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Early Predictors of Executive Function Abilities in School-Aged Children with Autism Spectrum Disorders

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Executive Functions (EF) are a set of cognitive processes that direct and regulate behavior for the purpose of future goal attainment. These processes include working memory, inhibition, cognitive flexibility, planning, and fluency. Previous research has delineated impairments in individual processes of EF that may be related to the core social and communicative deficits typically found in children and adolescents with Autism Spectrum Disorders (ASDs). This line of research thus far has yielded mixed results, and further clarification is needed to determine if EF are directly related to clinical measures of ASD symptoms. Understanding the development of EF is critical, as measures of EF have been used to positively predict mathematical and reading ability, and academic and social functioning. While trajectories of EF development have been studied in typically developing children, few studies have examined predictors of EF in ASDs. Studies that have examined predictors of outcome in children with ASDs suggest that motor and language development may be important developmental markers of later functioning. The current study examined early predictors of EF and the concurrent development of EF and ASD symptoms in a sample of adolescents with High Functioning Autism (n = 22). Participants were evaluated at three time points with developmental data collected at the approximate ages of 2 (Time 1) and 4 (Time 2) and measures of EF and ASD symptoms collected at age 9 (Time 3). EF measures collected

at Time 3 included performance based measures and parent report of EF. Consistent with previous literature, largest impairments in EF were found on tasks of cognitive flexibility, planning, and simple memory and attention. There was very little overlap between parent report of EF at home and lab based measures of analogous processes. Tests of EF were inversely related to ASD symptoms and adaptive functioning. Lastly, in examining developmental precursors of EF, the current study found that motor functioning at Time 1 positively predicted performance across multiple tasks of EF.

Early Predictors of Executive Function Abilities in School-Aged Children with Autism Spectrum Disorders

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APPROVAL PAGE

Doctor of Philosophy Dissertation

Early Predictors of Executive Function Abilities in School-Aged Children with Autism Spectrum Disorders

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Introduction

Autism Spectrum Disorders (ASDs) are characterized by common behavioral deficits viewed across three domains: social relatedness, communication, and restricted interests or repetitive behaviors (RSB). ASD is an umbrella term that includes the diagnoses of Autistic Disorder, Asperger's Disorder, and Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS). ASDs are highly prevalent, with the Centers for Disease Control and Prevention estimating that 1 in 88 children are afflicted with the disorder (CDC, 2012).

Currently, a single known cause for autism has yet to be identified, although several models have been suggested to explain the pattern of behavioral deficits typically seen in the disorder. One such model, the executive dysfunction hypothesis, proposes that deficits in executive functions underlie the core social, communicative, and repetitive behavior deficits seen in individuals with autism (Turner, 1999; Hughes, 1993; Ozonoff, 1991; Rogers 1991). Executive function (EF) is a term used to describe a variety of cognitive processes that are under a supervisory control mechanism (Baddeley, 1988) and which direct and regulate behavior for the purpose of future goal attainment (Welsh & Pennington, 1988). These processes often include planning, organization, inhibition, cognitive flexibility, and working memory (Rogers & Bennetto, 2000; Welsh, Pennington, & Groisser, 1991). Rogers and Pennington (1991) theorized that EF may enable an individual to form and coordinate representations of the self and others in order to guide behaviors, and that these abilities would affect imitation, sharing of emotions,

and joint attention. The researchers went on to propose that EFs associated with the prefrontal cortex may have a central role in the pathogenesis of autism, given that the core social deficits in autism often include difficulties with emotional reciprocity, imitation, and joint attention.

Executive function in typically developing children has been well studied. The overall system of executive function is thought to develop as a multi-stage process where each individual element develops along its own trajectory. The first phase begins in infancy and marks the emergence of basic executive function skills, such as the ability to inhibit specific behaviors and shift to a new response set. These skills then undergo a second phase of maturation during childhood, where the greatest improvements in planning, fluency, problem-solving ability, and inhibition of perseveration emerge (Romine & Reynolds, 2005). The third phase occurs in adolescence when executive function skills become fully functional (Anderson, 2002; Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Dennis et al., 1999; Romine & Reynolds, 2005). While the extended developmental trajectory of executive function means that this set of capacities is highly vulnerable to insult over an extended time period, it also may mean that executive function is amenable to intervention for an extended time (Garon, Bryson, & Smith, 2008). In the literature on typical development, performance on executive function tasks is somewhat independent of intelligence (Espy, Kaufmann, & Glisky, 2001; Levin, Culhane, Hartmann, & Evankovich, 1991; Welsh et al., 1991), with only minor differences based on gender (Anderson et al., 2001; Espy et al., 2001; Levin et al., 1991; Pentland, Todd, & Anderson, 1998; Welsh et al., 1991).

Since executive function is not a unitary construct (Bishop & Norbury, 2005; Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004) and there is variation in task performance based on the clinical population (e.g., ASD, ADHD, Tourette's Syndrome) (Ozonoff & Jensen, 1999b), previous work in this area has focused on delineating the specific executive function deficits in children with ASDs, across the areas of inhibition, cognitive flexibility, planning, and working memory (Eigsti, 2011; Hill, 2004; Kenworthy, Yerys, Anthony, & Wallace, 2008; Mullen, 1995). Researchers have also begun to explore the relationship between performance on tasks of executive function and the social-communicative deficits typically viewed in individuals with ASDs, and the importance of these functions in typical and atypical development.

Attempting to demarcate the components of executive control within a laboratory setting can lead to methodological complications. Tasks that only measure one aspect of executive control tend to be highly controlled and simplistic when compared to the everyday demands on the executive systems. These laboratory studies are useful for disentangling specific cognitive processes of executive dysfunctions in ASD, but with the trade-off of losing ecological validity. As a result, researchers have relied on self, parent and teacher report to measure everyday tasks of executive function, using tools such as the Behavior Rating Inventory of Executive Function (BRIEF, Gioia, Isquith, Retzlaff, & Espy, 2002). Results from these measures yield deficits not typically measured in highly controlled laboratory tests, but that are consistent with clinical observations of individuals with ASD (Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Kenworthy, et al., 2008) and with independent measures of occupational functioning (Barkley & Fischer, 2011). Unfortunately, by approximating tasks from everyday activities, these measures often

assess multiple components of executive functions, thereby confounding their ability to measure domain specific dysfunctions (for review see Kenworthy, et al., 2008). As a result, the current study included both laboratory measures of EF and parent report on the BRIEF to assess the differing roles these measures may play in studying the development of EF in children with ASDs.

