of children in household	29	2.24	1.06	.07	-.16	-.30	.20	-.11	.52**	.09	-.05
Household income [e]	27	--	--	.45*	.01	-.14	-.08	-.02	.17	.13	.04

Note. NIHEF = NIH Toolbox Early Childhood Cognition Composite Score; BRIEF-P (reverse-scored) = the BRIEF-P Global Executive Composite Score; ADOS = the ADOS-2 Comparison Score; EC = temperamental effortful control on the CBQ-SF; SR = reward sensitivity composite score on SPSRQ-C; ABC = the Vineland-3 Adaptive Behavior Composite Score; BSE = behavioral school engagement on TRSSA; ESE = emotional school engagement on SLAQ.

[a] Parent's education level coded as 1= Less than high school 8 = Doctorate degree; [b] Martial status coded as 0 = Non-married/ Non-committed partnership and 1 = Married/ Committed partnership; [c] Nativity status coded as 0 = U.S. and 1 = Non-U.S.;

* $p < .05$. ** $p < .01$. *** $p < .001$

direct EF measure, the NIHTB-ECB, r_s (29) = .58, p = .001, such that children whose mother with a higher educational degree performed better on the NIHTB-ECB than those whose mother had a relatively lower educational level. Similarly, father's educational level was found to be significantly positively correlated with children's performance on the NIHTB-ECB measure, r_s (29) = .39, p = .034, such that children whose father received higher levels of education had a better performance on the measure than their peers whose father had a relatively lower educational level. Family's socioeconomic status measured by the annual household income was also found to be significantly positively correlated with children's performance on the NIHTB-ECB measure, r_s (27) = .45, p = .019, such that children from a wealthier family had a better performance on the test. Mother's and father's educational levels were both found to be significantly associated with family's socio-economic status, r_s (25) = .60, p = .001 and r_s (25) = .59, p = .001.

A multiple regression analysis was conducted to test if the NIHTB-ECB composite score of children with ASD in the study was predicted by their mother's education level, father's education level, and family socioeconomic status, while controlling for the covariate children's ethnicity (White vs. not). All test assumptions were met. The multiple regression model significantly predicted children's NIHTB-ECB composite score, R^2 = .54, F (4, 21) = 6.18, p = .002. There was a main effect of the mother's education level, β =.52, p = .009, after controlling for the covariate and each of the other independent variables. There were no significant main effects of the father's education level and family socioeconomic status. Regression coefficients and standard errors can be found in Table 5. These findings reveal that the mother's educational level of children with ASD provided a meaningful contribution to explaining the composite scores they got on the NIHTB-ECB. Therefore, the mother's education level was used as a covariate in the subsequent analyses related to children's EF measured by the NIHTB-ECB.

For the parental report of EF, there was a significant association between the parent's nativity and the scores reported in the BRIEF-P, r_{pb} (27) = .50, p = .007. Children whose parents were born outside of U.S. received higher scores on the BRIEF-P (M = - 61.5, SD = 15.89) than their peers whose parents were natives in the U.S. (M = - 78. 08, SD = 13.37). This result indicates that children whose parents were born outside of U.S. demonstrated higher levels of EF relative to parents' expectations than their peers whose parents were born in this country.

Gender was also found to be related to self-regulation in children with ASD in the study. Results showed that children's gender was significantly associated with the BRIEF-P composite score reported by parents, r_{pb} (30) = .42, p = .028, with female preschoolers with ASD received a higher average score (M = - 56.71, SD = 11.70) than their male peers (M = - 72.57, SD = 16.58). This indicated that male children with ASD demonstrated higher levels of executive dysfunction as indicated by their lower scores on the BRIEF-P compared to their female peers relative to their parents' expectations. Similarly, a statistically significant association was found between gender and the level of EC reported by parents on the CBQ-SF, r_{pb} (30) = .41, p = .029. Male preschoolers with ASD were reported higher levels of EC delays, indicated by their lower scores on the CBQ-SF (M = 4.48, SD = .70), than their female peers (M = 5.14, SD = .45). These findings together revealed that male preschoolers with ASD demonstrated more delays in self-regulation development than their female peers, as reported by parents.

A multiple regression analysis was conducted to test if the BRIEF-P composite score of children with ASD in the study was predicted by their gender and family's nativity status controlling for the covariate children's ethnicity (Hispanic vs. not). All test assumptions were met. The multiple regression model significantly predicted children's BRIEF-P composite score, R^2 = .56, F (3, 24) = 9.971, p < .001. There was a main effect of children's gender, β =

-.47, p = .003, controlling for children's ethnicity and their family's nativity. There was also a main effect of the family's nativity, β = -.46, p = .008, controlling for children's ethnicity and gender. Regression coefficients and standard errors can be found in Table 5. Thus, both children's gender and family's nativity contributed significantly to the prediction of the BRIEF-P composite score reported by parents and thereby served as covariates in the subsequent analyses related to children's EF measured by the BRIEF-P.

Children's temperamental EC was associated with their ethnicity (Hispanic vs. not) and gender, as shown above. A multiple regression model was conducted to test if children's EC level reported on the CBQ-SF was predicted by their gender after controlling for ethnicity (Hispanic vs. not). The significant model emerged, R^2 = .30, F (2, 25) = 5.26, p =.012. There was a main effect of gender after controlling for children's ethnicity, β = .38, p = .035. Therefore, children's gender served as a covariate in the subsequent relevant analyses related to children's EC.

As for sensitivity to reward, a significant association was found between the ethnicity of young children with ASD (Hispanic vs. not) and the score of reward sensitivity reported by parents on the SPSRQ-C, r_{pb} (27) = -.42, p = .026, with Hispanic students with ASD had less reward sensitivity (M = 1.68, SD = .13) than their non-Hispanic peers (M = 1.83, SD = .14). There was also a significant correlation between children's second language status and their reward sensitivity, as reported by parents on the SPSRQ-C, r_{pb} (27) = -.50, p = .007. Children who were monolingual was found to have higher sensitivity to reward (M = 1.84, SD = .13) than their peers who can speak a second language (M = 1.66, SD = .13). Also, a significant correlation was found between the family nativity status and children's reward sensitivity reported by parents on the SPSRQ-C, r_{pb} (27) = -.44, p = .019, with children whose parents were born outside of U.S. had smaller reward sensitivity (M = 1.75, SD = .13) than those

Table 5

Multiple Regression Results for the Direct and Parent-reported Self-regulation Measures Predicted by Demographic Variables

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	ΔR^2
		LL	*UL*				
Prediction of NIHTB-ECB Composite Model						.54	.45**
Constant	64.55	45.20	83.90	9.30			
Ethnicity (White vs. not)	8.66	-.65	17.97	4.48	.31		
Mom Educational Level	5.33**	1.48	9.18	1.85	.52*		
Dad Education Level	2.07	-1.36	5.50	1.65	.24		
Family Socio-economic Status	-.67	-3.77	2.43	1.49	-.09		
Prediction of BRIEF-P Composite Model						.56	.50***
Constant	84.00	76.00	92.00	3.88			
Ethnicity (Hispanic vs. not)	-10.52	-23.47	2.42	6.27	-.26		
Children's Gender	-17.76**	-28.85	-6.66	5.38	-.47**		
Family Nativity Status	-15.23**	-26.06	-4.40	5.25	-.46**		
Prediction of EC Composite Model						.30	.24*
Constant	4.37	4.07	4.66	.14			
Ethnicity (Hispanic vs. not)	.60*	0.02	1.18	.28	.36*		
Children's Gender	.60*	0.05	1.15	.27	.38*		

Note. Model = "Enter" method in SPSS Statistics; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; NIHTB-ECB = the NIH Toolbox Early Childhood Cognition Battery composite score; BRIEF-P (reverse-scored) = Behavior Rating Inventory of Executive Function Preschool Version composite score; EC = effortful control derived from the Children's Behavior Questionnaire Short Form; Ethnicity was dummy coded as 1= White, 0 = Others or 1 = Hispanic, 0 = Others as specified.
* $p < .05$. ** $p < .01$. *** $p < .001$

whose parents were locals (*M* = 1.87, *SD* = .14). Also, children's second language status was significantly associated with their family's nativity, $\chi^2(1, N = 29) = 6.51$, $p = .01$. A multiple regression model was conducted to test if children's reward sensitivity was predicted by their second language status and family nativity controlling for the covariate children's ethnicity (Hispanic vs. not). A significant model emerged without any significant main effects from the predictors, indicating that all three factors contributed to children's reward sensitivity jointly while they were highly correlated with each other. Children's second language status emerged as the factor explaining most of the variances in children's scores on the SPSRQ-C ($R^2 = .25$) and thereby served as a covariate in the subsequent analyses related to children's reward sensitivity.

Descriptive Statistics of Child Learning Variables

Table 6 provides the descriptive statistics of child learning variables based on the school data of five literacy and three mathematics programs. The average sessions to criteria were derived from each program to represent students' learning progress in different academic domains. Specifically, two literacy programs (the Textual Responding to Dolch Words and the Reading A-Z curriculum) and two mathematics programs (the Number Skills and the STEM-Math curriculum) generated a composite score respectively, due to their similar academic goals and teaching approaches.

On average, the descriptive data of child learning variables in the study were derived from a total of 73.63 learning sessions in all academic programs (*SD* = 49.15, range = 6-175), the number of which excluded the sessions in which the participants showed a mastery of academic contents in the repertoire indicated by an initial accuracy rate of 90%. On average, the participants achieved a total of 21.66 learning objectives in all academic programs (*SD* = 17.24, range = 2-62). Specifically, children with ASD in the study required an average of 3.76 and 4.96 sessions (*SD* = 1.69 and 2.38) to achieve a learning objective in literacy and mathematics programs respectively, showing that the participants mastered literacy skills slightly faster than mathematics skills at school. No significant association emerged between the average sessions to criteria in literacy and mathematics programs, indicating that the rates of literacy and mathematics learning in children with ASD may be independent of one another.

Considering the small samples of having learning tactics in each academic program, a total number of learning tactics was summarized from all literacy and mathematics programs to represent the extent to which children with ASD required additional one-to-one intervention in academic learning at school. Of the 32 participants, an average total number of 0.69 learning tactics (*SD* = 1.20, range = 0-6) was needed to achieve an objective in the academic programs in the study. Specifically, 13 of the full sample (40.63%) required a learning tactic. On average, these participants were introduced a total number of 1.69 tactics (*SD* = 1.38, range = 1-6) to facilitate their learning in all of the literacy and mathematics programs included in the study.

Table 6

Descriptive Statistics of Child Learning Variables in Literacy and Mathematics Programs

Child Learning Variables	*n*	*M*	*SD*	*Min*	*Max*
Average Sessions to Criteria in Literacy Programs	31	3.76	1.69	2	9
Alphabetic Knowledge [a]	19	4.54	1.89	2	9
Phonemic Awareness [b]	17	2.89	0.95	2	5.67
Word Recognition [c]	15	3.35	1.29	2.09	6
Reading Comprehension [d]	7	2.41	0.35	2	3
Total Learning Tactics Used in Literacy Programs	4	1.5	1	1	3
Alphabetic Knowledge [a]	2	2	1.41	1	3
Phonemic Awareness [b]	1	1	1	1	1
Word Recognition [c]	0	-	-	-	-
Reading Comprehension [d]	1	1	1	1	1
Total Learning Sessions in Literacy Programs	31	51.65	41.32	5	170

Letter Names and Sounds	19	19.89	16.10	6	72
The 100 Easy Lesson Curriculum	17	32.07	24.36	4	95
Textual Responding to Dolch Words	6	23	19.31	12	62
The Reading A-Z Curriculum	10	35.2	24.73	5	90
The Reading A-Z Comprehension Quizzes	7	26.86	26.37	3	80
Average Sessions to Criteria in Maths Programs	30	4.96	2.38	2	10
Number and Prob-Solving Skills through MEI [e]	26	5.76	2.52	2	12
Number and Prob-Solving Skills through DI [f]	9	2.62	0.80	2	4
Total Learning Tactics Used in Maths Programs	11	1.45	0.69	1	3
Number and Prob-Solving Skills through MEI [e]	11	1.45	0.69	1	3
Number and Prob-Solving Skills through DI [f]	0	-	-	-	-
Total Learning Sessions in Maths Programs	28	26.96	19.28	2	92
Number Skills	5	24.8	10.99	12	36
The STEM Math Curriculum	21	21.71	11.90	2	51
The Connecting Math Concepts Curriculum	9	19.45	16.85	4	56

Note. MEI = the Multiple Exemplar Instruction; DI = direct instruction;
Composite scores were generated from [a] the Letter Names and Sounds program; [b] the 100 Easy Lessons program; [c] the Textual Responding Dolch Words program and the Reading A-Z program; [d] the Reading A-Z Comprehension Quizzes; [e] the Number Skills program and the STEM Math curriculum; [f] the Connecting Math Concepts curriculum

Relations between Demographic Factors and Academic Learning

Associations between demographic variables and academic learning of children with ASD were tested to identify individual and family factors associated with the rate of learning in this atypical population. Composite scores of average sessions to criteria were generated from the five literacy programs and three mathematics programs in the study to represent the overall academic learning in literacy and mathematics of children with ASD. Table 7 provides the correlations between child demographic variables and their academic learning. Table 8 provides correlations between family demographic variables and children's academic learning.

Table 7

Correlations between Child Academic Learning Variables and Child Demographic Variables

	STC_Literacy	STC_AK	STC_PA	STC_WR	STC_RC	STC_Maths	STC_MATHMEI	STC_MATHDI	Number of Tactics
Child age [a]	-.44*	-.35	-.40	-.18	.35	-.14	-.07	-.37	.06
Child gender [b]	-.05	-.05	-.23	-.02	-.35	-.13	-.18	-.37	-.05
Child Ethnicity (White vs. not) [c]	-.05	.28	.04	-.45	-.09	-.33	-.11	.16	-.34
Child Ethnicity (Hispanic vs. not) [c]	-.11	-.31	-.17	.12	-.52	.09	.05	-.16	.49**
Second language status [c]	-.16	-.24	-.09	-.27	-.52	.13	.09	-.14	.26
Sibling status [c]	.08	.16	.10	.29	.51	.13	.04	.37	.29
Sibling with DD [c]	.36	.71**	.41	-.30	-.21	.33	.11	.64	.15

Note. STC = the average sessions to criteria; Literacy = all five literacy programs; AK = alphabetic knowledge; PA = phonemic awareness; WR = word recognition; RC = reading comprehension; MATHMEI = the math programs using the Multiple Exemplar Instruction; MATHDI = the math programs using direct instruction; DD = developmental delay.

[a] Child age coded in months; [b] Child gender coded as 0 = Male and 1 = Female; [c] Child ethnicity (White vs. not), Child ethnicity (Hispanic vs. not), Second language status, Sibling status, and Sibling with DD [c] Child ethnicity (White vs. not) coded as 0 = No and 1 = Yes.

* p < .05. ** p < .01. *** p < .001

Table 8

Correlations between Child Academic Learning Variables and Family Demographic Variables

	STC_Literacy	STC_AK	STC_PA	STC_WR	STC_RC	STC_Maths	STC_MATH MEI	STC_MATH DI	Number of Tactics
Mother's education level [a, e]	-.08	.24	-.19	-.28	-.82*	-.03	.10	-.21	.27
Father's education level [a, e]	-.16	-.21	-.25	.11	-.21	-.15	-.09	-.04	.02
Marital status [b]	.03	.03	-.43	.07	-.71	-.03	-.25	.00	.29
Nativity status [c]	-.25	-.29	.14	-.02	.09	.31	.21	.18	.31
Number of adults in household	-.18	-.07	-.02	-.07	.71	.17	-.06	.48	.13
Number of children in household	.31	.50*	.30	.25	.84*	.27	.05	.18	.25
Household income [e]	.06	.01	.40	.03	-.95	.08	.17	-.13	.22

Note. STC = the average sessions to criteria; Literacy = all five literacy programs; AK = alphabetic knowledge; PA = phonemic awareness; WR = word recognition; RC = reading comprehension; MATHMEI = the math programs using the Multiple Exemplar Instruction; MATHDI = the math programs using direct instruction; DD = developmental delay.

[a] Parent's education level coded as 1= Less than high school 8 = Doctorate degree; [b] Martial status coded as 0 = Non-married/ Non-committed partnership and 1 = Married/ Committed partnership; [c] Nativity status coded as 0 = U.S. and 1 = Non-U.S.; [d].

* $p < .05$. ** $p < .01$. *** $p < .001$

For the overall academic learning performance in literacy, a significant negative association was found between children's age and the average session to criteria in all literacy programs, r (31) = -.44, p = .014, such that children with ASD who were younger required more sessions to achieve an objective in the literacy programs. Therefore, children's age was considered as a covariate in the subsequent analyses related to overall literacy learning.

For children's academic learning in alphabetic knowledge based on their performance on the Letter Names and Sounds program, there was a significant positive association between whether children with ASD had siblings with developmental delays and their average sessions to criteria in the alphabetic knowledge learning, r_{pb} (14) = .71, p = .01. On average, children with siblings with developmental delays required more sessions to achieve an objective in the learning of alphabetic knowledge through the Letter Names and Sounds program (M = 6.17, SD = 2.19) than those without siblings with developmental delays (M = 3.35, SD = 0.73), t (5.84) = 3.04, p = .024. Also, the number of children in the household was significantly positively correlated with the participants' average sessions to criteria in the alphabetic knowledge learning, r (17) = .50, p = .04, such that the participants who lived in a house with more siblings or other children required more sessions to achieve an objective in the learning of alphabetic knowledge. Considering whether having siblings with developmental delays and the number of children in the household was significantly correlated, r_{pb} (25) = .42, p = .04, a regression model was constructed to test the factor which explained the learning rate in alphabetic knowledge the most to avoid multicollinearity issue in the subsequent analysis. A significant model emerged, R^2 = .56, F (2, 11) = 7.10, p = .01, with a main effect of the status of siblings with developmental delays, β = .58, p = .023 after controlling for the number of children in the household. Therefore, having siblings with developmental delays was considered a covariate in the subsequent analyses related to the alphabetic knowledge learning.

For children's academic learning in reading comprehension based on the performance on the Reading A-Z curriculum comprehension quizzes, the average sessions to criteria in this program were found to be significantly negatively associated with the participant mother's education level, r_s (6) = -.89, p = .026, and positively correlated with the number of children in the household, r (6) = .84, p = .04. Due to the small sample size, a non-parametric analysis was conducted. Despite this, given the very small degrees of freedom in these tests, these results should be interpreted with caution, and the demographic variables were not considered as covariates in the subsequent analyses. For children's academic learning in mathematics, no significant association was found between any child or family demographic variables and the average sessions to criteria in the mathematics programs.

For the number of learning tactics, there was a significant positive association between children's ethnicity (Hispanic vs. not) and their total number of learning tactics needed in all academic programs, r_{pb} (29) = .49, p = .007. On average, Hispanic children with ASD required more learning tactics (M = 1.14, SD = .90) than those other ethnic backgrounds (M = .32, SD = .57), t (27) = 2.90, p = .007. Therefore, children's ethnicity (Hispanic vs. not) was considered as a covariate in the subsequent analyses related to the number of learning tactics needed in the academic programs.

Testing Research Questions

All hypotheses were tested with the IBM SPSS Version 27.

Research Question 1. Is There an Association between Self-regulation, Including EF and EC, in Children with ASD, as Measured by Direct Assessments and Parental Reports?

In the study, self-regulation of children with ASD was assessed through two dimensions: EF and EC. Table 9 provides the descriptive data and correlations among all self-regulation variables, including EF skills measured by the four subscales on the NIHTB-

ECB and the five subscales on the BRIEF-P and the level of EC reported on the CBQ-SF. Surprisingly, the overall EF levels of children with ASD measured by the NIHTB-ECB were not significantly associated with the overall EF skills reported on the BRIEF-P, r (28) = .05, p = .79. A partial correlation and a hierarchical regression were conducted to re-examine the association between the EF levels on the two measures while controlling for the demographic covariates (mother's education level, gender, and family nativity) and children's language level (receptive, expressive, and overall) respectively. No significant correlation emerged between children's EF levels on the NIHTB-ECB and the BRIEF-P after controlling for the covariates.

On the NIHTB-ECB, a significant positive association emerged between children's receptive vocabulary on the Vocabulary Test and their episodic memory on the Memory Test, r (32) = .36, p = .046, such that children with ASD who had a better vocabulary showed greater levels of episodic memory on the NIHTB-ECB. Surprisingly, children's other core EF skills, including attention, inhibitory control, and cognitive flexibility, were not found to be associated with one another on the other subscales of the NIHTB-ECB. In contrast, the five core domains of EF reported on the BRIEF-P were significantly intercorrelated with one another (see Table 9), including inhibitory control, shift, emotional control, working memory, and plan/ organize.

Regarding the temperamental EC of children with ASD, there was no significant association between children's performance on the NIHTB-ECB and the EC level reported by parents on the CBQ-SF. In contrast, children's EC level was significantly positively associated with their overall EF skills reported on the BRIEF-P (reversed), r (28) = .76, p < .001, and every single core domain of EF on this parental report (see Table 9), such that children with ASD who had higher levels of temperamental EC were also reported higher levels of EF by their parents.

Table 9

Means, Standard Deviations, and Correlations of Executive Function and Effortful Control in Preschoolers with ASD

	1	1.1	1.2	1.3	1.4	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	3
1. NIHTB-ECB	--														
1.1 Vocabulary	.63**	--													
1.2 Flanker	.34	-.01	--												
1.3 DCCST	.49**	.28	.08	--											
1.4 Memory	.79**	.36*	-.12	.15	--										
2. BRIEF-P [a]	.05	.01	.03	.15	-.02	--									
2.1 Inhibit	-.07	-.08	.02	.05	-.12	.92**	--								
2.2 Shift	.15	.08	-.04	.07	.17	.81**	.67**	--							
2.3 Emotional Control	.17	-.01	.22	.19	.02	.86**	.81**	.68**	--						
2.4 Working Memory	.06	.05	.02	.24	-.06	.93**	.78**	.69**	.68**	--					
2.5 Plan/ Organize	.04	.02	-.01	.13	-.02	.89**	.76**	.59**	.68**	.88**	--				
2.6 ISCI	.01	-.05	.08	.10	-.07	.95**	.97**	.72**	.92**	.78**	.78**	--			
2.7 FI	.16	.03	.09	.13	.10	.91**	.80**	.93**	.91**	.75**	.70**	.89**	--		

2.8 EMI	.06	.04	.01	.20	-.04	.94**	.80**	.67**	.71**	.98**	.96**	.81**	.76**	--	
3. EC [b]	-.01	.17	.02	.24	-.05	.76**	.75**	.52**	.64**	.70**	.67**	.75**	.63**	.71**	--
n	32	32	32	32	32	28	28	28	28	28	28	28	28	28	28
M	98.59	93.28	98.34	98.97	106.97	-68.61	-63.50	-61.39	-63.68	-68.68	-64.79	-65.39	-63.96	-68.46	4.65
SD	14.62	11.74	14.87	10.23	25.56	16.82	15.00	12.96	13.68	16.05	15.96	15.36	13.50	16.80	0.70

Note. NIHTB-ECB= the NIH Toolbox Early Childhood Cognition Battery Composite Score; Vocabulary = the Picture Vocabulary Test Age 3+; Flanker = the Flanker Inhibitory Control and Attention Test Ages 3-7; DCCST = the Dimensional Change Card Sort Test Ages 3-7; Memory = the Picture Sequence Memory Test Ages 3-4; BRIEF-P (reverse-scored) = the Behavior Rating Inventory of Executive Function, Preschool Version, Global Executive Composite; ISCI = Inhibitory Self-Control Index (Inhibit + Emotional Control); FI = Flexibility Index (Shift + Emotional Control); EMI = Emergent Metacognition Index (Working Memory + Plan/ Organize); EC = temperamental effortful control on the Children's Behavior Questionnaire, Short Form.

[a] BRIEF-P was reversed coded as higher the scores, higher levels of EF

[b] Parent-reported EC coded as 1= Extremely untrue 7= Extremely true, such that higher scores indicated higher levels of EC

* $p < .05$. ** $p < .01$. *** $p < .001$

Research Question 2. How is Self-regulation Related to Other Characteristics and Behaviors in Children with ASD, Including ASD Symptoms Severity, Reward Sensitivity, School Engagement, and Adaptive Behavior?

Table 10 provides correlations between self-regulation, including EF and EC, and other child characteristics variables in the study based on measures' composite scores.

For children's EF skills, significant associations emerged between the participants' performance on the NIHTB-ECB and their ASD symptoms severity, school engagement, and adaptive behavior. First, children's EF was correlated with the severity of ASD-related symptoms. There was a significant negative association between children's performance on the ADOS-2 Social Affect subscale and the NIHTB-ECB Flanker test, r (32) = -.40, p = .025, such that children with ASD who had better communication and reciprocal social interaction, as indicated by a lower score on the ADOS-2 Social Affect subscale, demonstrated better inhibitory control and attention. A significant negative correlation also emerged between children's performance on the NIHTB-ECB Vocabulary test and the ADOS-2 Restricted and Repetitive Behavior subscale, r (32) = -.40, p = .024, such that children with ASD who had a larger vocabulary demonstrated fewer restricted and repetitive behaviors on the ADOS-2.

Second, children's EF was associated with their behavioral school engagement. Children's episodic memory measured by the NIHTB-ECB Memory test was significantly positively correlated with their behavioral school engagement reported by teachers on the TRSSA, r (32) = .37, p = .038, such that children who had better episodic memory demonstrated greater cooperative and independent participation at school. There was also a significant positive association between children's overall EF levels measured by the NIHTB-ECB and their behavioral school engagement, r (32) = .40, p =.022, such that children who had better overall EF skills had a greater cooperative and independent participation in school activities. Considering mother's education level was highly associated with children's overall levels of EF on the NIHTB-ECB, a regression model was constructed to further identify how children's behavioral school engagement predicted their EF after accounting for this demographic covariate. All test assumptions were met. A significant prediction model emerged (R^2 = .36, F (2, 26) = 7.145, p = .003) with a main effect of the mother's education level, β = -.52, p = .003, controlling for children's behavioral engagement. However, no main effect of children's behavioral engagement was identified after controlling for mother's education level. This finding revealed that children's behavioral school engagement did not significantly predict their EF levels while holding their mother's education level constant.

Third, children's EF was related to their adaptive behavior. After controlling for mother's education level, significant positive associations emerged between children's overall EF skills, as measured by the NIHTB-ECB, and their adaptive behavior reported by teachers on the Vineland-3, r (25) = .44, p = .018, as well as their communication skills reported on the Vineland-3 Communication subscale, r (26) = .54, p = .003, such that children who had higher levels of EF showed better adaptive behavior and communication skills at school after accounting for their mother's education level. Significant positive associations were also found between children's performance on the NIHTB-ECB Vocabulary Test and their communication skills reported by teachers on the Vineland-3 Communication subscale, r (32) = .41, p = .021, such that children who had a larger vocabulary demonstrated better communication at school. Also, children's performance on the NIHTB-ECB DCCST test was significantly positively associated with their overall adaptive behavior reported by teachers on the Vineland-3, r (32) = .44, p = .013, and their communication skills on the Vineland-3 Communication subscale, r (32) = .36, p = .04, such that children with ASD with better planning, cognitive flexibility, and attention demonstrated better adaptive behavior and communication skills at school. Last, children's episodic memory measured by the NIHTB-ECB Memory Test was significantly positively associated with their overall adaptive behavior reported on the Vineland-3, *r* (32) = .39, *p* = .028, the communication skills on the Vineland-3 Communication subscale, *r* (32) = .54, *p* = .002, and the daily living skills reported on the Vineland-3 Daily Living Skills subscale, r_s (32) = .35, *p* = .05, such that children with ASD with better episodic memory skills also demonstrated better adaptive behavior, communication, and daily living skills at school.

For children's EF measured by the parental-report BRIEF-P, there was a significant negative association between the overall levels of EF and the reward sensitivity reported by parents on the SPSRQ-C, *r* (28) = -.46, *p* = .013, such that children with lower levels of EF had greater sensitivity to reward. Significant negative associations also emerged between the reward sensitivity of children with ASD and their inhibitory control measured by the BRIEF-P Inhibit subscale, *r* (28) = -.60, *p* = .001, the BRIEF-P Shift subscale, *r* (28) = -.46, *p* = .014, and the BRIEF-P Emotional Control subscale, *r* (28) = -.49, *p* = .008, such that children with ASD who had greater reward sensitivity demonstrated more deficits in inhibiting inappropriate impulses, shifting from tasks to tasks, and controlling for emotions in daily lives.

Considering gender and family nativity were significantly related to children's overall EF levels on the BRIEF-P, a regression model was constructed to further identify how children's EF was predicted by their reward sensitivity while accounting for these demographic covariates. All test assumptions were met. A significant prediction model emerged (R^2 = .55, *F* (3, 24) = 9.61, *p* < .001) with a main effect of gender, β = .49, *p* = .002, and family nativity, β = .48, *p* = .006, after controlling for one another variables. However, no main effect of reward sensitivity remained after controlling for the two demographic covariates. This finding revealed that children's reward sensitivity did not significantly predict their EF levels, as reported by parents on the BRIEF-P while holding their gender and family nativity status constant.

For children's temperamental EC, there was a significant positive association between their levels of EC reported by parents on the CBQ-SF and their overall adaptive behavior reported by teachers on the Vineland-3, r (28) = .45, p = .015, such that children who had higher levels of EC showed better adaptive behavior at school. This association remained significant after controlling for children's gender and ethnicity (Hispanic vs. not), the two demographic covariates highly related to children's EC levels, R^2 = .45, F (3, 24) = 6.46, p = .002, with a main effect of adaptive behavior, β = .40, p = .017, and a main effect of ethnicity (Hispanic vs. not), β = .38, p = .02. No main effect of children's gender was found in predicting their EC levels after controlling for their adaptive behavior and ethnicity. This finding revealed that children's adaptive behavior at school significantly predicted their levels of EC after accounting for their gender and ethnicity. Children's temperamental EC was also significantly positively associated with their social skills reported by teachers on the Vineland-3 Socialization subscale, r (28) = .43, p = .024, such that children with ASD who had higher levels of EC showed better social skills at school.

For children's developmental variables, a significant association was found between children's adaptive behavior, as reported by teachers on the Vineland-3 and their behavioral school engagement on the teacher-reported TRSSA, r (32) = .48, p = .006, such that children who had better adaptive behavior demonstrated greater levels of cooperation and independent participation in school activities. Children's behavioral and emotional school engagement reported by teachers was significantly positively related to one another, r_s (32) = .49, p = .004, such that children who had greater levels of participation in school activities also demonstrated more school liking. There was also a positive association between children's emotional school engagement and the level of social skills reported by teachers on the

Table 10

Means, Standard Deviations, and Correlations among Study Variables Reported in Composite Scores

	M	*SD*	1	2	3	4	5	6	7	8
1. NIHTB-ECB	98.59	14.62	--							
2. BRIEF-P [a]	68.61	16.82	.05	--						
3. EC [b]	4.65	0.70	-.01	.76***	--					
4. ADOS-2 [c]	6.81	1.60	-.06	-.22	-.07	--				
5. SR [d]	3.26	0.54	.19	-.46*	-.34	-.17	--			
6. ABC	85.56	9.61	.35	.26	.45*	-.14	-.02	--		
7. BSE [e]	2.20	0.46	.37*	-.09	.14	-.01	.25	.48**	--	
8. ESE [f]	2.80	0.35	.00	.10	.21	-.02	.20	.09	.49**	--

Note. NIHTB-ECB = the NIH Toolbox Early Childhood Cognition composite score; BRIEF-P (reverse-scored) = the Behavior Rating Inventory of Executive Function, Preschool Version, Global Executive Composite; EC = temperamental effortful control on the the Children's Behavior Questionnaire, Short Form; ADOS = the Autism Diagnostic Observation Schedule, Second Edition, comparison score; SR = sensitivity to reward composite score on the Sensitivity to Punishment and Sensitivity to Reward Questionnaire for Children; ABC = the Vineland-3 Adaptive Behavior Composite Score; BSE = behavioral school engagement on the Teacher Rating Scale of School Adjustment; ESE = emotional school engagement on the School Liking and Avoidance Questionnaire.

[a] BRIEF-P was reversed coded as higher the scores, higher levels of EF

[b] Parent-reported EC coded as 1= Extremely untrue 7= Extremely true, such that higher scores indicated higher levels of EC;

[c] ADOS-2 coded as 1= minimum-to-no evidence of level of ASD-related symptoms 10 = high level of ASD-related symptoms, such that higher scores indicated more severe ASD-related symptoms;

[d] Parent-reported sensitivity to reward coded as 1= Strongly disagree 5= Strongly agree, such that higher scores indicated greater sensitivity to rewards;

[e] Teacher-reported behavioral school engagement coded as 1 = Doesn't apply 3 = Certainly applies, such that higher scores indicated higher behavioral participation; [f] Teacher-reported emotional school engagement coded as 1 = Doesn't apply 3 = Certainly applies, such that higher scores indicated higher school liking.

* p < .05. ** p < .01. *** p < .001

Vineland-3 Social subscale, r_s (32) = .51, p = .003, such that children with ASD who demonstrated higher levels of social skills also had more school liking.

Research Question 3. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning in the Literacy Programs?

A composite score of average sessions to criteria was generated from the five literacy programs in the study to represent the overall academic learning in literacy of children with ASD. No significant associations emerged between children's overall average sessions to criteria in the literacy programs and their overall EF levels, as measured by the NIHTB-ECB and the parent-reported BRIEF-P, or their levels of EC reported by parents on the CBQ-SF. A further correlation analysis revealed that the composite average sessions to criteria in literacy programs was significantly negatively associated with the emotional control skills in children with ASD, as reported by parents on the BRIEF-P Emotional Control subscale, r (28) = -.42, p = .028, such that children with ASD who were better in controlling their emotions in daily lives required fewer learning opportunities to achieve an objective in the literacy programs at school. After controlling for children's age, no additional significant correlation emerged, while the association between the BRIEF-P Emotional Control subscale score and the rate of literacy learning in children with ASD remained significant. Also, the number of learning objectives in the programs was not a significant covariate within the association between self-regulation and literacy learning.

This research question was further answered by targeting different foundational components of literacy, including alphabetic knowledge, phonemic awareness, word recognition, and reading comprehension, based on school data of five different literacy programs. The average sessions to criteria were calculated in each program to represent students' learning progress in different literacy domains.

Research Question 3.1. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning of Alphabetic Knowledge?

The average sessions to criteria in the Letter Names and Sounds program were derived to represent children's learning progress in alphabetic knowledge in the study. Contrary to the hypothesis, a significant positive correlation was found between children's NIHTB-ECB scores and their average sessions to criteria in the Letter Names and Sounds program, r (19) = .53, p = .018, such that children with ASD who had higher levels of EF, as measured by the NIHTB-ECB, required more sessions to meet an objective in the learning of alphabetic knowledge. As children's learning of alphabetic knowledge was significantly associated with whether they had siblings with developmental delays, a partial correlation was conducted to test the association between children's EF levels on the NIHTB-ECB and their average sessions to criteria in the Letter Names and Sounds program. Results showed that this association was no longer significant after accounting for the demographic covariate of whether the participants had siblings with developmental delays.

No significant association was found between children's average sessions to criteria in the Letter Names and Sounds program and their levels of EF reported by parents on the BRIEF-P or their levels of EC reported on the CBQ-SF. No additional significant correlation was found between the self-regulation variables reported by parents and the average sessions to criteria in the alphabetic knowledge learning after controlling for demographic covariates.

Research Question 3.2. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning of Phonemic Awareness?

The average sessions to criteria in the 100 Easy Lessons program were derived to demonstrate children's learning progress in phonemic awareness in the study. No significant associations were found between children's overall EF levels or specific EF skills measured by the NIHTB-ECB and their average sessions to criteria in the 100 Easy Lessons program.

Also, no significant correlation emerged between children's average sessions to criteria in this literacy program and their levels of EF reported by parents on the BRIEF-P or levels of EC reported on the CBQ-SF.

Research Question 3.3. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning of Word Recognition?

Two literacy programs, the Textual Responding to Dolch Words and the Reading A-Z curriculum, had similar academic goals of targeting word recognition in children with ASD in the study. A composite score of average sessions to criteria was generated from these two programs to represent the participants' learning progress in word recognition. No significant association was found between children's overall EF levels based on the NIHTB-ECB composite scores and their composite average sessions to criteria in the two programs. However, further correlation analyses found that students' performance on the Flanker test of the NIHTB-ECB was significantly negatively associated with their composite average sessions to criteria in the word recognition programs, r (15) = -.60, p = .019, such that children with ASD who demonstrated better attention and inhibitory control required fewer sessions to achieve an objective in their learning of word recognition. No significant correlation was found between the composite average sessions to criteria in the learning of word recognition and the parent-reported EF profiles on the BRIEF-P or the EC levels on the CBQ-SF of children with ASD. Also, no additional significant correlation was found between the self-regulation variables and the average sessions to criteria in the word recognition learning after controlling for demographic covariates. Together, these findings revealed that the learning progress in word recognition of children with ASD was associated with two specific self-regulatory abilities, attention and inhibitory control, rather than the overall levels of self-regulation, as reported by both direct measures and parental reports. Children with

ASD who were better at paying attention and inhibiting impulsive behaviors learned new words faster at school.

Research Question 3.4. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning of Reading Comprehension?

The average sessions to criteria in the Reading A-Z Comprehension Quizzes were derived to demonstrate children's academic learning progress in reading comprehension in the study. No significant association was found between children's overall EF levels measured by the NIHTB-ECB and their average sessions to criteria in the reading comprehension program based on the Reading A-Z curriculum. Again, further correlation analyses revealed that children's performance on the Flanker test of the NIHTB-ECB was significantly negatively associated with their average sessions to criteria in the reading comprehension program, r (7) = -.94, p = .001, such that students who had better attention and inhibitory control needed fewer sessions to achieve a learning objective in reading comprehension. The average sessions to criteria in the learning of reading comprehension were not related to children's EF levels reported by parents on the BRIEF-P or the EC levels on the CBQ-SF. No additional significant correlation was found between the self-regulation variables and the average sessions to criteria in the reading comprehension learning after controlling for the demographic covariates. These findings demonstrated that attention and inhibitory control of children with ASD appeared to be the salient self-regulatory abilities associated with their learning in reading comprehension. Children with ASD who paid better attention and were better in controlling impulsive behaviors acquired reading comprehension skills faster at school.

Research Question 4. Are There any Associations between Self-regulation in Children with ASD and Their Academic Learning in the Mathematics Programs?