Executive Function in Autism Spectrum Disorders

Inhibition

Inhibition, or the ability to suppress a response, was originally thought to be largely intact in individuals with ASDs (Brian, Tipper, Weaver, & Bryson, 2003; Eskes, Bryson, & McCormick, 1990; Ozonoff, Strayer, McMahon, & Filloux, 1994). However, it has since been demonstrated that deficits in inhibiting prepotent responses exist, and have been found across a variety of tasks, including antisaccade tasks (Agam, Joseph, Barton, & Manoach, 2010; Luna, Doll, Hegedus, Minshew, & Sweeney, 2007), a motor inhibitory response task (Joseph, McGrath, & Tager-Flusberg, 2005), and a computer-based go/no-go tasks (Christ, Holt, White, & Green, 2007; Geurts et al., 2004). The Stroop Test is a class test of inhibition, where participants have to read the color that words are printed in while ignoring the color word itself (e.g., red, blue). Performance on the card version of this task has been found to not differ significantly between children and adolescents with ASD and a control group (Ozonoff & Jensen, 1999b). However, when administered a computerized version of the Stroop Test, children with high functioning autism (HFA), when compared to age and verbally matched typically developing children correctly inhibited significantly fewer incongruent items (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009) and had slower reaction times. Overall,

deficits in inhibiting prepotent responses have been shown across a variety of tasks, including computer-administered tests, which are more sensitive to subtle differences in task performance, such as differences in the participants' reaction times.

Cognitive Flexibility

Cognitive flexibility, also known as set-shifting, is the ability to change a thought or strategy based on the environmental situation. Both adults and children with ASDs consistently display highly perseverative responses on tasks such as the Wisconsin Card Sort Task (WCST) (Bennetto, Pennington, & Rogers, 1996; Heaton, Chelune, Talley, Kay, & Curtiss, 1993; Ozonoff & Jensen, 1999a; Rumsey, 1985; Rumsey & Hamburger, 1988, 1990). On the WCST, participants are given a set of cards and told to match them. They are not given instructions of how to do so, but they are given feedback as to whether they have matched correctly or incorrectly. As a result, the participant has to change strategies for matching the cards based upon the examiner's feedback. It has been suggested that performance on this task in individuals with ASD may be confounded with the participant's intellectual level and the social-motivation deficits that exist in individuals with ASDs while interacting with test administrators (Liss et al., 2001; Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998; Rumsey, 1985). In particular, Ozonoff (1995) found that while children with ASDs had significantly more perseverative errors on the traditional WCST when compared to a control group, these differences were attenuated when given the computerized version of the WCST. Furthermore, there was low to moderate reliability across the two measures in children with ASD and in typically developing children. In contrast, several studies utilizing the computerized version of the WCST have found that children and adolescents with ASDs

continue to display more loss of set errors (Kaland, Smith, & Mortensen, 2008), fewer conceptual responses, and more perseverative and loss-of-set errors (Shu, Lung, Tien, & Chen, 2001). These results suggest that deficits in cognitive flexibility on the WCST may still exist in individuals with ASDs, even while controlling for the social-motivational deficits typically viewed in these individuals.

Perseverative errors have been shown on other tasks as well, including a language task (Waterhouse & Fein, 1982) and the extra-dimensional shift task of the Cambridge Neuropsychological Test Automated Battery (CANTAB) (Hughes, Russell, & Robbins, 1994; Ozonoff et al., 2004). On the NEPSY-II, Children with ASDs showed impairments on the Animal Sorting subtest, a task of concept formation that requires participants to shift set between categories (Korkman, Kirk, & Kemp, 2007). In addition, parents of children with ASDs rate their child as having greater difficulties shifting attention during everyday tasks of executive function when compared to typically-developing controls (Gioia, Isquith, Kenworthy, & Barton, 2002, Zandt, Prior, & Kyrios, 2009). Thus, the overall pattern of findings indicate that children and adults with ASDs have difficulty shifting between concepts and that they tend to have more perserverative errors on tasks of cognitive flexibility.

Planning

Joseph and colleagues (2005) administered the Tower test from the NEPSY-II to school-aged children with ASDs and non-autistic participants who were matched on age and on verbal and nonverbal IQ. On the Tower test, participants had to execute a sequence of moves in order to obtain a final goal. How well a participant performed on the task depended upon how successfully the individual planned the initial sequence. In

the study, the researchers found that children with autism performed significantly worse on the Tower test when compared to the control group, and that language ability was not directly related to performance in the ASD group. Furthermore, research has suggested that these impairments in planning are consistent across development (Pellicano, 2010). Impairments in planning on the tower test have been found both when an examiner administers the tests, using variations such as the Tower of London and Tower of Hanoi (Bennetto et al., 1996; Geurts et al., 2004; Joseph et al., 2005; Ozonoff & Jensen, 1999b; Ozonoff & McEvoy, 1994; Pellicano, Maybery, Durkin, & Maley, 2006; Verte, Geurts, Roeyers, Oosterlaan, & Sergeant, 2005) and with analogous computer-based tests, such as the Stockings of Cambridge. However, for the Stockings of Cambridge test, these impairments existed only during "hard" and not "easy" trials (Hughes et al., 1994). Hughes and colleagues (1994) concluded that the simple tests of planning might not suffice in measuring the planning deficits seen clinically in these individuals. Her findings, however, have failed to be replicated with similar samples of children with high functioning autism on the Stockings of Cambridge test (Goldberg et al., 2005; Happé & Frith, 2006; Landa & Goldberg, 2005; Ozonoff et al., 2004; Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008). Thus, mixed results across studies may be due to variation in the difficulty level of the various assessments of planning, with most studies indicating deficits on Tower tests in children with HFA. On the BRIEF, parents of children with ASDs report significantly more difficulties on the Plan/Organize scale when compared to typically developing controls, but not when compared to other clinical groups (e.g., ADHD, TBI) (Gioia, Isquith, Kenworthy, & Barton, 2002).

Working Memory

Unlike several of the other cognitive processes involved in executive functioning, robust findings for working memory deficits in individuals with ASD have been found. Impairments have been shown to occur on a variety of spatial working memory tasks, such as block span backwards (Joseph et al., 2005), an oculomotor delayed response task (Luna et al., 2007), a computerized test from the CANTAB (Goldberg et al., 2005; Landa & Goldberg, 2005), and other behavioral measures of spatial working memory (Sinzig et al., 2008; Verte et al., 2005; Williams, Goldstein, Carpenter, & Minshew, 2005).