A composite score of average sessions to criteria was generated from all three mathematics programs in the study to represent the overall academic learning in mathematics of children with ASD. No significant associations emerged between children's average sessions to criteria in all mathematics programs and their overall EF levels measured by the NIHTB-ECB or the parent-reported BRIEF-P. Also, no significant association was found between children's average sessions to criteria in all mathematics programs in the study and their levels of EC reported by parents on the CBQ-SF. After accounting for the demographic covariates of gender and family nativity background, a significant negative association emerged between children's overall EF skills, as measured by the BRIEF-P, and the average sessions to criteria in mathematic learning, r (23) = -.54, p = .006, such that children with ASD who had higher levels of EF required fewer sessions to achieve a learning objective in the mathematics programs at school. Also, the number of learning objectives in the programs was not a significant covariate within the association between self-regulation and mathematic learning.

Even though the three mathematics programs shared similar academic goals of fundamental mathematic skills, such as basic skills of recognizing numbers and quantities, understanding numeric relationships, and mastering problem-solving skills for mathematics problems, different teaching approaches were adopted in these programs. Therefore, this research question was further answered by composing average sessions to criteria in different programs to represent student's mathematics learning under two teaching instructions: the MEI instruction and direct instruction.

Research Question 4.1. Are There any Associations between Self-regulation in Children with ASD and Their Learning of Basic Number Skills and Mathematics Problem-solving Skills Through Trial-based Programs?

The average sessions to criteria in the Number Skills program and the STEM Math curriculum were generated to represent children's learning progress in basic knowledge of numbers and quantities as well as problem-solving skills in mathematics through the MEI instruction in the study. No significant association emerged between children's overall EF levels, as measured by the NIHTB-ECB, and their average sessions to criteria in the two mathematics programs. There was also no significant association between children's overall EF levels, as reported by parents on the BRIEF-P, and their average sessions to criteria in the two programs. However, it found that the working memory in children with ASD, as reported by the BRIEF-P Working Memory subscale, were significantly negatively associated with their rates of learning in the two programs, r (23) = -.44, p = .038, such that children with ASD who had better working memory in daily lives required fewer sessions to achieve a learning objective in the academic programs for basic mathematical knowledge and problem-solving skills using the MEI instruction. After controlling for the demographic covariates of gender and family nativity, a significant negative association emerged between children's EF levels on the BRIEF-P and their average sessions to criteria in the MEI mathematic programs, r (19) = -.54, p = .012, such that children with ASD who had higher levels of EF required fewer sessions to achieve a learning criterion in the mathematics programs using the MEI instruction after accounting for their gender and family nativity background. No significant association emerged between children's EC levels reported on the CBQ-SF and their average sessions to criteria in the two mathematic programs using the MEI instruction while accounting or not accounting for demographic covariates. These findings revealed that the mathematic learning of basic number skills and problem-solving skills through the MEI instruction in children with ASD was associated with their working memory, a core domain of EF.

Research Question 4.2. Are There any Associations between Self-regulation in Children with ASD and Their Learning of Basic Number Skills and Mathematic Problem-solving Skills Through Script-based Programs?

The average sessions to criteria in the Connecting Math Concepts curriculum were generated to represent children's learning progress in basic mathematical knowledge and problem-solving skills through direct instruction in the study. No significant association was found between children's overall EF levels represented by their NIHTB-ECB scores and their average sessions to criteria in the Connecting Math Concepts curriculum. In contrast, children's overall EF levels reported by parents on the BRIEF-P was significantly negatively correlated with their average sessions to criteria in the Connecting Math Concepts curriculum, r (8) = -.76, p = .027, such that children with higher levels of EF in daily lives required fewer sessions to achieve a learning objective in this program. This association remained significant after controlling for the demographic covariates of gender and family nativity background. More specifically, children's learning rate in this mathematics program was significantly negatively associated with their scores on the BRIEF-P Shift subscale, r (8) = -.77, p = .026, and the BRIEF-P Plan/ Organize subscale, r (8) = -.72, p = .045, such that children with ASD who were better in shifting from tasks to tasks and taking steps to achieve a goal required fewer learning opportunities to achieve an objective in the mathematics program using direct instruction. Also, there was a significant negative association between children's EC levels reported by parents on the CBQ-SF and their average sessions to criteria in the Connecting Math Concepts curriculum, r (8) = -.72, p = .046, such that children with ASD who had higher levels of EC as reported by parents required fewer learning opportunities to achieve an objective in the mathematics program using direct instruction.

Together, these findings revealed that children's mathematic learning through direct instruction was associated with their overall self-regulation skills reported by parents. Children with ASD who had higher levels of EF and EC relative to parents' expectation, especially with better shifting strategies and planning abilities to achieve a goal, mastered faster the basic mathematics knowledge and problem-solving skills through direct instruction at school. It should be noted that the number of students participating in the Connecting Math Concepts curriculum was small. Therefore, these findings should be interpreted with caution.

Research Question 5. Are There any Associations Between Self-regulation in Children with ASD and the Total Number of Tactics Needed in Literacy and Mathematics Learning?

The total number of learning tactics the participants needed was summarized from all literacy and mathematics programs to represent the extent to which children with ASD required additional one-to-one intervention in academic learning at school. Of the 32 participants in the study, no significant difference in self-regulation was found between those who needed and did not need a learning tactic in the academic programs. No significant associations were found between children's self-regulation, as measured by both the direct assessments and parental reports, and the number of learning tactics they needed in all literacy and mathematics programs at schools. No additional significant correlation was found after controlling for demographic covariates.

Table 11

Means and Standard Deviations of the Average Sessions to Criteria and the Total Number of Tactics Used in Literacy and Mathematics Programs and Their Correlations with Self-regulation Variables

	M	*SD*	NIHTB-ECB	BRIEF-P	EC
Average Sessions to Criteria in Literacy	31	3.76	.06	-.26	-.20
Alphabetic Knowledge [a]	4.54	1.89	.53*	-.32	-.20

Phonemic Awareness [b]	2.89	0.95	-.12	-.05	-.25
Word Recognition [c]	3.35	1.29	-.28	.35	.25
Reading Comprehension [d]	2.41	0.35	-.57	.19	.48
Average Sessions to Criteria in Maths	4.96	2.38	-.22	-.18	-.14
Number and Prob-Solving Skills through MEI [e]	5.76	2.52	-.15	-.28	-.17
Number and Prob-Solving Skills through DI [f]	2.62	0.80	-.09	-.76*	-.72*
Total Number of Tactics Needed	0.69	1.20	.10	.32	.21

Note. AvgSTC = the average sessions to criteria; NIHTB-ECB = the composite score on the NIH Toolbox Early Childhood Cognition Battery; Flanker = the Flanker Inhibitory Control and Attention subscale on the NIH Toolbox Early Childhood Cognition Battery; BRIEF-P (reverse-coded) = the Behavior Rating Inventory of Executive Function- Preschool Version; EC = the composite score of effortful control on the Children's Behavior Questionnaire Short Form; Prob-Solving = problem-solving; MEI = the Multiple Exemplar Instruction; DI = direct instruction; Composite scores were generated from [a] the Letter Names and Sounds program; [b] the 100 Easy Lessons program; [c] the Textual Responding Dolch Words program and the Reading A-Z program; [d] the Reading A-Z Comprehension Quizzes; [e] the Number Skills program and the STEM Math curriculum; [f] the Connecting Math Concepts curriculum
* $p < .05$. ** $p < .01$. *** $p < .001$.

Research Question 6. Are There any Associations Between Child Characteristics and Academic Learning in Literacy and Mathematics in Children with ASD?

Table 12 provides correlations between child characteristics and academic learning in children with ASD. For children's academic learning in literacy, children's reward sensitivity reported by parents on the SPSRQ-C was significantly positively correlated with their average session to criteria in the literacy programs, $r\ (28) = .39$, $p = .041$, such that children with greater sensitivity to rewards required more sessions to achieve an objective in the literacy learning. Surprisingly, there was a significant negative association between the scores on the Restricted and Repetitive Behavior subscale on the ADOS-2 and the average session to criteria in the literacy programs, $r\ (31) = -.40$, $p = .025$. However, these associations were no longer significant after controlling for children's age.

Table 12

Correlations between Academic Learning and Child Characteristics in Children with ASD

	STC_Literacy	STC_AK	STC_PA	STC_WR	STC_RC	STC_Maths	STC_MATH MEI	STC_MATH DI
ASD Severity – ADOS-2 [a]	-.19	-.28	.12	.07	-.34	.20	.31	.16
SA [a]	-.03	-.15	-.09	.18	.08	.47*	.43*	.21
RRB [a]	-.40*	-.46*	-.23	-.36	-.28	-.09	.13	-.04
SR – SPSRQ-C [b]	.39*	.33	.05	-.02	-.44	-.27	-.23	.36
BSE – TRSSA [c]	.16	.29	-.45	.06	-.11	-.14	-.08	-.28
ESE – SLAQ [d]	.18	.18	-.33	.58	.09	-.25	-.19	.23
Adaptive Behavior – Vineland-3	-.05	-.09	-.19	.03	.52	.28	.16	-.42
Communication	-.30	-.14	-.36	-.35	-.19	.10	.13	-.62
Daily Living Skills	-.16	.11	-.17	-.25	-.11	.29	.24	-.31
Socialization [e]	.14	-.09	-.10	.38	.63	.11	-.04	.05
Motor Skills [e]	.30	.30	.39	.28	-.14	-.16	-.01	.17

Note. [a]ADOS-2 = the ADOS-2 Comparison Score. ADOS-2 coded as 1= minimum-to-no evidence of level of ASD-related symptoms 10 = high level of ASD-related symptoms, such that higher scores indicated more severe ASD-related symptoms; SA = the Social Affect subscale on the ADOS-2; RRB = the Restricted and Repetitive Behavior subscale on the ADOS-2; [b]SR = sensitivity to reward composite score on the SPSRQ-C, which was coded as 1= Strongly disagree 5= Strongly agree, such that higher scores indicated greater sensitivity to punishment and reward; [c]BSE = behavioral school engagement on the TRSSA. Teacher-reported behavioral school engagement coded as 1 = Doesn't apply 3 = Certainly applies, such that higher scores indicated higher behavioral participation; [d]ESE = emotional school engagement on the SLAQ. Teacher-reported emotional school engagement coded as 1 = Doesn't apply 3 = Certainly applies, such that higher scores indicated higher school liking.
* $p < .05$. ** $p < .01$. *** $p < .001$

For children's academic learning in mathematics, a significant positive association was found between the scores on the Social Affect subscale on the ADOS-2 and the average sessions to criteria in the mathematics programs, r (30) = .47, p = .008, such that children with ASD who demonstrated more deficits in communication and reciprocal social interaction required more sessions to achieve an objective in mathematics learning.

Research Question 7. Does Self-regulation Mediate the Relationship Between the ASD-related Symptoms Severity and Academic Learning in Children with ASD?

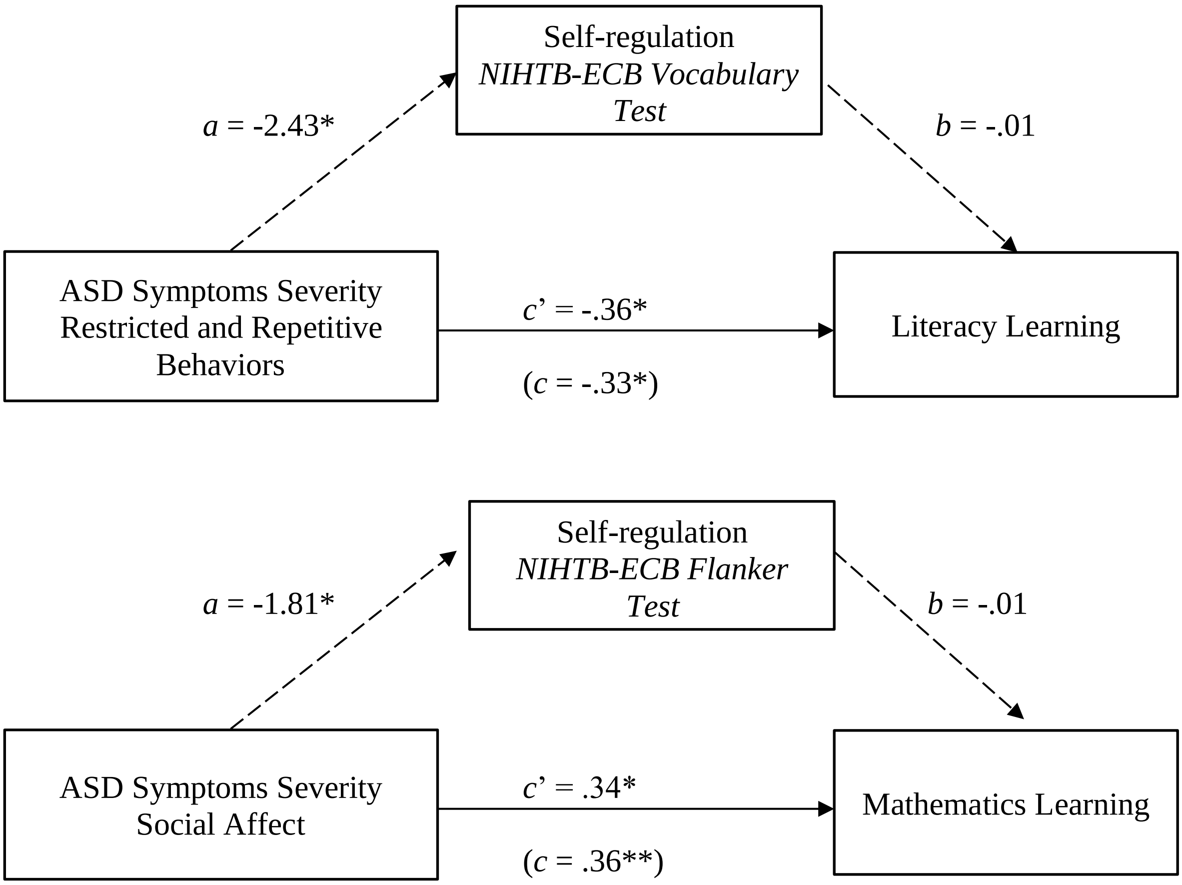
Correlation tests showed that the severity of ASD-related symptoms was significantly associated with academic learning in children with ASD. Mediation models were constructed to examine the mechanism that underlines the relation between the ASD-related symptoms severity and academic learning in children with ASD that had demonstrated significant total effect. First, self-regulation variables that were associated with the ASD-related symptoms were tested as the mediators (see Figure 3). Second, overall self-regulation levels as measured by direct assessments and parental reports were tested. The bootstrapping method developed by Preacher and Hayes (2004) was used for the mediation analyses. Contrary to the hypothesis, no significant mediating effect of self-regulation variables, including composite scores and individual skills measured by both direct assessments and parental reports, was found on the relationship between the ASD-related symptom severity and academic learning in children with ASD in the study.

Research Question 8. Do any Child Characteristics Moderate the Relationship Between Self-regulation and Academic Learning in Children with ASD?

Moderator analyses were constructed to test whether the relationship between self-regulation and academic learning in children with ASD depended on any child characteristics, including ASD-related symptoms severity, reward sensitivity, school

Figure 3

The Mediating Model of Self-regulation on the Relationship between ASD-related Symptoms Severity and Academic Learning in Children with ASD



engagement, and adaptive behavior. A composite of self-regulation was created by summing up children's NIHTB-ECB composite score, the BRIEF-P Global Executive Composite score (reversed), and the EC composite score on the CBQ-SF. Higher scores indicated higher levels of self-regulation. A composite of academic learning was also created by taking the mean of the average sessions to criteria in all literacy and mathematics programs in the study. Moderated multiple regression models were tested to identify the moderating effects of each child characteristic on the relation between children's self-regulation and academic learning using the composite scores. For each model, linearity was established confirmed with the visual inspection of a scatterplot of the variables. No evidence of multicollinearity was found based on the VIF value. Homoscedasticity existed through the visual inspection of a scatterplot of residuals. And the assumption of normality was not violated based on the Shapiro-Wilk's test.

First, a hierarchical multiple regression model was conducted to examine whether the severity of ASD-related symptoms, as measured by the ADOS-2, moderated the relation between children's self-regulation and academic learning. Findings showed that children's ASD-related symptoms severity did not significantly moderate the relationship between self-regulation and academic learning (see Table 13).

Table 13

Hierarchical Regression Results for the Interaction between Self-regulation and ASD-related Symptoms Severity in Predicting Academic Learning in Children with ASD (N = 32)

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	ΔR^2
		LL	*UL*				
Step 1						.02	-.05
Constant	4.42	3.38	5.46	.51			
Self-regulation	-.01	-.03	.01	.01	-.13		
ASD Severity	-.06	-.43	.31	.18	-.07		
Step 2						.03	-.08
Constant	4.37	3.30	5.44	.52			
Self-regulation	-.01	-.03	.01	.01	-.15		
ASD Severity	.07	-.53	.67	.29	.08		
Self-regulation*ASD Severity	-.00	-.02	.01	.01	-.19		

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; Self-regulation = the composite score of the NIHTB-ECB score, the BRIEF-P score (reversed), and the EC score on the CBQ-SF; ASD Severity = ASD-related symptoms severity derived from the ADOS-2 comparison score.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Second, a hierarchical multiple regression model was tested to identify the moderating effect of children's behavior school engagement, as reported by teachers on the TRSSA, on the relation between self-regulation and academic learning. Results showed that children's behavior school engagement significantly moderated the relation, as evidenced by a statistically significant increase in total variation explained of 23%, *F* (1, 28) = 8.388, *p* = .007, such that greater levels of behavior school engagement promoted a stronger relation between self-regulation and academic learning in children with ASD (see Table 14).

Table 14

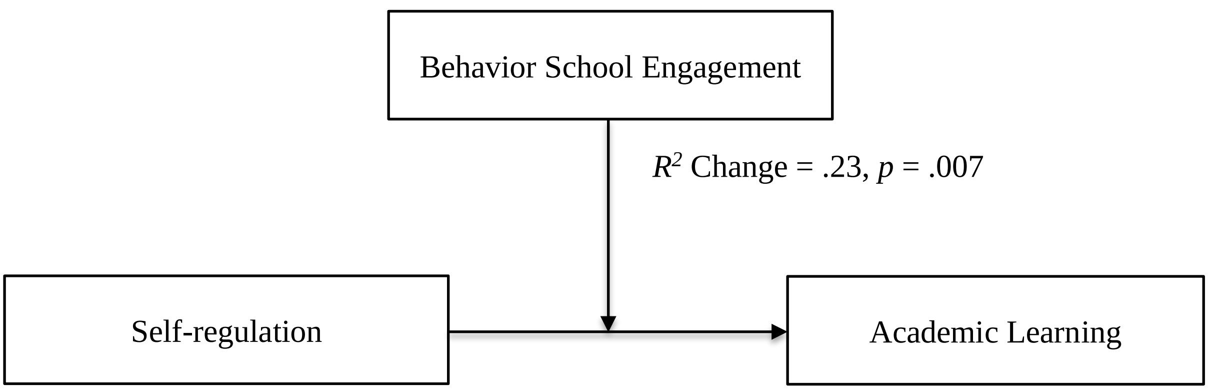
Hierarchical Regression Results for the Interaction between Self-regulation and Behavior School Engagement in Predicting Academic Learning in Children with ASD (N = 32)

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	Δ R^2
		LL	*UL*				
Step 1						.01	-.06
Constant	4.37	3.39	5.35	.48			
Self-regulation	-.01	-.03	.01	.01	-.11		
BSE	.12	-1.07	1.30	.58	.04		
Step 2						.24	.16**
Constant	4.36	3.48	5.24	.43			
Self-regulation	-.00	-.02	.01	.01	-.07		
BSE	2.22*	.39	4.04	.89	.71*		
Self-regulation*BSE	-.05**	-.09	-.02	.02	-.83**		

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; Self-regulation = the composite score of the NIHTB-ECB score, the BRIEF-P score (reversed), and the EC score on the CBQ-SF; BSE = the composite score of behavior school engagement on the TRSSA.
* *p* < .05. ** *p* < .01. *** *p* < .001.

Figure 4

The Moderating Effect of Behavior School Engagement on the Relationship between Self-regulation and Academic Learning in Children with ASD



Third, a hierarchical multiple regression model was conducted to examine whether children's emotional school engagement, as reported by teachers on the SLAQ, moderated the relation between children's self-regulation and academic learning. Findings showed that children's emotional school engagement did not significantly moderate the relationship between self-regulation and academic learning (see Table 15).

Fourth, a hierarchical multiple regression model was conducted to examine whether children's reward sensitivity, as reported by parents on the SPSRQ-C, moderated the relation between children's self-regulation and academic learning. Results showed that children's reward sensitivity significantly moderated the relation, as evidenced by a statistically significant increase in total variation explained of 16%, F (1, 24) = 4.814, p = .038, such that greater levels of reward sensitivity promoted a stronger relation between self-regulation and academic learning in children with ASD (see Table 16).

Table 15

Hierarchical Regression Results for the Interaction between Self-regulation and Emotional School Engagement in Predicting Academic Learning in Children with ASD (N = 32)

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	ΔR^2
		LL	*UL*				
Step 1						.01	-.06
Constant	4.36	3.38	5.34	.48			
Self-regulation	-.01	-.03	.01	.01	-.11		
ESE	.13	-1.41	1.68	.76	.03		
Step 2						.02	-.09
Constant	4.36	3.37	5.36	.49			
Self-regulation	-.01	-.03	.01	.01	-.11		
ESE	.46	-2.56	3.48	1.48	.11		
Self-regulation*ESE	-.01	-.09	.07	.04	-.09		

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; Self-regulation = the composite score of the NIHTB-ECB score, the BRIEF-P score (reversed), and the EC score on the CBQ-SF; ESE = the composite score of emotional school engagement on the SLAQ. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 16

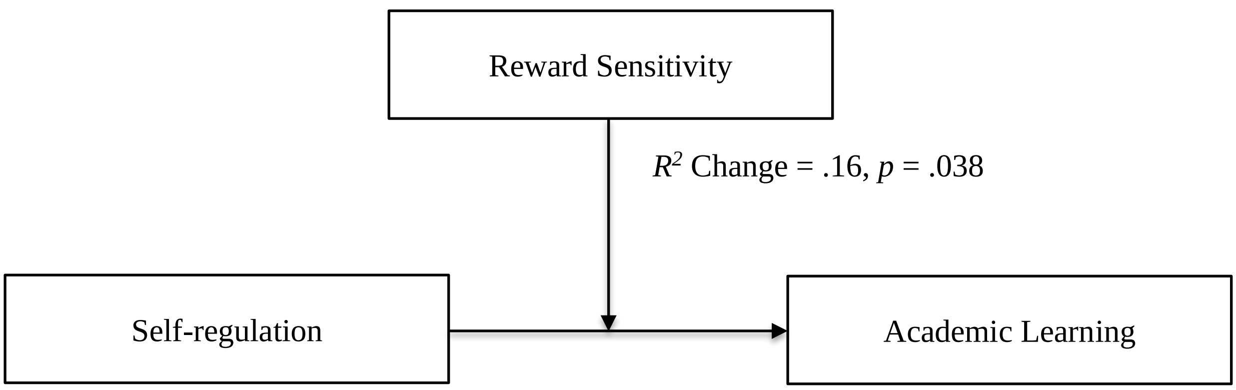
Hierarchical Regression Results for the Interaction between Self-regulation and Reward Sensitivity in Predicting Academic Learning in Children with ASD (N = 28)

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	Δ R^2
		LL	*UL*				
Step 1						.05	-.03
Constant	4.54	3.40	5.68	.55			
Self-regulation	-.01	-.04	.02	.01	-.19		
Reward Sensitivity	.18	-.95	1.31	.55	.07		
Step 2						.21	.11*
Constant	4.33	3.25	5.41	.52			
Self-regulation	-.01	-.04	.02	.01	-.17		
Reward Sensitivity	1.86	-.04	3.76	.92	.68		
Self-regulation*Reward Sensitivity	-.05*	-.10	-.00	.02	-.73*		

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; Self-regulation = the composite score of the NIHTB-ECB score, the BRIEF-P score (reversed), and the EC score on the CBQ-SF; Reward Sensitivity = the composite score of the sensitivity to reward subscales on the SPSRQ-C.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Figure 5

The Moderating Effect of Reward Sensitivity on the Relationship between Self-regulation and Academic Learning in Children with ASD



Last, a hierarchical multiple regression model was conducted to examine whether children's adaptive behavior, as reported by teachers on the Vineland-3, moderated the relation between children's self-regulation and academic learning. Findings showed that children's adaptive behavior did not significantly moderate the relationship between self-regulation and academic learning (see Table 17).

Table 17

Hierarchical Regression Results for the Interaction between Self-regulation and Adaptive Behavior in Predicting Academic Learning in Children with ASD (N = 32)

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	ΔR^2
		LL	*UL*				
Step 1						.03	-.04
Constant	4.41	3.42	5.39	.48			
Self-regulation	-.01	-.03	.01	.01	-.13		
Adaptive Behavior	.02	-.04	.07	.03	.12		
Step 2						.08	-.02
Constant	4.63	3.59	5.67	.51			
Self-regulation	-.01	-.03	.01	.01	-.20		
Adaptive Behavior	.07	-.03	.17	.05	.47		
Self-regulation*Adaptive Behavior	-.00	-.00	.00	.00	-.41		

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; Self-regulation = the composite score of the NIHTB-ECB score, the BRIEF-P score (reversed), and the EC score on the CBQ-SF; Adaptive Behavior = the composite score on the Vineland-3.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Research Question 9. What Are the Distraction Strategies Used by Children with ASD in Response to Delayed Reinforcement? How Are the Wait During Delay in Reinforcement Associated with Self-regulation and Other Child Characteristics in Children with ASD?

Delayed Turn-Taking with an Adult. In the task of delayed turn-taking with an adult, on average, children with ASD successfully waited for the whole duration of 10.38 sessions (*SD* = 3.36) in a total of 16 opportunities, during which they responded to the delayed reinforcement of a toy car without touching it. Children with ASD had an average cumulative wait duration of 38.28 s (*SD* = 22.43s) in the Request session, waiting for the experimenter to pass the toy car after requesting it vocally. They had an average cumulative wait duration of 49.17 s (*SD* = 16.00s) in the Wait session, waiting for the experimenter to finish a turn without touching the car or the ramp. These findings indicated that children with ASD may be able to wait longer for another person's turn rather than their own in a turn-taking activity in the classroom.

Children with ASD in the study were found to use multiple distraction strategies under the frustrating situations of receiving delayed reinforcement. A total of 23 children with ASD (79.3%) used language during the waits to self-talk or to communicate with the experimenter. Examples of the language were, "You forgot to push it; I like this new game; You need to push it a little; It's a special toy." The frequency of using language by children with ASD in the total 16 sessions was significantly positively associated with their cumulative wait duration in the Request session, r (29) = .42, p = .023, such that children with ASD who used language more frequently in the task waited significantly longer for the experimenter to pass the toy after a vocal request than those who used less; and the cumulative wait duration in the Wait session, r (29) = .63, $p < .001$, such that children with ASD who used language more frequently waited significantly longer for the experimenter to finish playing without touching the toy. Another distraction strategy used by children with ASD was using gestures to communicate their needs during the wait (n = 18, 62.1%). Examples of gestures included pointing to the car or the ramp, imitating the car going down the ramp, and blowing the car from a distance. Similarly, the frequency of using gestures by the children with ASD in the total 16 sessions was significantly positively related with their cumulative wait duration in the Request session, r (29) = .42, p = .024, and their cumulative wait duration in the Wait session, r (29) = .44, p = .017, such that children with ASD who used more gestures to communicate waited significantly longer for the delayed reinforcement on the task. The third distraction strategy used by children with ASD in the study was initiating and maintaining eye contact with the experimenter during the wait (n = 13, 44.8%).

The frequency of having eye contact with the experimenter was also found to be significantly positively associated with the children's cumulative wait duration in the Request session, r (29) = .45, p = .014, and their cumulative wait duration in the Wait session, r (29) = .40, p = .032, such that children with ASD who initiated and maintained more eye contact with the experimenter waited significantly longer for their own and the other's turn on the delayed turn-taking task. These three distraction strategies, including talking to the experimenter or self, using gestures, and having eye contact, were considered to be socially oriented. Figure 6 shows group differences in the wait durations by using and not using the three distraction strategies.

To further examine factors associated with the performance of children with ASD in response to delayed reinforcement, bivariate correlations were conducted to assess the associations between child characteristics and the wait durations as well as the frequency of using social-oriented distraction strategies in this interactive task. Children's NIHTB-ECB scores were significantly positively correlated with their cumulative wait duration in the Wait session, r (29) = .45, p = .015, and their frequency of using language during the waits, r (29) = .46, p = .012, such that children with higher levels of EF waited significantly longer for the experimenter to finish a turn and used language more frequently to distract attention during the waits. Also, the participant's behavioral school engagement performance reported by the teachers was significantly positively associated with their cumulative wait duration in the Wait session, r (29) = .66, p < .001, and their frequency of using language during the waits, r (29) = .51, p = .005, such that children who had better cooperative and independent participation in classroom activities waited significantly longer for the experimenter's turn and used language more frequently for distraction during the waits. Similarly, the participant's emotional school engagement reported by the teachers was positively associated with their cumulative wait duration in the Wait session, r_s (29) = .40, p = .034, such that students who had higher levels of school liking waited significantly longer for the experimenter to complete a turn in the delayed turn-taking task.

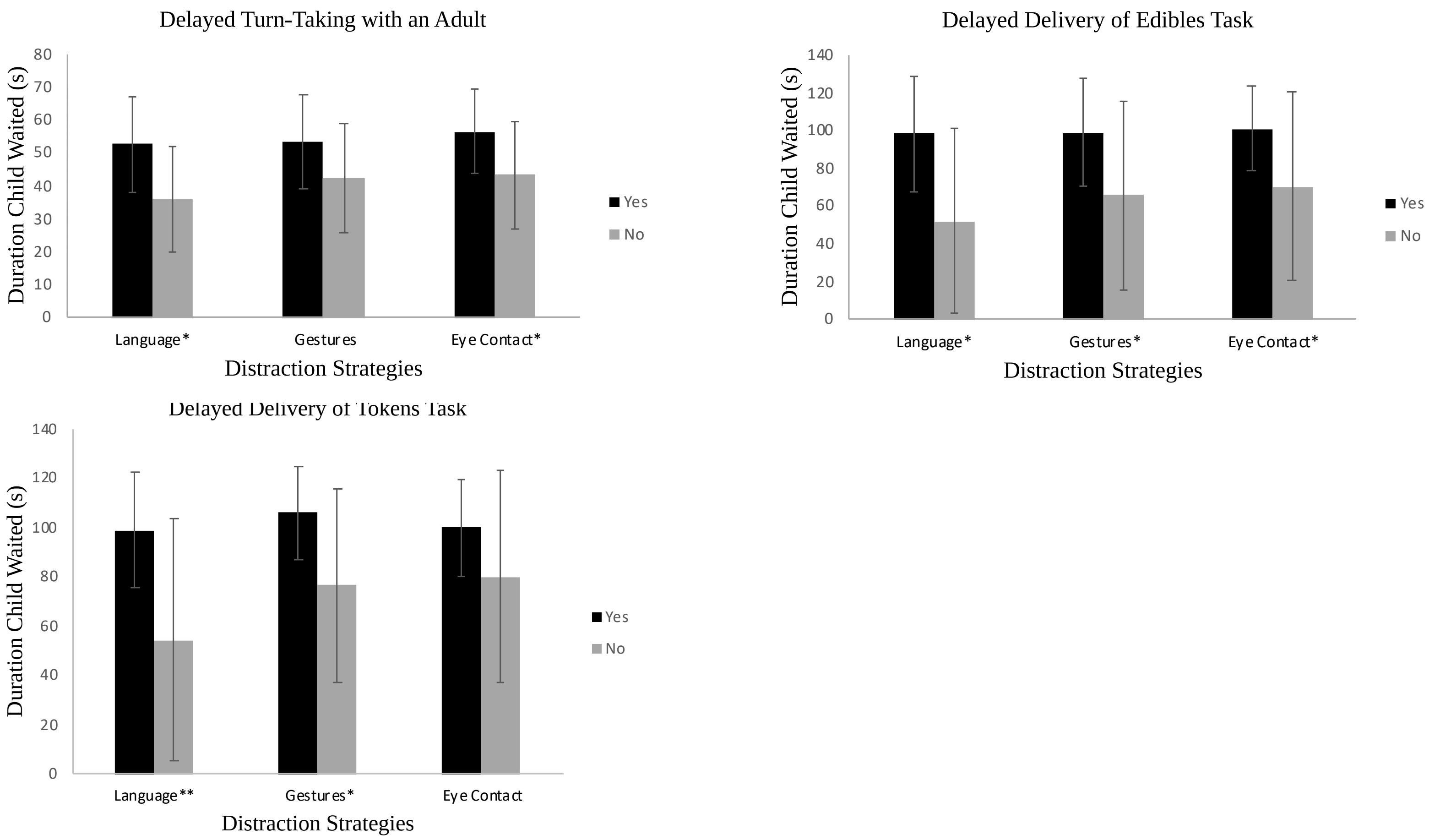
A hierarchical regression analysis model was conducted to test if children's cumulative wait duration for the other person's turn was predicted by their frequency of using the three socially-oriented distraction strategies (language, gestures, and eye contacts), their EF levels measured by the NIHTB-ECB, and behavioral and emotional school engagement reported by teachers. A composite frequency of using social-oriented distraction strategies was generated by adding up the number of sessions in which language, gestures, or eye contact was used. All variables were centered to eliminate the multicollinearity within the interaction terms. In the first step, the composite frequencies of using social-oriented distraction strategies, the NIHTB-ECB composite score, behavioral school engagement, and emotional school engagement were entered. In the second step, the interaction terms (NIHTB-ECB composite score * the frequency of using distraction strategies; behavioral school engagement * the frequency of using distraction; emotional school engagement * the frequency of using distraction) were entered. No multicollinearity was identified, as the variance inflation factor (VIF) was less than 10. Other assumptions of linearity, independence of residuals, homoscedasticity, and normality of residuals were met. The full model significantly predicted children's cumulative wait duration for teacher's turn, $R^2 = .70$, F (7, 21) = 6.89, $p < .001$. Among the variables, the frequency of using social-oriented distraction strategies added significantly to the prediction, $\beta = .53$, $p = .005$, above and beyond all other factors. Children's EF level and their school engagement did not provide a significant contribution to explaining their waits in response to the delayed reinforcement in this interactive turn-taking task. Also, no interactive effect was identified between children's usage of distraction strategies and their developmental characteristics. Regression coefficients and standard errors can be found in Table 18. Together, these findings reveal that children's cumulative wait duration for the other person's turn was best explained by their frequency of using social-oriented distraction strategies during the wait, including talking, using gestures, or having eye contact with others.

Delayed Delivery of Edibles. On the task of delayed delivery of edibles, children with ASD earned preferred edibles by completing a performance task, matching non-identical pictures with two non-exemplars. All participants completed the performance task with a 100% accuracy rate. Within the 12 opportunities of delayed reinforcement, on average, children with ASD waited for the whole duration of 8.83 sessions (*SD* = 3.37), during which they waited for the signal from the experimenter to get a preferred edible. Children with ASD in the study had an average cumulative wait duration of 83.86 s (*SD* = 42.28 s) of the maximum possible duration of 124 s. Three distraction strategies were identified being used by the participants during the wait on this task. First, a total of 20 children with ASD (69%) used language during the wait by either talking to themselves or the experimenter. Examples of the language were, "Can I take one? Yummy! We have to wait. Goldfish? Remember, we can take one." The frequency of using language by children with ASD in the 12 delayed sessions was significantly positively associated with their cumulative wait duration on the task, r (29) = .44, p = .016, and the number of sessions they waited for the whole durations, r (29) = .43, p = .02, such that children with ASD who used language more frequently during the delays waited significantly longer for the experimenter's signals of getting an edible and also successfully waited for more delayed sessions. Another distraction strategy used by children with ASD (n = 16) on the task was using gestures to communicate their needs during the wait. Examples of gestures included raising hands, pretending to eat, pointing to the edibles, and waving. The frequency of using gestures by children with ASD in the total of 12 delayed sessions was not found to be significantly associated with their cumulative wait duration or the number of sessions they waited for the whole duration. Children with ASD in the study were also found to be initiating and maintaining eye contact with the experimenter during the wait (n = 13). However, the frequency of having eye contact with the experimenter was not found to be significantly correlated with children’s cumulative wait duration or the number of sessions waited for the whole duration on the task. Figure 6 shows group differences in the wait durations by using and not using the three distraction strategies.

Bivariate correlations were also conducted to examine other factors associated with the performance of children with ASD in response to delayed delivery of edibles. No significant association emerged between any child characteristics and the cumulative wait duration or the frequency of using language during the waits on this task. Together, these findings revealed that the frequency of using language to self-talk or communicate with others was the salient factor that was associated with children’s wait duration of delayed delivery of edibles.