However, when examining performance on tasks of verbal working memory, the majority of research has failed to find group differences when comparing performance between children and adults with ASDs and typically developing controls (Koshino et al., 2005; Lopez, Lincoln, Ozonoff, & Lai, 2005; Nakahachi et al., 2006; Williams et al., 2005; Williams, Goldstein, & Minshew, 2006). Lopez and colleagues (2005) administered the Wechsler Adult Intelligence Scale – III (Wechsler, 1997) to adults with autism and typically developing controls. They found no significant group differences on the Working Memory Index or on the letter-number sequencing subtest. Williams and colleagues (2005) administered a verbal n-back test and a letter-number sequencing test to school-aged children with ASDs and a control group matched on age and on verbal and nonverbal IQ. Findings suggested that there were no significant group differences on either task of verbal working memory. In contrast, Schuh & Eigsti (2012) found that adolescents and teens with HFA performed significantly worse than a control group matched on age, IQ, and language, when given tests of spatial, simple phonological verbal, and complex verbal working memory tests. Taken together, these studies suggest that in general working memory deficits, especially those involving spatial memory, are

pervasive in children and adults with ASDs and are likely to have a significant impact on daily functioning.

Overall there is accumulating evidence that deficits in executive functioning exist in adolescents and adults with ASDs. In particular, difficulties in inhibiting prepotent responses, set shifting, and working memory, appear to be areas of specific executive dysfunction. However, more research is needed to determine how these difficulties develop in individuals with ASDs and how executive deficits may relate to the core social deficits usually viewed in these individuals.

Relationship of Executive Function to Symptoms of ASDs

In order to further explore the executive dysfunction hypothesis in children with ASDs, researchers have studied a possible association between the development of executive functions and the social symptoms associated with ASDs. Joseph and Tager-Flusberg (2004) were one of the first researchers to explore a direct association between performance on tasks of executive function (working memory, inhibitory control, and planning) and performance on a clinical measure of ASD symptoms, the Autism Diagnostic Observation Schedule (ADOS) (Lord et al., 2000). The study found that planning ability was inversely related to communication symptoms in school-aged children with ASDs, but that there were no significant relationships between other executive functions and social deficits or between executive functions and severity of repetitive behaviors, when controlling for language abilities in the children. Ozonoff and colleagues (2004) also failed to find an association between executive function and social deficits in children with ASDs.

In contrast, Kenworthy and colleagues (2009) used multiple regression analyses to explore the relationship between executive abilities and ASDs symptoms, while controlling for the age of the participants. Results yielded an inverse association between semantic fluency and social deficits, as well as between auditory divided attention abilities and social deficits. However, there were several important methodological differences among these three studies. Kenworthy and colleagues used an aggregate score from the Autism Diagnostic Interview (ADI or ADI-R) and the ADOS to measure communication, social, and repetitive behavior symptoms, whereas Ozonoff and colleagues examined the ADI and ADOS independently and Joseph and colleagues only used the ADOS. In addition, there was very little overlap in the tests of EF, which included different subtests of the NEPSY, BRIEF, and CANTAB.

When examining communication and repetitive behavior symptoms, Bishop and Norbury (2005) and Kenworthy and colleagues (2009), showed that semantic fluency was associated with fewer communication symptoms. Furthermore, scores on the Behavior Regulation Index (BRI) of the BRIEF, a parent report measure of executive functioning, predicted the presence of restricted and repetitive behaviors in children with ASDs. There were no significant relationships between examiner administered tests of EF and symptoms of RRB on the ADI or ADOS, while controlling for the age of the participants, or between computer administered tests of EF and symptoms of RRB (Kenworthy, Black, Harrison, Rosa, & Wallace, 2009; Ozonoff et al., 2004). While more research is needed to replicate the findings that core deficits of ASDs are related to some measures of EF. Kenworthy and colleagues (2009) did report an association between EF and social

deficits and EF and communication deficits in children with ASDs, when using aggregate scores from the ADOS and ADI.

Development of Executive Function

A third important area of the existing literature has begun to explore how deficits in executive function develop and are maintained during childhood. This area of research is critical, as measures of executive function in typically developing children predict later mathematical ability (Blair & Razza, 2007; Bull & Scerif, 2001; St Clair-Thompson & Gathercole, 2006), reading ability (Protopapas, Archonti, & Skaloumbakas, 2007; van der Schoot, Licht, Horsley, & Sergeant, 2000) and overall academic functioning (Riggs, Blair, & Greenberg, 2003). Executive function has also been implicated in the development of social functioning and emotional control in typically developing children (Eigsti et al., 2006; Friedman et al., 2007; Gonzalez, Fuentes, Carranza, & Estevez, 2001; Rothbart, Ahadi, Hershey, & Fisher, 2001; Simonds, Kieras, Rueda, & Rothbart, 2007). Cole and colleagues (1993) conducted a longitudinal study in which executive function skills in typically developing preschoolers predicted later emotional-behavioral control at age 5, further confirming the importance of early executive function abilities in social development.

While there appears to be a relationship among executive abilities, academic functioning, and social-emotional skills in typically developing children, few studies have examined the factors in early childhood that are necessary for, or predict, the maturation of executive abilities in later childhood and adolescence. One line of research has found that early motor skill acquisition is directly related to the ability to use cognitive categorizations in adulthood (Murray et al., 2006) and furthermore predicted cognitive

dysfunction in a sample of adults with schizophrenia. Early motor and language skills also predicted verbal fluency in typical adults (Murray, Jones, Kuh, & Richards, 2007). In children ages 7-14, teacher-reported attentional problems predicted later levels of response inhibition and working memory in late adolescence (Friedman et al., 2007).

Similar predictors of executive abilities in children with ASD have yet to be examined; however, the role of early motor and language development in later outcomes has been explored. Rutter (1970) found that the attainment of language skills by age 5-6 discriminated higher versus lower functioning individuals with ASD. In a more recent study, Mayo and colleagues (2013) found that the attainment of first words by 24 months was a salient marker of prognosis in children with ASDs. In the study, children with first words at 24 months tended to score significantly higher on a measure of cognitive development, language, and adaptive functioning at 52 months when compared to children without first words. Luyster et al. (2007) found that receptive and expressive language skills at age 2 and 3 significantly predicted verbal and nonverbal IQ, language ability, and ASD symptoms at age 9 in a sample of children with ASDs (Luyster, Qiu, Lopez, & Lord, 2007, Helt et al., 2008). Furthermore, when comparing a sample of 2-year-old children with ASD who went on to no longer qualify for the diagnosis at age 4 to those children who retained their ASD diagnosis, motor skills at age 2 was able to significantly distinguish the two groups (Sutera et al., 2007). It is important to continue studying predictors of outcome, because it allows clinicians to suggest areas to target for early intervention and helps service providers to better understanding the prognosis of children diagnosed with an ASD.