Figure 6

Means and Standard Deviations of the Duration Children with ASD Waited by Groups of Using and Not Using a Specific Distraction Strategy Across Different Strategies in the Three Delayed Behavioral Tasks



* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 18

Hierarchical Regression Results for the Wait Duration in the Delayed Turn-Taking Task (N = 29)

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	ΔR^2
		LL	*UL*				
Step 1						.65	.65***
Constant	.98	-53.75	55.71	26.52			
Freq of Using SOS	2.20**	.86	3.54	.65	.53**		
NIHTB-ECB	.07	-.27	.41	.16	.07		
BSE	11.51	-.92	23.94	6.02	.33		
ESE	1.28	-14.89	17.45	7.83	.03		
Step 2						.70	.05***
Constant	20.85	-47.25	88.95	32.75			
Freq of Using SOS	2.21**	.74	3.68	.71	.53**		
NIHTB-ECB	-.02	-.39	.34	.18	-.02		
BSE	13.82	-.08	27.72	6.68	.39		
ESE	-3.85	-25.16	17.46	10.25	-.08		
NIHTB-ECB* Freq of Using SOS	-.07	-.16	.03	.05	-.23		
BSE * Freq of Using SOS	1.77	-1.60	5.15	1.62	.19		
ESE * Freq of Using SOS	-2.96	-7.66	1.74	2.26	-.25		

Note. Model = "Enter" method in SPSS Statistics; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; Freq of Using SOS = the frequency of using social-oriented distraction strategies; NIHTB-ECB = composite score in the NIH Toolbox Early Childhood Cognition Battery; BSE = teacher-reported behavioral school engagement in the Teacher Rating Scale of School Adjustment; ESE = teacher-reported emotional school engagement in the School Liking and Avoidance Questionnaire.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Delayed Delivery of Tokens. On the task of delayed delivery of tokens, children with ASD earned a token by completing a performance task, matching non-identical pictures with two non-exemplars. All participants completed the performance task with a 100% accuracy rate. Within the 12 opportunities of delayed reinforcement, on average, children with ASD waited for the whole duration of 9.57 sessions (*SD* = 2.40), during which they waited for the signal from the experimenter to get a token in a bowl in front of them and put the token into a token tower to exchange a backup reinforcer later. Children with ASD in the study had an average cumulative wait duration of 89.66 s (*SD* = 34.65 s) of the maximum possible duration of 124 s. Three distraction strategies were identified being used by the participants during the wait on this task. First, a total of 23 children with ASD (79.3%) used language during the wait by either talking to themselves or the experimenter. Examples of the language were, "More token? Next! I am going to count the token. What happens if it reaches 30?" The frequency of using language by children with ASD in the 12 delayed sessions was significantly positively associated with their cumulative wait duration on the task, r (28) = .47, p = .011, and the number of sessions they waited for the whole duration, r (28) = .43, p = .02, such that children with ASD who used language more frequently during the delays waited significantly longer for the experimenter's signals to get a token and also successfully waited for more delayed sessions. Another distraction strategy used by the children with ASD (n =13) on the task was using gestures to communicate their needs during the wait. Examples of gestures included pointing to the tokens, pretending to take a token by holding the hands above the token bowl, clapping hands, raising hands, and nodding the head. The frequency of using gestures by children with ASD in the total of 12 delayed sessions was found to be significantly associated with their cumulative wait duration, r (29) = .41, p = .026, but was not significantly related to the number of sessions the child waited for the whole duration on this task. Children with ASD in the study were also found to be initiating and maintaining eye contact with the experimenter during the wait (*n* = 14). However, the frequency of having eye contact with the experimenter was not found to be significantly correlated with children's cumulative wait duration or the number of sessions in which children with ASD waited for the whole duration on the task. Figure 6 shows group differences in the wait durations by using and not using the three distraction strategies.

To further examine factors associated with the performance of children with ASD in response to delayed reinforcement on this task, bivariate correlations were conducted to assess the associations between child characteristics and the wait durations as well as the frequency of using social-oriented distraction strategies during delayed delivery of tokens. Children's overall EF levels, as measured by the NIHTB-ECB, were significantly positively associated with their cumulative wait duration of getting tokens, r (29) = .41, p = .028, such that children with higher levels of EF waited significantly longer for the signal of getting a token from the experimenter without touching the token bowl or the token tower.

A hierarchical regression analysis model was conducted to test if children's EF levels moderated the relation between the frequency of using social-oriented distraction strategies and the cumulative wait duration of getting tokens. A composite frequency of using social-oriented distraction strategies was generated by adding up the number of sessions in which language or gestures was used. All variables were centered to eliminate the multicollinearity within the interaction terms. In the first step, the composite frequencies of using social-oriented distraction strategies and the NIHTB-ECB composite score were entered. In the second step, the interaction term (the frequency of using distraction strategies * NIHTB-ECB composite score) was entered. No multicollinearity was identified, as the variance inflation factor (VIF) was less than 10. Other assumptions of linearity, independence of residuals, homoscedasticity, and normality of residuals were met. The full model significantly predicted children's cumulative wait duration of getting tokens, R^2 = .46, F (3, 25) = 7.16, p = .001.

There was main effect of the frequency of using social-oriented distraction strategies, β = .52, p = .002, and children's EF level, β = .34, p = .03. No moderating effect was identified. Regression coefficients and standard errors can be found in Table 19. Together, these findings reveal that children's cumulative wait duration of getting tokens was best explained by their frequency of using social-oriented distraction strategies during the wait and their overall EF levels, as measured by the NIHTB-ECB.

Research Question 10. Do Children with ASD Respond Better Under Token or Social Attention Condition in the Classroom Setting? How is the Reinforcement Preference Related to Self-regulation and Other Child Characteristics in Children with ASD?

Figure 7 shows the total number of correct and incorrect responses in a Matching performance task between the Token and Social Reinforcement conditions in children with ASD in the study. Results showed that the majority of the participants (n = 23, 92%) had better performance with token reinforcers compared to social reinforcement, as indicated by a higher total number of correct responses in two minutes under the token conditions compared to the social reinforcement conditions. There were statistically significant differences in the participants' number of correct responses between the first Token condition (M = 30.24, SD = 6.54) and the first Social Reinforcement condition (M = 26.58, SD = 6.75), t (24) = 5.41, p < .001, and the second Token condition (M = 33.65, SD = 5.95) and the second Social Reinforcement condition (M = 28.17, SD = 7.22), t (22) = 5.997, p < .001. Significant positive correlations were found on the participant's correct responses under the two Token conditions, r (24) = .83, p < .001, and the two Social Reinforcement conditions, r (23) = .89, p < .001. Together, these findings suggest that children with ASD had consistently better performance with token reinforcers over social reinforcement.

Table 19

Hierarchical Regression Results for the Wait Duration in the Delayed Delivery of Tokens Task (N = 29)

Variable	*B*	95% CI for *B*		*SE B*	β	R^2	ΔR^2
		LL	*UL*				
Step 1						.40	.40**
Constant	-4.75	-74.92	65.42	34.14			
Freq of Using SOS	5.30**	1.86	8.74	1.67	.49**		
NIHTB-ECB	.76*	.05	1.47	.35	.34*		
Step 2						.46	.06**
Constant	-5.70	-73.56	62.15	32.95			
Freq of Using SOS	5.62**	2.28	8.97	1.63	.52**		
NIHTB-ECB	.77*	.08	1.46	.34	.34*		
NIHTB-ECB* Freq of Using SOS	-.19	-.41	.04	.11	-.25		

Note. Model = "Enter" method in SPSS Statistics; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; Freq of Using SOS = the frequency of using social-oriented distraction strategies; NIHTB-ECB = composite score in the NIH Toolbox Early Childhood Cognition Battery
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 20

Means and Standard Deviations of Wait Durations and Their Correlations with Child Characteristics Variables and the Frequencies of Using Different Distraction Strategies on the Three Delayed Behavioral Tasks

	M (s)	*SD* (s)	NIHEF	ADOS	BRIEF-P	EC	SR	ABC	BSE	ESE	Lang	Gest	ECX
Wait_TTMand	38.28	22.43	-.07	-.13	.14	.27	.12	.24	.28	.30	.42*	.42*	.45*
Wait_TTWait	49.17	16.00	.45*	-.13	.11	.36	.33	.31	.66**	.40*	.63***	.44*	.40*
Wait_Edibles	83.86	42.28	.25	-.31	-.10	.06	.40	-.09	.23	.27	.44*	.31	.20
Wait_Tokens	89.66	34.65	.41*	.03	.14	.16	.11	-.06	.10	-.06	.47*	.41*	.13

Note. Lang = the frequency of using language in the delayed sessions; Gest = the frequency of using gestures in the delayed sessions; ECX = the frequency of initiating eye contacts with the experimenter in the delayed sessions; Wait_Edibles = the cumulative wait duration in the delayed delivery of edibles task; Wait_Tokens = the cumulative wait duration in the delayed delivery of tokens task; Wait_TTMand = the cumulative wait duration in the Request session in the delayed turn-taking task with an adult; Wait_TTWait = the cumulative wait duration in the Wait session in the delayed turn-taking task with an adult;
* $p < .05$. ** $p < .01$. *** $p < .001$.

Residuals between the Token and Social Reinforcement conditions were calculated by summing up the differences in the mean correct responses under the two conditions across the two phrases. Higher residuals indicated that children with ASD had a better performance with the provision of token reinforcers than social attention reinforcement. Factors associated with the performance difference of children with ASD between the two conditions were examined through correlation tests involving self-regulation variables and other child characteristics.

Self-regulation of children with ASD was significantly associated with their performance under both Token and Social Reinforcement conditions. The number of correct responses provided by children with ASD was significantly correlated with their levels of EF measured by both of the NIHTB-ECB (r (25) = .60, p = .001 in the Token conditions, r (25) = .49, p = .012 in the Social Reinforcement conditions), and the parental report BRIEF-P (r (21) = .52, p = .015 in the Token conditions, r (21) = .54, p = .012 in the Social Reinforcement conditions), as well as with their levels of EC reported on the CBQ-SF (r (21) = .49, p = .026 in the Token conditions, r (21) = .52, p = .017 in the Social Reinforcement conditions). Together, these findings showed that children with better self-regulation skills provided more correct responses on the tasks of matching non-identical pictures or matching upper- and lower-case letters. However, none of the self-regulation skills was significantly associated with the differences in the children's performance between the two conditions. These findings revealed that self-regulation in children with ASD was correlated with their performance on a task that they have mastered in the repertoire but was not associated with their performance difference between token and social attention conditions.

Instead, the performance of children with ASD between the two conditions was found to be associated with two other child characteristics: the severity of ASD-related symptoms and school engagement. First, children with a high level of ASD-related symptoms, indicated by the ADOS-2 comparison score, had higher discrepancies in their performance between the

Token and Social Reinforcement conditions (*M* = 17.28, *SD* = 9.80) than those with a moderate level of ASD-related symptoms (*M* = 7.57, *SD* = 4.97), t (21) = - 2.99, p = .007. This finding revealed that children with more severe ASD-related symptoms had a better performance with token reinforcers than social reinforcement to a greater extent. More specifically, there was a significant positive association between children's scores on the Social Affect subscale on the ADOS-2 and the discrepancies in their performance between the Token and Social Reinforcement conditions, r (23) = .41, p = .05, such that children with ASD who had more deficits in communication and reciprocal social interaction were more inclined to token reinforcement than social reinforcement in the classroom environment.

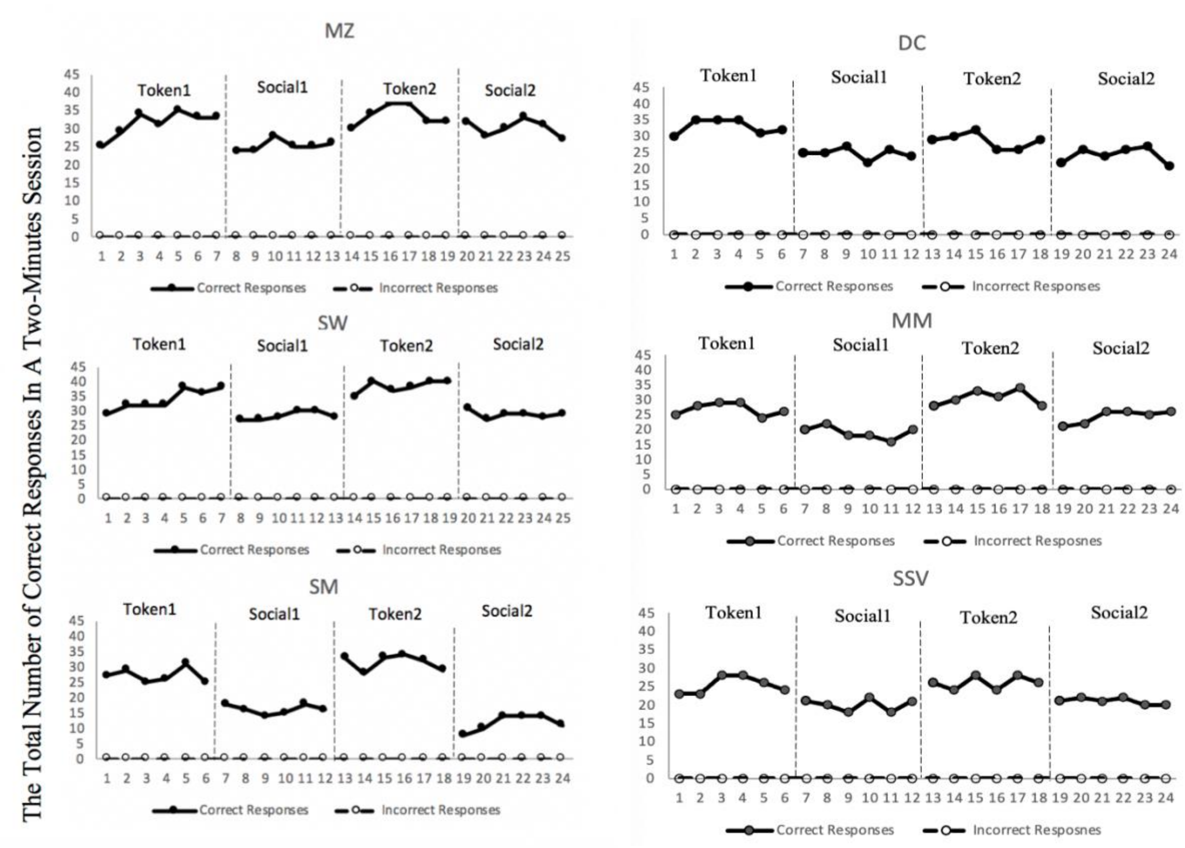
Second, the performance difference of children with ASD due to the availability of token or social attention was associated with their school engagement. A significant negative correlation emerged between children's behavioral cooperative participation at school reported by teachers on the TRSSA and the discrepancies in their performance between the Token and Social Reinforcement conditions, r (23) = -.47, p = .022, such that children with ASD who were more cooperative and responsible to the demands in the classroom environment demonstrated fewer differences in their performance between token and social reinforcement. Similarly, there was a significant negative association between children's emotional school engagement in school activities reported by teachers on the SLAQ and the discrepancies in their performance between the Token and Social Reinforcement conditions, r (23) = -.62, p = .002, such that children with ASD who showed greater desire to like the school activities and environment demonstrated fewer differences in their performance between token and social reinforcement.

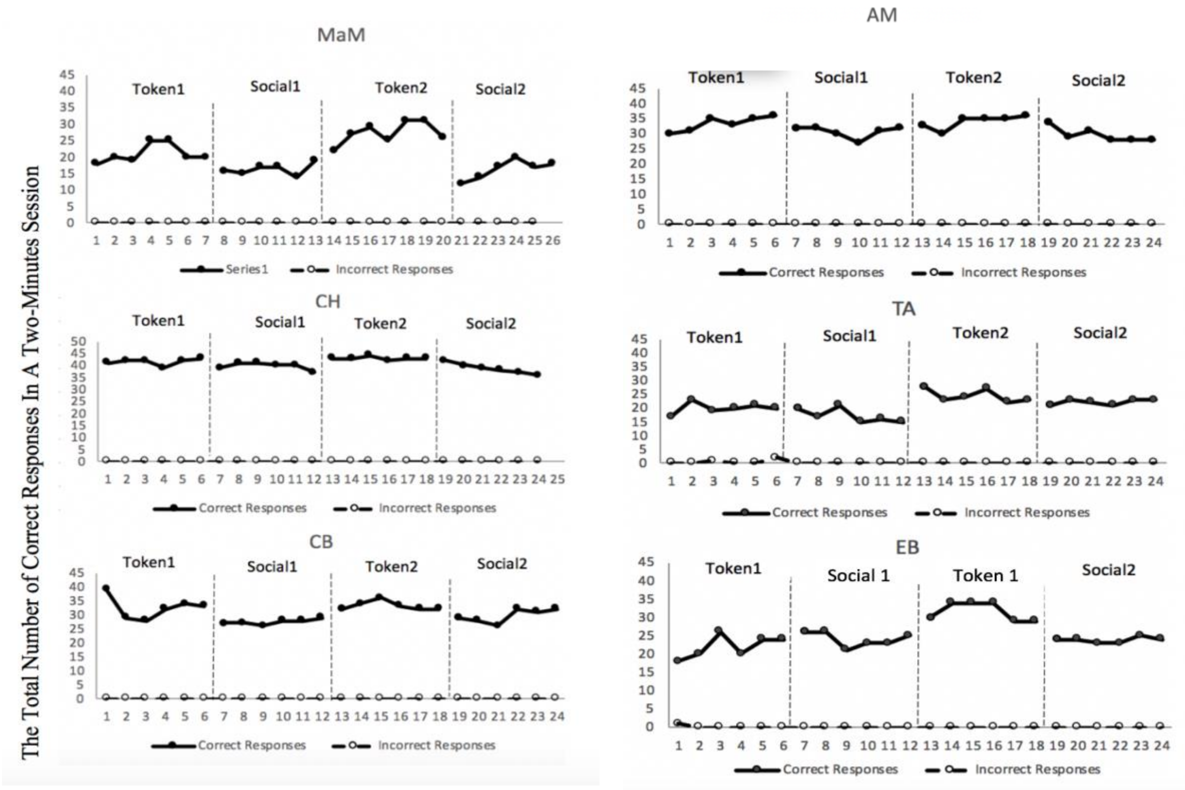
Also, a significant positive association was found in the residuals of children's performance between the Token and Social Reinforcement conditions and their average sessions to criteria in the mathematics programs using the MEI instruction, r (19) = .49, p

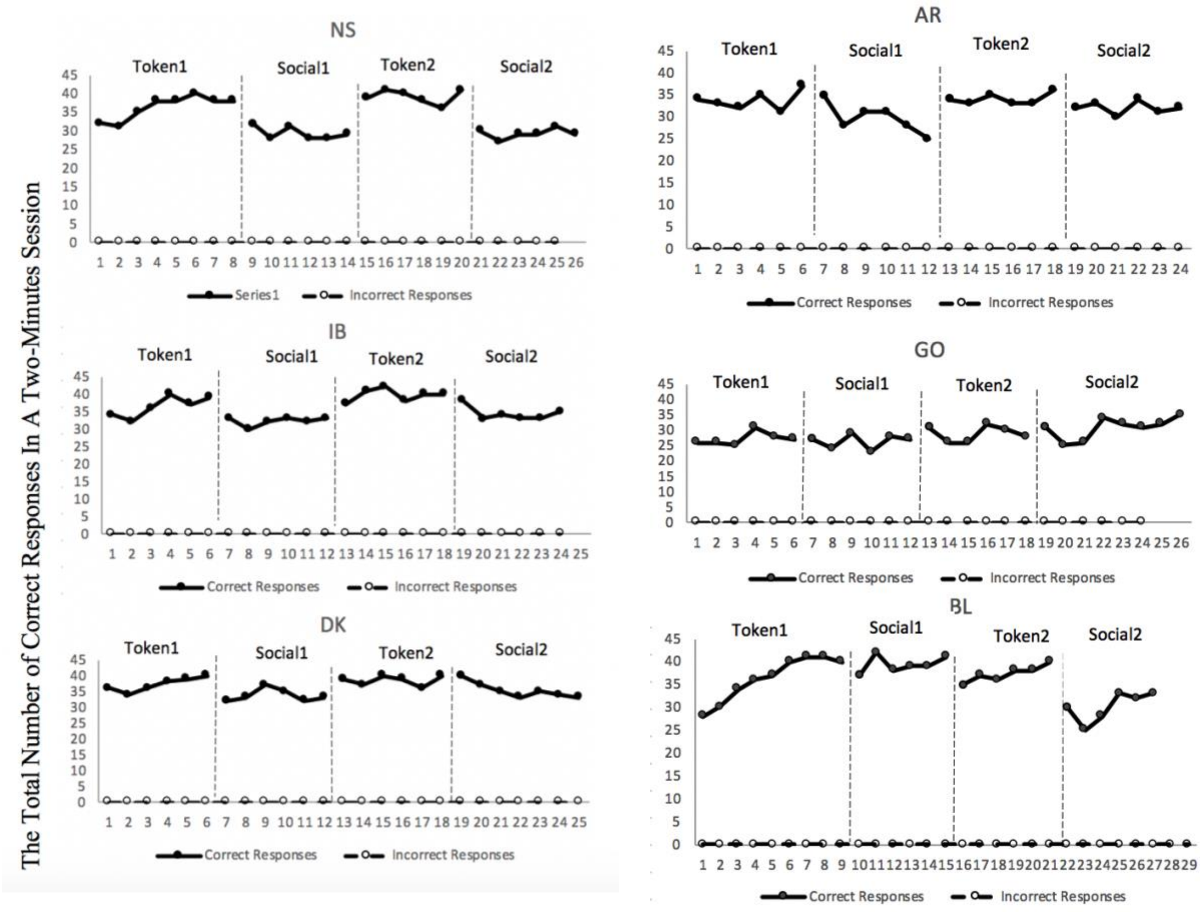
= .035, such that children with ASD who had better performance under token reinforcement required more opportunities to achieve an objective in mathematics learning in the programs using trial-based instruction. In other words, children with ASD who did not show an obvious performance difference with token over social reinforcement learned basic mathematics concepts faster through the trial-based programs.