While predictors of EF in children with ASDs have yet to be explored, there are two related lines of study, which may inform future research. These areas include examining the relationship between early EF skills and ASD symptoms in preschool-aged children and how early EF skills in young childhood can predict the development of later social skills. McEvoy and colleagues (1993) presented preschool children with ASDs, developmental delays, and typically developing children with multiple tests of executive function and social communication skills. Consistent with the adult literature, preschool-aged children with ASDs exhibited more perseverative responses on the tests of executive function, while also displaying fewer instances of joint attention and social interaction behaviors. When comparing associations between measures, there was a significant relationship between executive function abilities and the two measures of social communication skills, independent of group membership and verbal ability (McEvoy, Rogers, & Pennington, 1993). The discovery of a relationship between the severity of executive dysfunction and an impairment in social skills, independent of diagnosis, has since been replicated (Griffith, Pennington, Wehner, & Rogers, 1999), but in the absence of significant group differences on tasks of executive function.

Dawson and colleagues (2002) found that prefrontal tasks of executive function that are related to the ventromedial area, and not the dorsolateral area, are strongly correlated with measures of joint attention. Furthermore, these results held true across diagnosis and intellectual level in a group of preschool children (Dawson, et al., 2002). These studies contribute to the literature by suggesting that measures of executive function used with preschool children are directly related to early social skills attainment, including joint attention.

Theory of Mind (TOM), or the ability to attribute mental states, intentions, or desires to others, is often used as a proxy for social abilities and has been thoroughly studied in children with ASDs. In typically developing preschool children, measures of TOM have been related to performance on measures of inhibitory control, attentional flexibility, and tests of deceit (Carlson & Moses, 2001; Hughes, 1998; Hughes, Dunn, & White, 1998). A longitudinal study found that executive function abilities at age 2 facilitated performance on tasks of TOM at age 4, when controlling for verbal ability (Hughes & Ensor, 2007). In young children (age 5) with ASDs, performance on tasks of planning, set-shifting, and inhibition were predictive of TOM performance, independent of age and ability level. This conclusion helps support the identification of executive function as an important factor in the development of TOM, even within this young population (Pellicano, 2007). In a longitudinal study, executive function skills were predictive of change in children's TOM abilities independent of age, language, nonverbal intelligence, and early TOM skills (Pellicano, 2010b). All together, these studies suggest that executive function abilities are crucial to the development of appropriate TOM skills in young children with or without autism.

Studies examining the relationship between executive functions and different areas of social development have yielded a robust finding; that a clear association exists among measures of TOM, joint attention, emotional control, and executive function abilities in young children. Furthermore, EF may be a positive predictor of performance on certain tasks of social skills across early development. However, it is unclear what role early developmental factors, such as language, motor skills, or ASD symptoms, may play in the development and maintenance of EF in adolescents with ASDs.

The current study aimed to extend the literature on typical precursors of executive functioning by examining executive functioning abilities and potential developmental precursors across time in a sample of children with High Functioning Autism (HFA), as well as by further exploring the association between concurrent executive functioning and ASD symptoms. Based on previous literature, we expected our participants to display greatest level of executive dysfunction on tasks of planning and working memory, with less impairment on tasks of inhibition and cognitive flexibility. In order to further explore the executive dysfunction hypothesis of autism, we examined the relationship between performance on tasks of executive function and the social deficits typically viewed in children with ASDs. To measure social impairment, we not only used behavioral measures (ADOS), but also parent report (Social Responsiveness Scale), and graduate student clinician's judgment (Childhood Autism Rating Scale). Lastly, to explore the development of executive abilities in children with ASDs, we examined early predictors of executive abilities by utilizing developmental data collected from the participants at the approximate ages of 2 and 4 to predict executive abilities at age 8-10. We hypothesized that motor and language abilities at age 2 and 4 would be the strongest predictors of executive ability at school age.

Methods

Participants

Participants were a subset of a sample from a larger federally funded project at the University of Connecticut. The goals of the original study focused on creating and validating the Modified Checklist for Autism in Toddlers (Robins et al., 2001), a population-based screening instrument used to detect ASDs in young children.

Participants screened positive on the M-CHAT between the ages of 16 and 30 months and received a developmental and diagnostic evaluation at the approximate ages of 2 and 4. In order to have a well-characterized sample of children with an ASD, participants were deemed eligible for the current study if they received a diagnosis of either Autistic Disorder, Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS), or Asperger's Disorder at both evaluations. They were then invited back for a follow-up evaluation in middle childhood. Due to the goals of the original M-CHAT study, there was no available control group of typically-developing children, a limitation of the current study. As a result, the findings in the current study investigated the development of executive function over time within children with ASDs and any relevant findings may not necessarily be specific to these disorders. In the current study, only participants who were between the ages of 8 years, 0-months, and 10 years, 11-months were included. Exclusion criteria included sensory impairments (e.g., blindness) or severe deficits in motor functioning (e.g., severe cerebral palsy) that would prohibit the participant's ability to complete the testing. Participants and their families were recruited by telephone or by letter.

One hundred and three participants from the original M-CHAT study were deemed eligible for the current study. Of those participants, 49 were contacted and given the opportunity to participate in the current study (47.6%), the remainder were unable to be contacted by phone or by mail. Of the 49 families, 1 moved (1%), 7 refused to participate (6.8%), and 41 were evaluated (39.8%) (Table 1). Analyses were performed to explore for differential attrition between the children who participated in the current study and those who were unable to be contacted. Analyses of variance revealed no

significant group differences on gender, ethnicity, cognitive functioning, adaptive skills, or ASD symptom severity between the two groups at the Time 1 and Time 2 evaluations. During the Time 3 evaluation, a measure of each child's cognitive ability was given. If a child received a score of 70 or greater on the Special Nonverbal Composite on the Differential Abilities Scale, Second Edition (DAS-II), they were administered tasks of executive function. By using a nonverbal intelligence score cut-off of 70, the examiner was able to create a well-characterized sample of children with high functioning autism (HFA) who were able to complete most measures of EF and also minimized task frustration for the participants.

The final sample contained 22 children with HFA, 18 males and 4 females. Parents self-identified their child's race as White (n = 20), Black (n = 1), or Asian/Pacific Islander (n = 1). During the initial evaluation (Time 1), 17 participants were diagnosed with Autistic Disorder (AD) and 5 participants were diagnosed with PDD-NOS. Mean age of evaluation was 27 months (SD = 3.3). During the follow-up evaluation (Time 2), 15 participants were diagnosed with AD and 7 participants were diagnosed with PDD-NOS. The mean chronological age at the time of the re-evaluation was 54 months (SD = 11.2). At the Time 3 evaluation, the mean chronological age was 118.8 months (SD = 10.0) or 9-years, 9-months (Table 2).

Procedures

Caregivers were given the M-CHAT to complete at their pediatrician's office during their child's 18 or 24-month well-child visit, or by their Early Intervention service provider. Participants were screened between the ages of 16 and 30 months. The screeners were then mailed to the University of Connecticut where they were scored. For

screen positives, the child's caregiver received a follow-up phone interview to confirm the failed items on the screener. Children who continued to screen positive after the telephone interview were invited to the University of Connecticut to receive a free developmental and diagnostic evaluation.

The evaluations occurred at the Psychological Services Clinic at the University of Connecticut. Initial evaluations (Time 1) occurred when the children were between the ages of 17 and 37 months and all participants were then invited back for a second evaluation (Time 2) when the children were between the ages of 41 and 69 months. Participants who did not have transportation were provided with a free taxi service. A team of clinicians, consisting of one licensed psychologist or developmental pediatrician, and one clinical psychology doctoral student, completed the evaluations. Each assessment lasted approximately three hours, and included a feedback session where the results were reviewed with the child's caregiver.

During the assessments (Time 1 and 2), each child received a measure of his or her cognitive abilities, adaptive functioning, and ASD symptom severity (Table 3). Measures were determined based on the child's age and developmental level. Diagnoses of the participants were determined based on the results of behavioral measures, parental report, and the observations of an experienced clinical psychologist or developmental pediatrician. Diagnoses were assigned based on DSM-IV criteria (American Psychiatric Association Task Force on DSM-IV., 2000).

Children who were diagnosed with an ASD at both evaluations (Time 1 and 2) and who were between the ages of 8-years, 0-months and 10-years, 11-months (Time 3) were recruited for the current study by letter or via the telephone. The participants were

offered a free evaluation that was completed by two clinical psychology graduate students who were supervised by a licensed psychologist. The evaluation and parent interview were video recorded. The evaluations lasted up to 4 hours depending on the child's abilities. Measures were selected according to the child's developmental level. A full battery typically consisted of a measure of cognitive ability, adaptive behaviors, executive functioning, ASD symptoms, and academic, behavioral, and psychiatric functioning. For this study, measures of cognitive ability, executive functioning, and ASD symptoms were used (Table 3).

Measures

Cognitive

The *Mullen Scales of Early Learning* (Mullen, 1995) is a developmental assessment of cognitive, motor, and language abilities. The measure consists of five scales including, gross motor, visual reception, fine motor, and both expressive and receptive language. The current study used visual receptive, fine motor, and language to measure a child's developmental abilities at Time 1 and Time 2. Only standard scores based on a child's chronological age were used.

The *Differential Abilities Scales-II* (Elliott, 2005) measures cognitive ability in children between the ages of 2-years, 6-months and 17-years, 11-months. The test utilizes several diagnostic subtests that measure verbal and visual working memory, visual-perceptual abilities, nonverbal reasoning, processing speed, and naming ability. The average reliability coefficients for the School-Age subtests range from .74 to .96 (Marshall, McGoey, & Moschos, 2011). This measure was collected at Time 3. Participants had to receive a Special Nonverbal Composite score equal to or greater than

70 to be included in the current study. The participant's Verbal standard score was also used to characterize the sample.

Adaptive Behaviors

The *Vineland Adaptive Behavior Scales: Interview Edition Survey Form, VABS* (Sparrow, Balla, & Cicchetti, 1984) is a parent interview survey that assesses adaptive functioning in the areas of socialization, communication, daily living, and motor skills. Each item is scored from 0-2, with a 0 indicating that the child does not perform the particular behavior, 1 meaning that the child sometimes performs the behavior, and 2 indicating that the child performs the behavior on a regular basis. Interrater reliability ranged from .62 to .78 across the four domains. Standard scores across the domains of Socialization, Communication, and Daily Living, as well as, the Adaptive Behavior Composite score were collected at all three evaluations (Time 1, 2, & 3).

ASD Symptoms

The *Autism Diagnostic Observation Schedule - Generic, ADOS* (Lord et al., 2000) is a semi-structured assessment designed to measure potential ASDs. Only behaviors viewed during test administration are scored on this measure. The ADOS-G includes four modules, one of which is administered depending on the child's expressive language level and chronological age. The current study used modules one and two during the initial evaluations (Time 1 and 2), and modules two or three during the school-age evaluation (Time 3). On this measure, exceeding cut-off scores in the following domains dictated diagnostic classifications: social, communication, combined social and communication, and restricted repetitive behaviors. The inter-rater reliability is considered good across all domains: social (.93), communication (.84), social

communication (.92), and restricted repetitive behaviors (.82). The cut-off scores were used to classify each child as having an Autistic Disorder, ASDs, or not having an ASD. Cut-off scores from the modules were converted to severity scores based on previous literature (Gotham, Pickles, & Lord 2009). This allowed the examiner to compare severity ratings across the different modules within each time point.

The *Social Responsiveness Scale* (Constantino, 2002) is a 65-item scale that measures the severity of autism spectrum symptoms. Parents complete the form based upon their own behavioral observation of their child. It is appropriate for use with children from 4-18 years of age. The tool assesses the child's social awareness, social information processing, capacity for reciprocal social communication, social anxiety or avoidance, and autistic preoccupations. Inter-rater reliability ranges from .75 to .91.

The *Childhood Autism Rating Scale* (Schopler et al., 1980) is a behavior rating scale that consists of 15 subscales for rating aspects of autistic behavior. The scale is based on a clinician's direct observation of the child and parent report of behaviors. The scale yields a numerical score of ASD symptom severity. The score can be used to label a child's symptoms as non-autistic, mild, moderate, and severe. Inter-rater reliability is .71 and internal consistency is .94.

Executive Function

The *NEPSY-II* (Korkman, 1988) assesses neuropsychological development in children from age 3-16. The battery measures ability across six functional domains: attention and executive functions, language, sensorimotor functions, visual-spatial abilities, learning and memory, and social perception. Four subtests were used in the current study. The Animal Sorting subtest is a measure of cognitive flexibility that asks

the child to sort cards into two categories using varying self-initiated sorting criteria and to shift set from one criterion to another. The Inhibition subtest measures the individual's ability to inhibit automatic and learned responses. The Tower subtest measures planning and it requires a child to move three colored balls to a target position on three pegs in a designated number of moves while following rules presented by the evaluator. The Word Generation subtest is a measure of verbal fluency and requires the child to generate a verbal list of words that begin with a particular letter or that are part of a semantic category. Inter-rater reliability ranges from .93 to .99 across the subtests.

The *Wisconsin Card Sorting Test, WCST* (Heaton, 1981) is a computer administered test that requires abstract reasoning skills and for the child to shift cognitive strategies in response to environmental changes. The test uses a series of cards that the child has to sort based on a number of different principles (e.g., color, form, number). The test measures the child's ability to shift and maintain set, planning, attention, working memory, visual processing, and moderating previously-reinforced responses. The standard score of the participant's perseverative errors was used in the current study as a measure of cognitive flexibility. Inter-rater reliability ranges from .91 to .96.