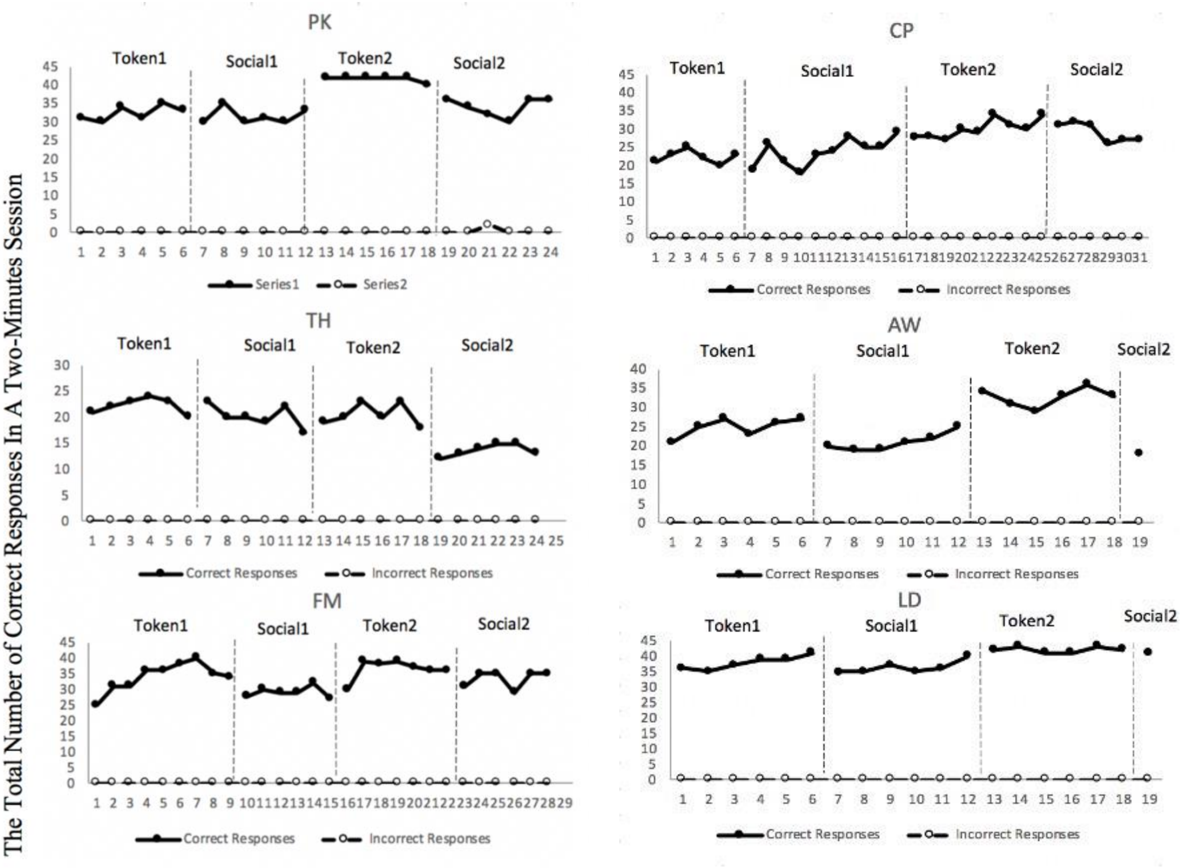
Figure 7

The Total Number of Correct and Incorrect Responses in Two Minutes between the Token Conditions and the Social Reinforcement Conditions




The Total Number of Correct Responses In A Two-Minutes Session
MaM
Token1
Social1
Token2
Social2
Series1
Incorrect Responses
AM
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
CH
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
TA
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
CB
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
EB
Token1
Social 1
Token 1
Social2
Correct Responses
Incorrect Responses


The Total Number of Correct Responses In A Two-Minutes Session
NS
Token1
Social1
Token2
Social2
Series1
Incorrect Responses
AR
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
IB
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
GO
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
DK
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
BL
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses


The Total Number of Correct Responses In A Two-Minutes Session
PK
Token1
Social1
Token2
Social2
Series1
Series2
CP
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
TH
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
AW
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
FM
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses
LD
Token1
Social1
Token2
Social2
Correct Responses
Incorrect Responses

Chapter V

Discussion

Children’s self-regulation has shown to be related to the trajectories across various domains of adaptive functioning and school success. It has been well documented that typically developing children with better cognitive self-regulatory executive function skills and temperamental effortful control had better academic achievement (e.g., Blair & Razza, 2007). However, few studies have extended the examination of the association between self-regulation and academic learning to populations with disabilities, especially to those with ASD, who often demonstrate self-regulatory challenges (e.g., Geurts et al., 2014) and academic difficulties compared to their typically developing peers (e.g., Wei et al., 2011). Additionally, the majority of previous studies solely relied on standardized assessments to reflect children’s temporary learning *outcomes* rather than their dynamic learning *process*. Little is known about how children’s self-regulatory skills are related to the way they learn and how various child characteristics moderated this association. Therefore, the goal of this study was to examine how the self-regulatory capacities of children with ASD were linked to their dynamic academic learning process. Instead of using one-time standardized assessments, this study derived school data from multiple literacy and mathematics programs over a period of time to investigate the number of learning opportunities and additional one-to-one educational interventions a child required to achieve an academic objective in the learning process. The moderating effects of various child characteristics were examined in the association between self-regulation and academic learning in children with ASD, including ASD-related symptoms severity, school engagement, reward sensitivity, and adaptive behavior, all of which represent areas of challenge for this group of students.

In addition, children with ASD often receive different types of reinforcement at school, which sometimes may be delayed in the natural environment, and thereby these children's behavioral regulation and reward sensitivity under such frustrating situations seem to be particularly important for their school success. Thus, another goal of this study was to understand children with ASD's ability to regulate their behaviors and their reactions to rewards under some frustrating situations that they often encountered at school related to delayed reinforcement, and to examine whether they respond better under token or social attention condition. Overall, the findings were summarized and discussed according to the following main goals of the study: 1) to explain the associations between self-regulation and various child characteristics; 2) to explain the relations between self-regulation and academic learning in literacy and mathematics; 3) to describe the moderating effects of child characteristics on the association between self-regulation and academic learning; 4) to summarize the strategies children with ASD used in response to delay of reinforcement and how the ability to wait is linked to self-regulation and other child characteristics; 5) to discuss how children with ASD responded differently between token and social attention conditions in the natural classroom environment.

Associations Among Self-regulation and Other Child Characteristics in Children with ASD

Overall, children with ASD in the present study represented a sample with more severe executive dysfunction and reduced effortful control compared to their typically developing peers, as reported by parents on the BRIEF-P and the CBQ-SF. These findings support previous literature that parents of children with ASD reported significantly more executive function deficits (e.g., Boyd et al., 2009; Demetriou et al., 2018) and effortful control delays (e.g., Jahromi et al., 2019; Konstantareas & Stewart, 2006) than those of typically developing children.

It was hypothesized that children's self-regulation skills would be intercorrelated with one another, as measured by direct assessments and reported by parents. Findings in this study partially supported this hypothesis and aligned with previous studies (e.g., Jahromi, Bryce, & Swanson, 2013), such that children's level of EC reported by parents were significantly correlated with their overall EF level as well as every single EF skill on the parental report, including inhibitory control, shift, emotional control, working memory, and plan/ organize. These findings provide evidence that EF tends to be a unitary construct during the preschool years relative to parents' expectations and are in line with previous work suggesting that EF skills are far less distinct in early childhood (e.g., Hughes et al., 2009; Willoughby et al., 2010).

Despite the strong associations among self-regulatory skills reported by parents, no significant association was found between children's performance on the direct EF measures on the NIH Toolbox and their levels of EF or any specific EF skill reported by parents on the BRIEF-P. This may be due to the differences in the nature of the two measures: the NIH Toolbox EF measures assess important aspects of EF alongside domain-specific content areas of cognition, such as episodic memory and language, whereas the BRIEF-P mainly measures the regulatory executive control processes. Therefore, the results on the two measures may reflect preschoolers' EF profiles from different dimensions. It is not rare to see domain-specific content areas included in many tests for one's EF profile, especially in those measuring early EF skills of preschoolers, whose abilities are often less differentiated than those of older children (Gioia, Espy, & Isquith, 2003). In fact, the strong link between language and EF abilities is supported by both theory and empirical evidence. According to the hierarchical competing system model of the emergence and development of EF proposed by Zelazo and colleagues (Marcovitch & Zelazo, 2009; Zelazo, 2004), language helps manage executive control by facilitating information retention and processing in working memory and enabling conscious reflection on goal-directed behaviors. Empirical studies also showed that language and EF abilities are closely linked in typical and atypical populations. For example, inhibitory control was linked to how typically developing children processed syntactic information (Mazuka et al., 2009), resolved lexical and syntactic issues (Khanna & Boland, 2010), and predicted their syntactic performance, even after controlling for age, IQ, and socioeconomic status (Kaushanskaya et al., 2017). Similarly, a study with school-age children with ASD revealed that both receptive and expressive language predicted performance in inhibition, shifting, and working memory tasks (Weismer et al., 2018). Thus, language abilities were often considered as important components in EF measures for children.

Second, the BRIEF-P reports the degree to which parents consider some EF-related behaviors problematic in everyday life. This measure reflects parental expectations rather than the absolute levels of children's EF skills. It may not be surprising to see some parents adjust their expectations for children who have a disability and do not consider some EF-associated behaviors as problems in everyday life (Gioia, Espy, & Isquith, 2003). As a result, some children with a disability who present EF deficits on direct measures may not be reported as having executive dysfunction behaviors by their parents on the BRIEF-P.

Regarding the severity of ASD-related symptoms, participants in the present study represented a sample with an overall moderate level of ASD-related symptoms. Consistent with the prediction, symptom severity among children with ASD in the present study was linked to their individual differences in EF. Children with ASD with better inhibitory control and attention on the NIH Toolbox EF measures demonstrated better communication and reciprocal social interaction on the ADOS-2. Those with a larger vocabulary, as measured by the NIH Toolbox measures, manifested fewer restricted and repetitive behaviors on the

ADOS-2. These findings indicated that improving children with ASD's self-regulation skills and expanding their vocabulary may help to reduce their symptom severity.

Interestingly, no significant association emerged between children's EC and their ASD-related symptom severity in the current study, which has been well-documented in previous literature (e.g., Konstantareas & Stewart, 2006; Samyn et al., 2011). Faja and Dawson (2015) found that children with ASD who had greater levels of EC reported by parents demonstrated fewer Social Affect symptoms on the ADOS-2. Children's impaired EC reported by parents was also found to be linked to their ASD symptom severity when it was assessed by other measures of autism other than the ADOS-2 (e.g., Konstantareas & Stewart, 2006; De Pauw et al., 2011). It should be noted that the age groups of participants with ASD were different in the present and these previous studies. For example, Konstantareas and Stewart (2006) included children with ASD from 3 to 10 years old, Faja and Dawson (2015) had participants with ASD between 6 and 7 years old, and De Pauw et al. (2011) had a sample with an average age of 10 years old. Considering the participants in the present study were averagely much younger (M= 51.35 months, SD = 7.59), one explanation could be that the association between EC and ASD-related symptom severity may not emerge clearly enough during the early childhood period. Much of the work on EC in ASD focused on middle childhood, while little is known about the association between temperamental EC development and the severity of ASD during infancy and the early preschool years (Garon et al., 2009). Some studies used retrospective parent reports and found that children who received an ASD diagnosis later in life began to demonstrate EC delays during infancy (Gomez & Baird, 2005; Watson et al., 2007). The prospective longitudinal study conducted by Garon et al. (2009) found that high-risk infants who had an older sibling with ASD demonstrated poorer temperamental development compared to the typically developing control group, and some aspects of these infant's temperament profiles (activity level, positive anticipation, and attentional shifting) predicted their ASD symptom severity. While this study provided some evidence on the relationship between temperament and ASD symptom severity, future work will be benefited from focusing more on the effortful control level of young children with ASD, which consists of attentional focusing, inhibitory control, low intensity pleasure, and perceptual sensitivity of the temperament profile (Putnam & Rothbart, 2006). More work is needed to examine further the association between level of EC and ASD symptom severity during the earlier developmental period.

Regarding children's adaptive behavior, participants in the present study were reported an overall moderately low to adequate adaptive level by teachers on the Vineland-3. This aligned with previous work that children with ASD demonstrated impaired adaptive behavior from early childhood (e.g., Kanne et al., 2011). As predicted in the hypothesis, children with ASD whose overall EF level were higher on the direct assessments showed better adaptive behavior, particularly stronger communication skills, at school after accounting for their mother's education level. More specifically, children with greater levels of cognitive flexibility, attention, planning, and episodic memory on the direct EF measures were reported better overall levels of adaptive behavior and communication skills by the teachers. These findings indicated that children who were better at shifting from tasks to tasks, adjusting their behaviors due to changing demands, anticipating future events, paying attention to what is expected, and remembering daily events tended to adapt to school lives more successfully. These findings support previous studies, which showed that executive dysfunction was associated with difficulty with adaptive behavior above and beyond the ASD symptom severity and IQ (Gilotty et al., 2002), and levels of EF predicted later gains in adaptive behavior, particularly in the domains of socialization and daily living skills, after controlling for IQ and age (Pugliese et al., 2016). Together, these findings showed that EF of children with ASD were linked to their adaptive behavior above and beyond multiple child and family factors.

Similarly, children with ASD who had higher levels of EC, as reported by parents, showed better adaptive behavior, especially better social skills at school, as reported by teachers. However, this pattern of association was mixed in previous studies when different measures were used. For example, Faja and Dawson (2015) found that the EC level of children with ASD reported by parents on the CBQ was not significantly correlated with their social skills on the parent-reported Vineland-2 Socialization subscale. Therefore, more work is needed in the future to investigate the association between EC and adaptive behavior in children with ASD. Despite this, these findings indicated that EF skills and EC level were important factors that were associated with the levels of adaptive functioning, particularly communication and social skills, in young children with ASD. It is suggested that self-regulation development should be an important component of the future social-emotional intervention for this group of students.

Regarding children's school engagement, it was hypothesized that self-regulation skills were positively related to the degree to which children with ASD behaviorally and emotionally engaged in school activities. Findings in the present study partially supported this hypothesis. Children with ASD who demonstrated better overall EF level, particularly better episodic memory, on direct measures were reported greater level of behavioral school engagement by teachers, such that they demonstrated better cooperative and independent participation in school activities. Similar findings were reported by Jahromi, Bryce, and Swanson (2013) that children with ASD who showed better EF skills in lab tasks and parent reports had better behavioral school engagement reported by teachers. However, contrary to the significant association between emotional school engagement and EF in Jahromi, Bryce, and Swanson (2013), children's EF skills were not linked to their desire to like or avoid school activities in the present study. Instead, children with ASD who were reported higher levels of social skills on the Vineland-3 demonstrated higher levels of school liking, according to their teachers. These findings in the current study showed that social skill may be a more important factor than self-regulation skill for the extent to which children with ASD emotionally engage in the school setting. The mixed findings in the current study and Jahromi, Bryce, and Swanson (2013) may be due to two reasons: First, different EF measures were used in these two studies. In the present study, children's EF profile was reflected by the Global Executive Composite score of the BRIEF-P, which included parent's ratings on all aspects of EF skills of children with ASD, alongside with children's performance on the direct EF measures on the NIH Toolbox. In contrast, Jahromi, Bryce, and Swanson (2013) used the Inhibitory Self-Control Index of the BRIEF-P, which included parent's rating on children's inhibitory control and emotional control, and children's performance on the Day/Night Task to composite scores for their EF level. Thus, the measures in the two studies may reflect different aspects of the EF profile of children with ASD. Second, samples were different in the two studies. Jahromi, Bryce, and Swason (2013) included 20 typically developing children in their analysis of the association between EF and emotional school engagement while controlling for the children's mental age. The present study did not have a typically developing control group and did not obtain information on the mental age of children with ASD. Thus, more work is needed in the future to investigate further how self-regulation is linked to school liking and avoidance in children with ASD.

Last, as predicted in the hypothesis, a significant negative association emerged between children's EF and reward sensitivity, such that children with ASD with overall lower levels of EF and more deficits in inhibitory control, shifting, and emotional control were reported greater sensitivity to reward by parents. These findings were in line with previous studies that higher levels of executive dysfunction and impulsivity were associated with greater behavioral system activation in response to rewards (e.g., de Vries et al., 2018; O' Connor & Golder, 2004). According to the Gray's (1982) Reinforcement Sensitivity Theory and the behavioral approach system (BAS) scale developed by Carver and White (1994), children with greater sensitivity to reward tend to attend more to cues of rewards, have more impulsive responses and fun-seeking behaviors, and stay more persistent in pursuing rewards. Thus, it was not surprising to see children with ASD with more severe executive dysfunction behaviors were more sensitive to reward in their daily lives.

Factors Associated with Academic Learning in Children with ASD

In line with previous research with typically developing children (e.g., Blair & Diamond, 2008; McClelland et al., 2017), it was hypothesized that self-regulation was positively associated with academic learning in literacy and mathematics in children with ASD. As predicted, findings in the present study showed that children with ASD who were better at controlling their emotions in daily lives, as reported by parents on the BRIEF-P Emotional Control subscale, required fewer learning opportunities to achieve an objective in literacy programs at school. Children's EF were suggested to be conceptualized as two distinct but interrelated construct: *hot* EF and *cold* EF (Blair et al., 2007; Metcalfe & Mischel, 1999; Zelazo & Muller, 2002). Emotional control ability in the parent-reported BRIEF-P represents hot EF, which includes the capacity to regulate emotional responses and solve problems with emotional components. Mixed findings were found in previous studies regarding how typically developing children's hot EF skills were related to their academic achievement during early childhood. For example, Brock et al. (2009) did not find a clear association between hot EF skills and academic achievement in reading among typically developing children in kindergarten. In contrast, Howse et al. (2003) reported that teacher ratings of hot EF skills in preschool predicted typically developing children's later academic achievement in kindergarten. The mixed results in the typically developing studies may be due to the overlapping variances shared by hot and cool EF. Findings on the current study added to the literature that emotional components of EF skills were significantly linked to young children with ASD's overall learning rates in various literacy programs.