Select subtests from the *Differential Abilities Scales-II* (Elliott, 2005) were also used to measure basic attention, memory, and working memory. The Digits Forward subtest requires participants to repeat a series of numbers directly upon hearing them. Digits Backward requires participants to repeat the series but in the reverse order of which they heard them. Standard scores from both of these subtests were collected at Time 3. The average reliability coefficients for the School-Age subtests range from .74 to .96 (Marshall, McGoey, & Moschos, 2011).

The *Behavior Rating Inventory of Executive Function, BRIEF* (Gioia, Isquith, Kenworthy, & Barton, 2002) is a parent-report scale that assesses executive function abilities in the home and school environments, and it was collected during time 3. This measure is designed for parents and teachers of children between the ages of 5 and 18 years and consists of 86 items that are grouped into eight clinical scales: Emotional Control, Inhibit, Initiate, Monitor, Organization of Material, Plan/Organize, Shift and Working Memory. These scales comprise three index scores: Behavioral Regulation Index, Metacognitive Index and the Global Executive Composite. T-scores from each of the indices were used. Scores above 65 represent clinically significant deficits. Test-retest reliability was measured over a period of three weeks and the correlation coefficients generally fell above .80 for most scales and index scores.

Data Analytic Plan

All data were analyzed for possible outliers and to determine if the assumptions of each statistical test were violated. Descriptive statistics were used to characterize group means and standard deviations for each executive function variable (Time 3). Executive function data collected from children with ASDs during the school-age evaluation (Time 3) were then examined for possible deficits in functioning across tasks of working memory, inhibition, cognitive flexibility, fluency and planning. Performance on tasks of executive function were analyzed as standard scores with a clinical cut-off of 1.5 standard deviations from the mean to indicate a deficit in performance, so that the percentage of the ASD group who were deficient in each function could be characterized.

Analyses with Pearson correlations were then used to measure the relationship between task performance on individual measures of executive function and ASD

symptoms (Time 3). Measures of ASD impairments included a behavioral task (ADOS), parent report (Social Responsiveness Scale), and clinician's judgment (Childhood Autism Rating Scale). To determine possible confounding variables, bivariate correlations were performed between tests of executive function and the child's nonverbal and verbal intelligence. Once possible confounding variables were determined, analyses between executive abilities and ASD symptoms were performed with multiple regressions, with possible confounds, such as intelligence level entered in step 1 of the regression. Results from Pearson correlations between intelligence and EF and adaptive functioning and EF were also analyzed.

Lastly, linear regression analyses were used to examine early predictors of executive abilities. For these analyses, developmental data collected during the Time 1 and Time 2 evaluations were used separately to predict current performance on tasks of executive function (Time 3). Possible predictor variables from the Time 1 and Time 2 evaluation include the four individual scales from the Mullen Scales of Early Learning that measure visuospatial skills, fine motor abilities, and expressive and receptive language, the Mullen Early Learning Composite score, the Vineland-II Adaptive Behavior Composite score, and two measures of ASD symptom severity, the CARS and the ADOS severity score. Outcome variables included executive function measures collected at Time 3. Any significant analyses were then run in a hierarchical regression, while controlling for the participant's current IQ in order to determine the amount of variance accounted for by the early predictor above and beyond the child's current level of intellectual functioning.

Results

Measures of Executive Function (Time 3)

Performance Based Measures

Performance based measures of EF included the following subtests from the NEPSY: Animal Sorting, Inhibition, Word Generation, and Tower, as well as Digits Forward and Digits Backward from the DAS-II and the Wisconsin Card Sorting Test (WCST). Group means, standard deviations, and ranges for these tests are shown in Table 4. If a participant scored more than 1.5 standard deviations from the mean on a subtest, they were labeled as having a clinically significant deficit in performance on that measure. On the NEPSY subtests, 30% of participants met the clinical cut-off based on their score on Animal Sorting and 30% of participants also met criteria on the Tower, suggesting that greatest deficits in performance were on tasks of planning and cognitive flexibility. Eleven percent of participants displayed clinically significant deficits on a task of phonemic fluency and eleven percent of participants also met the cut-off criteria on a task of inhibition. Of the participants who completed the measure, none of them displayed clinically significant deficits on a task of semantic fluency. When participants' digit span was characterized, greater deficits were found on digits forward (28% met clinical cut-off), a task of basic memory and attention, when compared to digits backward (6%), a task of working memory. Thirteen percent of the sample displayed a clinically significant level of perseveration errors on the WCST; however, the sample size for this task was relatively small (n = 8) and therefore the results of the task are limited (Table 5).

Parent Report of Everyday Tasks of EF

Parent report of everyday tasks of EF were measured with the BRIEF. Means, standard deviations, and ranges for the individual indices on the BRIEF can be found in

Table 4. On this measure, parents reported greatest difficulties on tasks that involve shifting attention (41%), initiation of behavior (41%), working memory (35%), and inhibiting responses (35%). Clinically significant difficulties with planning (29%), monitoring one's own behavior (29%), emotional control (24%), and organizing materials (12%) were also reported (Table 5).

Comparing Performance Based Measures to Parent Report of EF

Pearson correlations were used to test the hypothesis that performance-based measures of EF would negatively correlate with parent report of EF in the home environment, given that higher scores on the BRIEF are indicative of clinically significant impairments in functioning, whereas, higher scores on performance-based measures of EF indicate better performance. For example, we expected a significant negative relationship on individual test of EF that overlap with indices on the BRIEF, such as the inhibition scale on the BRIEF and performance on the Inhibition subtest of the NEPSY-II. However, the results suggest very little overlap between behavioral performance on individual laboratory measures of EF and parent report of a child's ability to use EF in the home. When comparing the individual indices on the BRIEF to the performance-based measures that were collected in the laboratory, only one significant correlation emerged. Analyses revealed a significant negative relationship between the BRIEF Plan/Organize subscale and semantic fluency on the NEPSY-II (r = -.65, p = .016). All other correlations were not significant ($p > .05$), with the majority of the correlations in the negative direction or in the positive direction, but negligible ($r \leq .1$) (Table 6).

The Relationship Between Performance on Tasks of EF and Other Important Developmental and Diagnostic Factors (Time 3)

To examine the relationship among EF, and ASD symptoms, intelligence level, and adaptive functioning, Pearson correlations were used. The relationships between EF and nonverbal IQ and EF and verbal IQ were analyzed first. Any significant relationships between EF and intelligence level were controlled for in further analyses, such as the relationship between EF and ASD symptoms, by using hierarchical regression analyses. Previous studies have also suggested that controlling for the age of the participants when examining the relationship between EF and ASD symptoms may be an important factor; however, because all of the measures of EF in the current study utilized standard scores that are already normalized based on a child's chronological age, there was no need to control for the age of the participants.

EF and Intellectual Ability

When examining the relationship between performance-based measures of EF and intellectual ability, we expected all correlations to be in the positive direction, where children with higher intellectual ability performed better on tasks of EF. Results yielded no significant correlations between performance on the NEPSY-II subtests or the WCST and nonverbal or verbal IQ on the DAS-II ($p > .05$). Performance on the DAS-II Digits Forward subtest, a supplementary subtest of the DAS-II that is not included in a child's nonverbal or verbal IQ, was significantly correlated with both nonverbal IQ ($r = .53$, $p = .024$) and verbal IQ ($r = .77$, $p < .01$). In this case, individuals with higher levels of IQ tended to perform better on the subtest. Similarly, there was a significant positive relationship between performance on the Digits Backward subtest and nonverbal IQ ($r =$

.62, $p < .01$), but not verbal IQ ($p > .05$) (Table 7). When examining the relationship between parent report on the BRIEF and intellectual ability, we expected all correlations to be in the negative direction, where parents who reported that their child had higher levels of executive dysfunction at home, would perform worse on tasks of IQ. There were no significant correlations between the subscales of the BRIEF and verbal or nonverbal IQ ($p > .05$). Given the lack of significant relationship among most measures of EF and IQ, all further correlations were performed without controlling for IQ. The exception was Digits Forward and Digits Backward, which were examined first by Pearson correlations and then any significant findings were further explored through regression analyses while controlling for IQ.

EF and Adaptive Functioning

The relationship between EF and the individual subscales of the Vineland-II (Communication, Socialization, and Daily Living Skills) were analyzed with Pearson correlations. There were significant positive correlations between the Communication and Tower test scores ($r = .64$, $p < .01$) and the Communication and Digits Forward scores ($r = .58$, $p = .01$). The overall model of the relationship between scores on the Communication domain and those on the Digits Forward subtest remained significant when run as a hierarchical regression with nonverbal and verbal IQ entered in step one of the model and the scores from the Digits Forward subtest entered in step two of the model ($R^2 = .604$, $F(3,12) = 6.11$, $p = .01$). These results indicate that children with higher scores on the Communication scale of the Vineland-II tend to have better performance on the Tower and Digits Forward subtests. All other analyses were not significant ($p > .05$) (Table 8).

There was a significant negative relationship among the BRIEF Inhibit (r = -.53, p = .03), Shift (r = -.65, p > .01), Emotional Control (r = -.51, p = .04), Initiate (r = -.50, p = .05), Working Memory (r = -.62, p = .01), and Monitor (r = -.63, p = .01) subscales and the Vineland-II Social score. The results suggest that children whose parents report larger social impairments in a child's daily functioning tend to report more difficulties with everyday tasks of executive functioning. The Vineland Daily Living and Communication scores were both correlated with the BRIEF Working Memory subscale. Almost all of the other correlations were in the expected negative direction, but did not reach statistical significance (p > .05) (Table 9).

EF and Symptoms of ASD

Symptoms of ASD were measured through direct observation on the ADOS, parent report on the SRS, and graduate student's judgment on the CARS. Higher scores on all three measures of ASD symptoms indicate larger impairments; therefore, we expected a negative relationship between scores on measures of ASD symptoms and performance-based measures of EF and a positive relationship between measures of ASD symptoms and parent report on the BRIEF (Table 10 & 11).

There was a significant negative correlation between the ADOS module 3 Combined Social-Communication Total and performance on the Animal Sorting subtest (r = -.55, p = .01). In the study, children who displayed a higher number of social and communication deficits on the ADOS scored more poorly on a task of cognitive flexibility. The relationship continued to be significant when examining the individual Social (r = -.53, p = .01) and Communication (r = -.53, p = .01) scores on the ADOS. The relationship between graduate student's judgment of ASD symptoms and cognitive

flexibility was approaching significance ($r = -.40$, $p = .09$), but there was no significant relationship between the Animal Sorting subtest and parent report of ASD symptoms at home, as measured on the SRS ($p > .05$).

Pearson correlations among the Tower subtest and the Social ($r = -.56$, $p = .01$), Communication ($r = -.45$, $p = .04$), and Social-Communication Combined ($r = -.54$, $p = .01$) scores on the ADOS were significant. The negative relationship between ASD symptoms and EF was also significant for graduate student's judgment of ASD symptoms on the CARS ($r = -.64$, $p < .01$) and parent report of ASD symptoms at home ($r = -.65$, $p = .01$). These findings suggest that children, who display a higher degree of ASD symptoms at home and during testing, tended to have poorer task performance on the Tower subtest, a measure of planning.

The results of our analyses yielded a significant negative relationship between digit span on the Digits Forward subtest of the DAS-II and symptoms of ASD when measured by the Social-Communication Combined score of the ADOS ($r = -.56$, $p = .02$). A similar result was found when analyzing the relationship between the graduate student's judgment of ASD symptoms on the CARS and performance on Digits Forward ($r = -.50$, $p = .04$), where children with fewer ASD symptoms performed better on the test of basic memory and attention. There was no significant relationship between task performance on Digits Forward and the SRS total score.

Performance on the WCST, Inhibition subtest, the phonetic fluency portion of the Word Generation subtest, and Digits Backward did not correlate significantly with measures of ASD symptoms that were based on behavioral observation or parent report. Performance on the semantic fluency portion of the Word Generation subtest was

significantly correlated with graduate student's judgment of ASD symptoms on the CARS (r = -.51, p = .03); however, performance on this task was not significantly correlated with scores on the SRS or ADOS.

The relationship among the BRIEF subscales and ASD symptoms were also analyzed. There were no significant correlations between scores on the BRIEF and ASD symptoms as measured on the ADOS or CARS. There were significant positive correlations among the BRIEF Inhibit, Shift, Initiate, Working Memory, Plan/Organize, and Monitor subscales and parent report of ASD symptoms in the home environment ($p < .05$). These results indicate that children who receive higher scores on the SRS tend to have higher, or more clinically significant, scores on the BRIEF.

Exploratory Analyses of Early Predictors of EF

Data collected from the participants' Time 1 and Time 2 evaluations were used to explore possible predictors of EF in the current sample. Possible predictors included measures of the participants' cognitive functioning on the Mullen, adaptive functioning on the Vineland, and symptoms of ASD from the ADOS severity score and the CARS total score. Relationships among the predictor variables were analyzed with Pearson correlations to assess for multicollinearity and to assist in choosing a limited number of variables that potentially could provide unique variance to the models. Based on the results of these analyses and previous literature that has suggested that motor and language skills may be strong predictors of outcome, it was determined that the Fine Motor and Expressive Language subscales from the Mullen, along with the ADOS severity score and Vineland Adaptive Behavior Composite would be used to predict EF ability at Time 3. Outcome EF variables included scores from the Animal Sorting,

Inhibition, Tower, Digits Forward, and Digits Backward subtests. The WCST was not used due to the small sample size and consequent limited power. Regression analyses were run separately for data collected at Time 1 and Time 2. While running the analyses the data was examined for violations of the assumptions of multiple regression by examining the data's linearity, normality, independence, and homogeneity of variance. Significant results were further explored while controlling for a child's current nonverbal IQ through the use of hierarchical regressions. These analyses were performed to further confirm the validity of the early developmental predictors above and beyond a child's current intellectual abilities.