When taking a closer investigation on different components of literacy learning, self-regulation skills of children with ASD in the present study were not associated with their learning in alphabetic knowledge nor phonemic awareness, but an association was found with word recognition and reading comprehension. Particularly, children with ASD who were better at paying attention and inhibiting impulsive behaviors learned new words and acquired reading comprehension skills faster at school. These findings were in line with a previous study with typically developing kindergarteners that EF skills were associated with these children's reading comprehension and word decoding performance (Haft et al., 2019). In particularly, typically developing kindergartener's attention and inhibitory control were associated with their reading comprehension and word decoding (Bierman et al., 2008). The present study added to the literature by showing that a similar association between EF and literacy learning existed among young children with ASD and that attention and inhibitory control seem to be particularly important for the learning of word recognition and reading comprehension in this atypical population. While Haft et al. (2019) found that typical children's word decoding skills mediated the association between their EF skills and reading comprehension performance, this study was unable to perform a similar mediation analysis due to a small sample size. Future research will be benefited by investigating deeply the direction and pattern of the association between EF skills and word recognition/ reading comprehension performance in children with ASD and the mechanism underlying this association.

Children's EF was also found to be associated with their mathematics learning in the present study. Specifically, children with ASD who had higher levels of EF reported by parents learned mathematics concepts and problem-solving skills faster at school, regardless of the type of curriculum instruction (trial-based vs. script-based). More specifically, children with ASD who had better working memory, as reported by parents, learned faster in the trial-based mathematics programs. Previous studies with typically developing samples showed similar results that children with better EF skills had better mathematics achievement (e.g., Brock et al., 2009), and working memory predicted young children's math performance at school (Mann et al., 2016) and this prediction was shown to last throughout adolescence in longitudinal study (Ahmed et al., 2018). The findings in the present study enriched the empirical evidence that EF level, particularly working memory, is a crucial for the mathematic learning in young children with ASD.

It is interesting to find that the overall EF level of children with ASD in the study was related to their learning rates in mathematics programs but not in literacy programs. One of the explanations could be that children at the early childhood ages may require to incorporate different dimensions of their EF skills to support the cognitive load during mathematics learning, while some specific EF skills emerged as important factors contributing to literacy learning, including inhibitory control and attention. This finding was in line with previous study suggesting that sustained attention and inhibitory linked most strongly to early literacy (Bierman et al., 2008).

Additionally, no significant association was found between children's EC and their academic learning in literacy or mathematics. This was in line with the work of Blair and Razza (2007), who found that parent-reported EC on the CBQ (Putnam & Rothbart, 2006) was unrelated to all measures of academic abilities in typically developing children. However, findings on whether EC relates to changes in achievement have been mixed in typically developing samples. For example, Valiente et al. (2010) showed that parent-reported, teacher-reported, and observed EC were positively linked to reading and math achievement in typical kindergarteners. The mixed findings may be due to different aspects of academic achievement that had been measured in these two studies: Blair and Razza (2007) focused on phonemic awareness, letter knowledge, and mathematics knowledge, while Valiente et al. (2010) measured children's word decoding, reading comprehension, and math problem-solving skills. The present study added to the literature that when focusing on the learning rates of literacy (alphabetic knowledge, phonemic awareness, word recognition, and reading comprehension) and mathematics (in trial-based and script-based curricula) in young children with ASD, EC did not emerge as an important factor. Together, findings in the present study suggest that children's EF but not EC were associated with their rates of learning in literacy and mathematics.

Child Characteristics as Moderators

This study also examined moderators of the association between self-regulation and academic learning. It intended to identify ways to help children with ASD improve their self-regulation skills and academic performance at school. It was hypothesized that self-regulation would be related to academic learning in young children with ASD and that higher levels of school engagement, adaptive behavior, ASD symptom severity, and reward sensitivity would strengthen this association. After compositing children's self-regulation skills and academic learning rates in literacy and mathematics programs, the present study found that behavior school engagement and reward sensitivity moderated the association between self-regulation and academic learning in children with ASD. In other words, greater levels of cooperative and independent participation in school activities and sensitivity to rewards promoted a stronger relationship between self-regulation and academic learning in children with ASD. These findings highlighted the importance of children's behavior school engagement and reward sensitivity in their self-regulation and academic performance at school.

School engagement reflects motivation for learning, guides behaviors linked to school success, and serves as a proximal contributor to the academic abilities for children (Dweck, 1989; Finn, 1993). When focusing on children's engagement behaviors in classroom activities, previous research showed that students who had disruptive or inattentive behaviors got lower scores on all achievement tests (Finn et al., 1995). This link remained true when children just entered school and over the entire course of their school years (Fredricks, Blumenfield, Friedel, & Paris, 2005). Previous literature also suggested that self-regulation level was associated with the degree to which children with ASD behaviorally engaged in school activities (Jahromi, Bryce, & Swanson, 2013). Together, these findings suggest that it is important to consider children's school engagement behaviors when targeting their self-regulation development and academic learning in future interventions. Improving young children with ASD's behavioral school engagement can help promote improvements in their self-regulation and academic learning.

Similarly, obtaining rewards through competent efforts is essential for goal-directed behaviors and learning (Damiano et al., 2012). Children with ASD had been reported altered reward sensitivity compared to their typically developing peers. Specifically, they had enhanced motivation to pursue non-social stimuli based on personal interests but also demonstrated reduced motivation to request social interactions (Dawson et al., 2004; Geurts, Luman, & van Mell, 2008). They also exhibit difficulties in understanding rules from stimulus-rewarding associations (Dawson et al., 2001; Jones et al., 2013). Previous studies argued that failing to assign reward values to social interactions resulted in language abilities delays in children with ASD (Damiano et al., 2012; Mundy & Neal, 2001). Children with ASD who demonstrated more executive dysfunction showed greater enhanced reward sensitivity and more severe ASD traits (De Vries et al., 2018; Faja et al., 2013). It is argued that the altered reward sensitivity to non-social stimuli in children with ASD may explain their repetitive behaviors because their behavioral patterns with certain non-social stimuli may be excessively rewarding to them, and their deficits in EF may limit their ability to flexibly shift between various stimuli in real life (Faja et al., 2013). Thus, it is also important to consider sensitivity to reward in children with ASD when targeting their self-regulation development and academic learning in future interventions.

Behavioral Responses to Delayed Reinforcement

Through the three delayed behavioral measures, this present study found that children with ASD who used three socially-oriented distraction strategies, including language, gestures, and eye contact, had significantly longer waits for delayed reinforcement. Overall, children with ASD who used language more frequently waited significantly longer in the tasks of delayed turn-taking, delayed delivery of edibles, and delayed delivery of tokens. Children with ASD who used gestures more frequently waited significantly longer in the tasks of delayed turn-taking and delayed delivery of tokens. Children with ASD who used eye contact more frequently waited significantly longer in the delayed turn-taking task. Further analysis showed that the frequency of using the three socially-oriented distraction strategies significantly predicted children’s cumulative wait duration in the delayed turn-taking task, above and beyond all other factors. Similarly, children’s frequency of using the three distraction strategies as well as their overall EF level together significantly predicted their waits in the delayed delivery of token task.

In the natural classroom environment, delayed reinforcement cannot be avoided. As suggested in previous studies, how children tolerate to delay of reinforcement is essential to their school success, social interaction, and learning (Whiting & Dixon, 2015). Individuals with ASD often demonstrate impulsive behaviors and have difficulties in inhibiting inappropriate impulses (e.g., Faja & Dawson, 2015; Jahromi et al., 2019). It is important to help them improve their regulating abilities in response to delayed reinforcement, a frustrating situation where the chances of impulsivity and regulatory demands increase. Findings in the present study suggest that improving young children with ASD's ability to use language, gestures, or eye contact to express their thoughts, emotions, or needs during situations involved delayed reinforcement can help them better regulate their behaviors and wait significantly longer before getting the reinforcer in the natural classroom environment. Children with ASD were observed to demonstrate significantly less positive affect than typically developing peers during a delay of gratification task (Jahromi et al., 2019). As suggested in previous research, language and emotion are related developmentally. The need to express emotions and interpret events motivates children to acquire language. In turn, language facilitates children's emotional expressions (Bloom, 1998). It is speculated that socially-oriented distraction strategies help children with ASD regulate their behaviors in response to delayed reinforcement through facilitating their emotional expression and regulation in this frustrating situation. Future research is needed to verify this notion. Furthermore, it may be that EF is the underpinning capacity to implement problem-solving strategies to respond to delayed reinforcement through language. Future work will be needed to examine the mediating effect of language on the association between EF and waiting behaviors during delayed delivery of reinforcement.

Reinforcing Efficacy of Token versus Social Reinforcement

Children with ASD receive reinforcement consistently at schools using instructions based on the principles of applied behavior analysis. This study attempted to understand the reward sensitivity of children with ASD more deeply by investigating whether they performed better under a token or social attention condition. In line with previous work suggesting that individuals with ASD had enhanced motivation to pursue non-social stimuli based on personal interests while having social reward hyposensitivity (Dawson et al., 2004; Mundy & Neal, 2001), this study found that the majority of children with ASD had significantly better performance under token condition compared to social attention condition, the pattern of which was relatively consistent over a period of time, regardless of their self-regulation level. This finding suggested that children with ASD demonstrated pervasive and sustained altered reward sensitivity towards non-social stimuli and had relatively reduced responsiveness to social attention. This may be due to their difficulties in processing and understanding social stimuli (Dawson et al., 2004) or their reduced assignment of reward values to social interactions (Damiano et al., 2012; Mundy & Neal, 2001). Children with ASD have been consistently offered tokens with backup reinforcers based on personal interests at schools, and tokens are effective in reinforcing and maintaining desirable behaviors for them. However, it is crucial to enhance children with ASD's sensitivity and responsiveness to social reinforcers, including attention, approval, appreciation, and encouragement. This would potentially support them to increase generalization and maintenance of desired behaviors in everyday environments and could facilitate the development of social skills.

Interestingly, this study found that children with more severe ASD-related symptoms, particularly with more deficits in communication and reciprocal social interaction, performed much better under the token condition compared to the social attention condition. Also, children with ASD who had lower levels of behavioral and emotional school engagement demonstrated much better performance under the token condition relative to the social attention condition. These findings suggest that it is particularly important to condition social reinforcers for children with severe ASD-related symptoms and poorer school engagement and to increase their sensitivity to social reinforcement to promote their school success. Meanwhile, it should be noted that it is not clear about the direction of the relationship between children's school engagement and the differences in their performance between the two conditions. Thus, we cannot conclude that whether children with ASD who were better engaged in school activities behaviorally and emotionally perform better with social attention or children with ASD who had better social skills showed higher levels of behavioral and emotional school engagement. Future research is needed to further examine these associations.

Strengths of the Study

Previous studies had predominantly relied on typically developing samples to investigate the association between self-regulation and academic achievement. One of the strengths of the present study was to add to the literature by including young children with ASD. Individuals with ASD often demonstrated more deficits in self-regulation compared to their typically developing peers (e.g., Demetriou et al., 2018; Hill, 2004; Jahromi, 2017). As self-regulatory skills begin to emerge and develop enormously during early childhood, it is significant to examine how young children's self-regulation shape trajectories across various domains of school success and adaptive functioning, including academic learning, school engagement, and reward sensitivity. Also, students with ASD are often reported to have academic underachievement at school (e.g., Boutot, 2017). Literacy (e.g., Nation et al., 2006) and mathematics (e.g., Wei et al., 2013) represent specific areas of challenge for them. However, factors that may be associated with variability in academic learning, including self-regulatory skills, have not yet been well studied in the populations with ASD. Understanding how self-regulation is linked to rates of academic learning and the need for additional individualized intervention provide us important information on future academic and self-regulation interventions for young children with ASD.

Another strength of this study was the use of individual student's school data on multiple academic programs over a period of time, which provided valuable information on a more comprehensive academic learning profile of children with ASD. At the CABAS® schools, all academic programs were tailored to individual student's developmental needs and academic levels. Thus, using school data on different programs makes it possible to investigate children's learning paths on the individual level. Data used in this study represented students' academic learning in different foundational literacy components, including alphabetic knowledge, phonemic awareness, word recognition, and reading comprehension. Students' mathematics learning performance on trial-based and script-based programs were also demonstrated in the data. As ASD is a heterogeneous spectrum disorder, children with ASD demonstrate diverse educational needs and require various levels of academic support. This study focused on the number of learning sessions required to achieve an academic objective and the number of individualized interventions needed in literacy and mathematics learning. This approach allowed us to dive deeper into the dynamic learning process of every participant with ASD rather than solely focusing on their temporary academic outcomes.

Also, this study adopted the ADOS-2 (Lord et al., 2012), the current gold standard for autism diagnosis, to determine the ASD-related symptoms severity of the participants. This measure not only yield an overall score representing the overall severity of symptoms, but also provided more thorough information about the specific challenges in the areas of social affect and restricted and repetitive behaviors of children with ASD in the study. This information allowed us to have a closer investigation on the association between ASD-related symptom severity, self-regulation, and academic learning in children with ASD.

Limitations

Despite the strengths of this study, the conclusions may be limited by the following factors: a relatively small sample size, the absence of a comparison group, and possible limitations to the generalizability of the findings. Due to a relatively smaller sample size, this study may have lacked sufficient statistical power to identify significant associations among various variables or to fully explore some of the group differences that emerged. For example, the small sample size may have limited our ability to explore whether differences in self-regulation were presented based on sibling status or family's nativity. Even though non-parametric analyses had been adopted to reduce the chances of errors, some of the post-hoc regression analyses and multiple comparisons should be interpreted with caution. Future work with larger samples will allow the field to have a better understanding of these patterns. Also, this study did not include a comparison group of typically developing children or children with other developmental disabilities. Although the association between self-regulation and academic achievement has been well-studied in the typical population, it is important to further investigate their dynamic learning process beyond temporary academic achievement reflected on standardized measures and to compare how diagnostic status may moderate the association between self-regulation abilities in children's learning process. Additionally, participants in this study were from specialized applied behavior analysis schools, where reinforcement had been delivered consistently to their desired behaviors and satisfactory academic performance. These students with ASD may have potentially developed greater levels of self-regulation with many years of positive behavioral interventions and supports. Moreover, a variety of evidence-based interventions had been implemented to foster their academic skills and social-emotional development. Academic programs, objectives, and types of additional learning tactics were individualized to tailor each student's needs. Thus, compared to peers in an inclusive setting, these students with ASD may have better academic performance in this more structured school setting and may have higher learning rates with the educational materials that fitted their individual levels and positive reinforcers that they preferred. Therefore, the findings in the present study may not be generalized to children with ASD in other school settings. In addition, children with ASD in the present study could speak at least three-word phrases. Some of them used complex sentences regularly. In terms of their levels of verbal behavior, all participants functioned on the Listener and Speaker levels. Therefore, the findings in this study may not be generalized to children with lower levels of language development, such as those who are nonverbal.

Future Directions

Results in the present study inform a number of future directions for research and intervention. First, additional research can be conducted to investigate whether children with ASD from different school settings, such as an inclusive general education classroom or an integrated co-teaching classroom, have different self-regulatory and academic learning profiles and whether the pattern of association among self-regulation, other child characteristics, and rates of learning remain the same in these different settings. Also, while academic achievement has been well-studied in typically developing children, it is important to extend the measure of the dynamic learning process to the typical population to see if their self-regulatory skills are linked to the rates at which they master different literacy and mathematics objectives.

Some of the mixed findings between this and previous studies also call for more future research. For example, children's impaired EC was found to be related to their ASD symptom severity during early to middle childhood in previous literature (e.g., Konstantareas & Stewart, 2006; De Pauw et al., 2011). However, this association did not emerge in the sample of young children with ASD in the present study. More work is needed to further examine the association between children's EC and ASD-related symptoms severity during early childhood. Also, this study found that children with ASD who had higher levels of parent-reported EC showed better adaptive behavior, especially better social skills at school, as reported by teachers. However, this pattern of association differed in previous studies when different measures were used. For instance, Faja and Dawson (2015) did not find a strong relationship between the EC level of children with ASD and their social skills reported by parents. It is important for future work to include multiple measures on the social function profiles of children with ASD further investigate the association between their EC and adaptive behavior. Moreover, previous literature suggested that children's EF skills were linked to their emotional school engagement (Jahromi, Bryce, & Swanson, 2013). However, the current study found social skills rather than self-regulation skills may be the factor that was associated with the degree to which children with ASD like or avoid school activities. Thus, more work is needed in the future to investigate how children's self-regulation is linked to their emotional school engagement.

Additionally, the coding of distraction strategies used by children with ASD in response to delayed reinforcement in the present study focused on the number of sessions in which language, gestures, or eye contact were initiated. Future research would be benefited from a more concrete coding of the level of language (e.g., the number of words), the types of gestures (e.g., descriptive or emotional), and the complex level of distraction strategies (e.g., if language is combined with gestures) used by children with ASD when reinforcement is delayed. That way, we can have a better understanding of the best strategy that we can teach children with ASD to use to respond to the delay of reinforcement.

Conclusion

Self-regulation has shown to be related to children's social-emotional development and school success. Delay in self-regulation development represents an area of major challenge for children with ASD. Findings in this study showed that, in terms of engagement and adaptive level at school, children with ASD with better self-regulation engaged in school activities to a greater extent, demonstrated better adaptive behavior at school, and were reported to have stronger social communication skills. The present study extended the literature by investigating an association between self-regulation and the dynamic academic learning process in young children with ASD. Findings in the present study suggested that children with ASD with better emotional control, attention, and inhibitory control achieved academic objectives in literacy faster, especially in the domains of word recognition and reading comprehension. Children with ASD with a better overall EF level learned math concepts and problem-solving skills faster in both trial-based and script-based curricula, and those with better working memory demonstrated a higher learning rate in the trial-based mathematics curriculum. Further analyses showed that the relationship between self-regulation and academic learning in children with ASD was influenced by their behavior school engagement and reward sensitivity. These results inform future interventions to focus on the school engagement behaviors and sensitivity to reward in children with ASD when developing their self-regulation and academic learning skills. Moreover, social-oriented strategies, such as language, gestures, and eye contact, helped children with ASD respond better to delayed reinforcement above and beyond their self-regulation level, and token reinforcer promoted better performance for this group of students in the natural classroom environment, especially for those with more severe ASD symptoms and poorer school engagement.

Overall, self-regulation emerged as a potential protective factor for young children with ASD in their school success in terms of engagement and adaptive level as well as rates of academic learning. Self-regulation development needs to be considered as an essential component in future academic and social-emotional interventions for children with ASD. Meanwhile, developing the ability to use language, gestures, or eye contact to communicate needs and emotions may help children with ASD during delayed reinforcement situations in the natural classroom environment. Considering the majority of children with ASD demonstrated altered reward sensitivity characterized by nonsocial stimuli hypersensitivity and social rewards hyposensitivity, it is important to enhance their responsiveness and sensitivity to social reinforcers to promote their school adjustment and success.

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Appendix A: IRB Approval

TEACHERS COLLEGE
COLUMBIA UNIVERSITY

Teachers College IRB	*Expedited Approval Notification*

To: Yanru Chen
From: Amy Camilleri
Subject: IRB Approval: 18-407 Protocol
Date: 07/10/2018

Please be informed that as of the date of this letter, the Institutional Review Board for the Protection of Human Subjects at Teachers College, Columbia University has given full approval to your study, entitled "*Learning in Preschoolers with Autism Spectrum Disorder: Individual Differences and Links to Executive Function, Effortful Control, Reward Sensitivity, and School Engagement*," under **Expedited Review** (Category **(7) Research on individual or group characteristics or behavior**) on 07/10/2018.

The approval is effective until **07/09/2019**.

The IRB Committee must be contacted if there are any changes to the protocol during this period. **Please note:** If you are planning to continue your study, a Continuing Review report must be submitted to either close the protocol or request permission to continue for another year. Please submit your report by **06/25/2019** so that the IRB has time to review and approve your report if you wish to continue your study. The IRB number assigned to your protocol is **18-407**. Feel free to contact the IRB Office (212-678-4105 or accamilleri@gmail.com) if you have any questions.

Please note that your Consent form bears an official IRB authorization stamp and is attached to this email. Copies of this form with the IRB stamp must be used for your research work. Further, all research recruitment materials must include the study's IRB-approved protocol number. You can retrieve a PDF copy of this approval letter as well as the stamped consent(s) and recruitment materials from the IRB Mentor site.

When your study ends, please visit the IRB Mentor site. Go to the Continuing Review tab and select "terminate" from the drop-down menu.

Best wishes for your research work.

Sincerely,
Amy Camilleri
IRB Administrator
accamilleri@gmail.com

Appendix B: Parent Informed Consent

Informed Consent

WRITTEN DESCRIPTION OF RESEARCH

Study Title: Learning in Preschoolers with Autism Spectrum Disorder: Individual Differences and Links to Executive Function, Effortful Control, Reward Sensitivity, and School Engagement

Name of the Principal Investigator: Yanru Chen

Name of Co-Investigator: Dr. Laudan Jahromi

Contact Name and Phone Number for Questions/ Problems:

Yanru Chen, 646-248-4666, yc3059@tc.columbia.edu

Dr. Laudan Jahromi, lbj2112@tc.columbia.edu

Dr. Lin Du, ldu@fredskeller.com

This is an educational research pilot study. This research study includes only participants who choose to take part. Please take your time to make your decisions. Discuss it with your friends and family. Your child is being asked to take part in this study because we as educators are interested in knowing how a child's self-regulatory skills affect his/her academic learning.

WHY IS THIS STUDY BEING DONE?

Children's cognitive and social development during early childhood has long-lasting impacts on their school success and psychosocial wellbeing. During the first five years of life, almost all children improve greatly in self-management and regulation capabilities. The ability to maintain attention, control for emotion, and solve problems may affect a child's learning at school. The purpose of this study is to examine how the challenges of self-management and regulation that are often found in children with autism affect their academic learning. Specifically, this study aims to investigate whether better self-regulatory skills, more sensitive to reward, and better school engagement will lead to faster learning of academic contents. This study can help to identify the key child characteristics that are affecting the academic learning process of young children, especially for those with autism.

HOW MANY PEOPLE WILL TAKE PART IN THE STUDY?

Two students as well as their classroom teachers and parents will participate in this pilot study. Participants will be from ages 3 to 5 attending the CABAS® preschool with a research diagnosis of autism.

WHAT IS INVOLVED IN THE STUDY?

Your child will be asked to complete one cognitive test and one diagnostic observational test. Your child's academic performance will be obtained from the school data. Particularly,
1) **The NIH Toolbox Early Childhood Cognition Battery**. It is a validated online instrument that implemented by an iPad to assess a child's cognitive abilities, including attention, memory, language, and executive function, which lasts around 20 minutes.
2) **The Autism Diagnostic Observation Schedule, Second Edition**. ADOS-2 is an autism diagnostic observational assessment, which contains 4 to 15 activities, including telling a story, playing with bubble, imaginative play with a doll, having a conversation with the examiner, and so on. This assessment aims to assess the child's social skills, language, and behavioral performance.
3) **The school data of four academic instruction** that are already parts of the student's programming at Keller, including Multiple Exemplar Instruction Number Skills, STEM Math Curriculum, Multiple Exemplar Instruction Letter Name & Sounds, "WH" Question or Reading A-Z Curriculum.

As parents, you will also be invited to complete one demographic questionnaire and three psychological scales regarding your child's self-regulatory abilities and reward sensitivity.
1) **A questionnaire** regarding the demographic information about your child and the family background will be sent to you via the Teachers College online survey tool.
2) **The Behavior Rating Inventory of Executive Function Preschool Version**. It is a parent-reported scale of a child's executive function skills, which takes around 10 minutes to complete.
3) **The Child Behavior Questionnaire-Short Form**. It is a parent-reported scale of a child's effortful control and behaviors, which takes around 10 minutes to complete.
4) **The Sensitivity to Reward Questionnaire for Children**. It is a parent-reported scale of a child's sensitivity to reward and punishment, which takes around 10 minutes to complete.

The classroom teacher of your child will be invited to complete three psychological scales regarding the school performance and engagement of your child too, which include:

1) **The Vineland Adaptive Behavior Scale, Third Edition**. It is a teacher-reported scale of a child's communication skills, daily living skills, socialization, motor skills, and maladaptive behaviors.

2) **Two subscales of the Teacher Rating Scale of School Adjustment- Cooperative Participation and Independent Participation**. They are the teacher-reported scales of a child's school engagement.

3) **The School Liking and Avoidance Questionnaire.** It is a teacher-reported questionnaire to examine a child's expressed desire to like or avoid school.

HOW LONG WILL I (MY CHILD) BE IN THE STUDY?

Your child will get involved in two tests. Particularly, the NIH Toolbox Early Childhood Cognition Battery takes around 20 minutes to comprehensively measure a child's cognitive abilities on an iPad. The ADOS-2 takes between 40 and 60 minutes to observe a child's behaviors in a series of play, imaginative use of materials, and communicative activities. Your child's academic performance will be obtained from the instructions that are currently conducting at school. No extra academic test will be conducted. So, your child will be in this study for around 60 to 80 minutes. For parents, the total time commitment for completing one demographic questionnaire and three parent-reported scales will be 40 minutes.

WHAT ARE THE RISKS OF THE STUDY?

There is no major risk to the participants in this study. Minimal risk may include fatigue or boredom, which are no greater than that of completing other school activities.

For more information about risks ask the researcher or contact

Yanru Chen, yc3059@tc.columbia.edu

Dr. Laudan Jahromi, lbj2112@tc.columbia.edu

Dr. Lin Du, ldu@fredskeller.com

ARE THERE BENEFITS TO TAKING PART IN THE STUDY?

There are no direct benefits to participants in this research. However, the findings of this study may provide essential information on the relation between self-regulatory abilities and the learning process of children with ASD, which can help to develop effective instructions to facilitate learning for this population in the future.

WHAT ABOUT CONFIDENTIALITY?

For the school records, we cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Organization that may inspect and/or copy your research records for quality assurance and data analysis include groups such as: The State Education Department and the Committee on Special Education.

However, I will use a coding system so that there is no identifying information in the data analysis and final report. Names will be removed for data analysis and write-up. Your child's demographic information will be collected through a survey designed by the principal investigator on TC Qualtrics, a survey tool of Teachers College, Columbia University, which is linked to the TC account belonging to the principal investigator and it is protected by a password. The identifiable consent forms will be kept in a separate, locked filing cabinet of the principal investigator. The NIH Toolbox Data will be stored in the co-investigator's lab computer at Teachers College, which is password-protected. The hard protocol data will be kept in a separate, locked location, and will only contain the participant's de-identified data.

WHAT ARE THE COSTS?

There are no additional costs to your child when participating in this study. You will receive no payment for taking part in the study.

WHAT ARE MY RIGHTS AS A PARTICIPANT?

Taking part in this study is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may choose not to take part, may leave the study at any time, or not answer research questions, which you consider inappropriate. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. We will tell you about any new information that may affect your welfare or willingness to stay in the study.

WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?

For questions about the study, contact the researcher(s),

Yanru Chen, yc3059@tc.columbia.edu

Dr. Laudan Jahromi, lbj2112@tc.columbia.edu

For questions about your rights as a research participant, contact the Fred S. Keller School Institutional Review Board at 914-965-1152, ext.227.

The Institutional Review Board of the Fred S. Keller School has determined that this research meets the criteria for human subjects according to Federal guidelines. You will get a copy of the approval letter.

CONSENT:

I have read or have had read to me the preceding information describing the study. All my questions have been answered to my satisfaction and this form is being signed voluntarily by me indicating my desire to participate in this study. I am not waving any of my legal rights by signing this form. I understand I will receive a copy of this consent form.

____

Printed Name of Child **Signature of Child** **Date**

PERMISSION:

I am the parent /legal guardian of______________________________and I voluntarily approve of his /her participation.

____

Printed Name of Parent Guardian **Signature of Parent/Guardian** **Date**

Appendix C: Teacher Informed Consent

Protocol Title: Learning in Preschoolers with Autism Spectrum Disorder: Individual Differences and Links to Executive Function, Effortful Control, Reward Sensitivity, and School Engagement

Principal Investigator: Yanru Chen, Ph.D. Candidate, Teachers College
646-248-4666, yc3059@tc.columbia.edu

INTRODUCTION

You are being invited to participate in this research study called "Learning in Preschoolers with Autism Spectrum Disorder: Individual Differences and Links to Executive Function, Effortful Control, Reward Sensitivity, and School Engagement." You may qualify to take part in this research study because your student is between 3 and 6 years old and has a diagnosis of autism spectrum disorder (ASD). Approximately twenty-five people will participate in this study and it will take 50 minutes of your time to complete.

WHY IS THIS STUDY BEING DONE?

This study is being done to determine how self-regulation, including executive function and effortful control, contributes to a child's learning progress in early childhood, especially for those with autism spectrum disorder (ASD) who demonstrate deficits in self-regulatory skills and to explore the child characteristics that potentially contribute to the relation between executive function or effortful control and academic learning, including ASD symptom severity, reward sensitivity and school engagement.

WHAT WILL I BE ASKED TO DO IF I AGREE TO TAKE PART IN THIS STUDY?

If you decide to participate, you will fill out three psychological scales regarding the school performance and engagement of your students who participate in this study, including the Vineland Adaptive Behavior Scale-Third Edition, two subscales of the Teacher Rating Scale of School Adjustment- Cooperative Participation and Independent Participation, and the School Liking and Avoidance Questionnaire. It will take about 50 minutes to complete all three psychological scales. You can complete these scales in your classroom at Fred S. Keller school at a time that is convenient to you.

WHAT POSSIBLE RISKS OR DISCOMFORTS CAN I EXPECT FROM TAKING PART IN THIS STUDY?

This is a minimal risk study, which means the harms or discomforts that you may experience are not greater than you would ordinarily encounter while completing other surveys. Potential risk includes fatigue. You can refuse to participate or stop participating in the study at any time without penalty.

The principal investigator is taking precautions to keep your information confidential and prevent anyone from discovering or guessing your identity, such as using a de-identified code that is randomly assigned to you instead of your name for data analysis and keeping all information on a password protected computer and locked in a file drawer. The master list will be kept locked and separated from the list of codes.

WHAT POSSIBLE BENEFITS CAN I EXPECT FROM TAKING PART IN THIS STUDY?

There is no direct benefit to you for participating in this study. Participation may provide critical information on understanding the effects of self-regulation on academic learning for students with ASD and therefore help teacher develop appropriate and effective intervention to facilitate the development of self-management skills and academic learning in applied school settings.

WILL I BE PAID FOR BEING IN THIS STUDY?
You will not be paid to participate. There are no costs to you for taking part in this study.

WHEN IS THE STUDY OVER? CAN I LEAVE THE STUDY BEFORE IT ENDS?
The study is over when you have completed the three psychological scales. However, you can leave the study at any time even if you haven't finished. Data will be kept for five years after the completion of the study.

PROTECTION OF YOUR CONFIDENTIALITY
The investigator will keep all written protocol data locked in a desk drawer in a locked office. Any electronic information for data analysis via computerized software will be stored on a computer that is password protected. You will be given a de-identified code that is randomly assigned to you for data analysis, and the master list will be kept locked and separated from the list of codes.

For quality assurance, the study team, the study sponsor (grant agency), and/or members of the Teachers College Institutional Review Board (IRB) may review the data collected from you as part of this study. Otherwise, all information obtained from your participation in this study will be held strictly confidential and will be disclosed only with your permission or as required by U.S. or State law.

HOW WILL THE RESULTS BE USED?
The results of this study will be used for the principle investigator's dissertation pilot study, published in journals and presented at academic conferences. Your identity will be removed from any data you provide before publication or use for educational purposes.

WHO MAY VIEW MY PARTICIPATION IN THIS STUDY

___I consent to allow written recorded materials viewed at an educational setting or at a conference outside of Teachers College

____
Signature

___I **do not** consent to allow written materials viewed outside of Teachers College Columbia University

____
Signature

WHO CAN ANSWER MY QUESTIONS ABOUT THIS STUDY?

If you have any questions about taking part in this research study, you should contact the principal investigator, Yanru Chen, at 646-248-4666 or at yc3059@tc.columbia.edu. You can also contact the faculty advisor, Dr. Laudan Jahromi at lbj2112@tc.columbia.edu.

If you have questions or concerns about your rights as a research subject, you should contact the Institutional Review Board (IRB) (the human research ethics committee) at 212-678-4105 or email IRB@tc.edu. Or you can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York, NY 1002. The IRB is the committee that oversees human research protection for Teachers College, Columbia University.

PARTICIPANT'S RIGHTS

- I have read and discussed the informed consent with the researcher. I have had ample opportunity to ask questions about the purposes, procedures, risks and benefits regarding this research study.
- I understand that my participation is voluntary. I may refuse to participate or withdraw participation at any time without penalty.
- The researcher may withdraw me from the research at his or her professional discretion if my student does not meet the inclusion criteria.
- If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue my participation, the investigator will provide this information to me.
- Any information derived from the research study that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.
- Identifiers will be removed from the data. De-identifiable data may be used for future research studies without additional informed consent from the subject
- I should receive a copy of the Informed Consent document.

My signature means that I agree to participate in this study

Print name: ______________________________________ **Date**: ________________________

Signature:
____

Appendix D: Demographic Questionnaire

Learning in Preschoolers with Autism Spectrum Disorder and Developmental Delay:
Individual Differences and Links to Executive Function, Effortful Control, Reward Sensitivity, and School Engagement

Dear Parent:

Thank you for your participation in this research study!

We are interested in understanding the association between self-regulatory capabilities and learning for preschoolers with autism and developmental delay. You will be presented with questions relevant to your child's demographic information. Please be assured that your responses will be kept completely confidential.

The study should take you around 10 minutes to complete. Your participation in this research is voluntary. You have the right to withdraw at any point during the study, for any reason, and without any prejudice. If you would like to contact the Principal Investigator in the study to discuss this research, please e-mail Yanru Chen (Phoebe) through yc3059@tc.columbia.edu. Thank you!

Q1. What is your relationship with the child with autism or developmental delay?

○ I am his/her mother

○ I am his/her father

○ I am his/her stepmother

○ I am his/her stepfather

○ I am his/her adoptive mother

○ I am his/her adoptive father

○ Others ______________________________

Q2. How old is your child?

____

Q3. How old are you?

____

Q4. What is your marital status?

- ○ Currently Married/ Committed Partnership
- ○ Widowed
- ○ Divorced
- ○ Separated
- ○ Never married/ partnered

Q5. Which of the following best represents **your child's** ethnicity? **Check all that apply.**

- ☐ Caucasian/ White
- ☐ Asian American/ Asian
- ☐ Hispanic, Latino or Spanish origin
- ☐ African American/ Black
- ☐ American Indian/ Alaska Native
- ☐ Native Hawaiian or other Pacific Islander

Q6. Were you born in the United States?

○ Yes (If yes, please skip Q6a and Q6b)

○ No

Q6a. If No, at what age did you move to the US?

____

Q6b. If No, what was your country of origin?

____

Q7. Can your child speak another language?

○ Yes

○ No (If no, please skip Q7a)

Q7a. If Yes, please indicate what another language your child speaks.

____

Q8. Does your child have any sibling?

○ Yes

○ No (If no, please skip Q8a and Q8b)

Q8a. If Yes, how many siblings does your child have?

____

Q8b. If Yes, how old are your child's siblings?

____

Q9. Do you have other children with any other developmental delay?

- ○ Yes
- ○ No (If no, please skip Q9a & Q9b)
- ○ Maybe

Q9a. If Yes, what kind of developmental delay do your other children have?

____

Q9b. If Yes, how old are the other children with developmental delay?

____

Q10. How many adults (aged 18 years and older) live in your household?

____

Q11. What is your home zip code?

____

Q12. What is your annual household income?

- ◯ Less than $10,000
- ◯ $10,000 to $14,999
- ◯ $15,000 to $24,999
- ◯ $25,000 to $34,999
- ◯ $35,000 to $49,999
- ◯ $50,000 to $74,999
- ◯ $75,000 to $99,999
- ◯ $100,000 to $ 149,999
- ◯ $150,000 to $199,999
- ◯ $200,000 or more

Q13. What is the highest educational level of your child's mother?

- ◯ Less than high school
- ◯ High school diploma
- ◯ GED or alternative credential
- ◯ Associate Degree (for example, AA, AS)
- ◯ Bachelor Degree (for example, BA, BS)
- ◯ Master Degree (for example, MA, MS, MBA)
- ◯ Professional Degree (for example, MD, DDS, DVM, JD)
- ◯ Doctorate Degree (for example, PhD, EdD)

Q14. Which of the following best describes your child's mother's current occupation?

- ○ Primary/ Secondary (K-12) Education
- ○ College, University, and Adult Education
- ○ Legal Services
- ○ Agriculture, Forestry, Fishing and Hunting
- ○ Computer, Software, Information Services, and Electronics Manufacturing
- ○ Real Estate, Rental and Leasing
- ○ Health Care
- ○ Hotel and Food Services
- ○ Construction, and Building Maintenance
- ○ Publishing
- ○ Telecommunications
- ○ Business, Finance, Banking and Insurance
- ○ Arts, Entertainment, Sports and Recreation
- ○ Government and Public Administration
- ○ Community and Social Service
- ○ Scientific, Engineering and Technical Services
- ○ Library
- ○ Retail and Sales
- ○ Transportation and Material Moving
- ○ Military
- ○ Religious
- ○ Retired

○ Unemployed

○ Others (please indicate) ______________________________

Q15. What is the highest educational level of your child's father?

- ◯ Less than high school
- ◯ High school diploma
- ◯ GED or alternative credential
- ◯ Associate Degree (for example, AA, AS)
- ◯ Bachelor Degree (for example, BA, BS)
- ◯ Master Degree (for example, MA, MS, MBA)
- ◯ Professional Degree (for example, MD, DDS, DVM, JD)
- ◯ Doctorate Degree (for example, PhD, EdD)

Q16. Which of the following best describes your child's father's current occupation?

- ◯ Primary/ Secondary (K-12) Education
- ◯ College, University, and Adult Education
- ◯ Legal Services
- ◯ Agriculture, Forestry, Fishing and Hunting
- ◯ Computer, Software, Information Services, and Electronics Manufacturing
- ◯ Real Estate, Rental and Leasing
- ◯ Health Care
- ◯ Hotel and Food Services
- ◯ Construction, and Building Maintenance
- ◯ Publishing
- ◯ Telecommunications
- ◯ Business, Finance, Banking and Insurance
- ◯ Arts, Entertainment, Sports and Recreation

○ Government and Public Administration

○ Community and Social Service

○ Scientific, Engineering and Technical Services

○ Library

○ Retail and Sales

○ Transportation and Material Moving

○ Military

○ Religious

○ Retired

○ Unemployed

○ Others (please indicate) ____