Developmental and Diagnostic Factors from Early Childhood that Predict Performance on Tasks of EF in School-Aged Children with HFA

Time 1 Variables Predicting EF

A simple linear regression analysis was conducted to determine if cognitive flexibility on the Animal Sorting subtest could be predicted from a child's Time 1 Fine Motor score, Expressive Language score, ADOS severity score, or Vineland Composite score. Results of the analyses suggest that the overall model did not account for a significant proportion of the total variation in cognitive flexibility ($F(4, 14) = 1.79$, $p = .18$). Similar analyses were run with the NEPSY Inhibition subtest as the predictor variable. The results of this model were significant ($F(4,13) = 3.38$, $p = .04$), and indicated that the four predictors explained 51% of the variance ($R^2 = .51$) in performance on the Inhibition subtest. In the model, a child's Time 1 fine motor ability significantly predicted the ability to inhibit prepotent responses at Time 3 ($\beta = .785$, $t(13) = 3.3$, $p < .01$). The Inhibition subtest and four predictor variables were then analyzed with a

hierarchical regression. In the regression, the participants' Time 3 nonverbal IQ score from the DAS-II was entered in step 1 and the remaining four predictor variables were entered in step 2. The results indicated that fine motor ability continued to be a significant positive predictor of a child's ability to inhibit responses (β = .713, t(12) = 2.4, p = .03).

Results from a simple linear regression using the Tower subtest as the predicted variable indicated that the four predictor variables did not significantly predict planning ability at Time 3; however, the model was approaching significance (R^2 = .43, F(4, 14) = 2.61, p = .08). In the model, fine motor ability significantly predicted planning ability (β = .61, t(14) = 2.5, p = .03). When these data were run as a hierarchical regression while controlling for nonverbal IQ, none of the predictor variables remained significant; however, fine motor ability had the highest standardized coefficient (β = .58).

The overall model with Digits Forward as the predicted variable was approaching significance (R^2 = .47, F(4, 12) = 2.67, p = .08). It was found that fine motor ability predicted basic memory and attention (β = .58, t(12) = 2.2, p = .04), as did expressive language (β = .62, t(12) = 2.2, p = .05). These predictor variables were no longer significant when controlling for current nonverbal IQ. The last regression analysis used Digits Backward as the predicted variable. The results of the regression indicated that the variables accounted for 62.9% of the variance (F(4, 11) = 4.67, p = .02). It was found that fine motor ability significantly predicted working memory at Time 3 (β = .95, t(11) = 4.21, $p < .01$). These results remained true when controlling for nonverbal IQ. The results of step one of the hierarchical regression were significant (F(1, 14) = 8.62, p = .01) and accounted for 38% of the variance. When the four predictor variables were

added to the model in step 2 the change in R^2 was equal to .30 and the overall model was significant ($F(5, 10) = 4.26$, $p = .02$). Performance on Digits Backward was predicted by current nonverbal IQ ($\beta = .62$, $t(14) = 2.93$, $p = .01$) and fine motor ability at Time 1 ($\beta = .72$, $t(10) = 2.70$, $p = .02$). Overall, the results indicate that fine motor ability at Time 1 is a positive predictor of inhibiting responses, planning, basic attention, and working memory in school-aged children with HFA and in many cases provides a unique contribution to the variance in performance while controlling for current nonverbal IQ.

Time 2 Variables Predicting EF

Linear regression analyses were used to predict shifting ability on the Animal Sorting subtest of the NEPSY from Time 2 variables. It was found that the four predictors, fine motor ability, expressive language, ASD symptom severity, and adaptive functioning, did not significantly predict performance on Animal Sorting ($F(4,13) = 1.73$, $p = .20$). Similarly, the predictor variables were unable to account for a significant amount of the variance on the Inhibition subtest ($F(4, 12) = 0.67$, $p = .62$).

Regression analyses were used to predict planning ability on the Tower subtest. Results of the overall model were significant and explained 54% of the variance ($F(4, 13) = 3.70$, $p = .03$). Within the model, expressive language ability significantly predicted planning ability ($\beta = .72$, $t(13) = 2.40$, $p = .03$). Fine motor ability was also a significant predictor ($\beta = -.65$, $t(13) = -2.64$, $p = .02$); however, this unexpected negative relationship between fine motor skills and EF could be the result of a suppressor variable. Fine motor ability at Time 2 is not significantly correlated with scores on the Tower subtest ($r = -.09$, $p > .05$), whereas expressive language ability does have a significant positive relationship with planning ability ($r = .52$, $p = .03$). Therefore we would expect language ability and

not fine motor skills to be significantly contributing to task performance on the Tower subtest. Similar results were obtained when the analyses between the Tower subtest and the four predictors were run as a hierarchical regression with participants' current nonverbal IQ added in step 1 of the model. Results from step 1 of the model were not significant ($F(1, 16) = 1.05$, p .32). Step two of the model was significant ($F(5, 12) = 3.08$, $p = .05$) with a change in R^2 value equal to .50. Among the predictor variables, expressive language ($\beta = .66$, $t(12) = 2.13$, $p = .05$) and fine motor ability ($\beta = -.69$, $t(12) = -2.66$, $p = .02$) significantly contributed to the variance in performance.

Performance on Digits Forward was significantly predicted from the model, with the predictor variables accounting for 72% of the variance in performance ($F(4,11) = 7.07$, $p < .01$). Within the model, the Vineland Adaptive Behavior Composite score significantly predicted basic memory and attention ($\beta = .693$, $t(11) = 2.66$, $p = .02$). The overall model remained significant when nonverbal IQ was entered in step 1 of a hierarchical regression ($F(10, 5) = 6.18$, $p > .01$) with a change in R^2 value of .48. Adaptive skills at Time 2 were a significant predictor when controlling for nonverbal ability ($\beta = .68$, $t(10) = 2.66$, $p = .02$). Regression analyses were used to analyze performance on Digits Backward. Results indicated that the overall model did not significantly account for variance in performance ($F(4,10) = .74$, $p > .05$).

Overall, therefore, at Time 2, fine motor ability no longer remained a positive predictor of EF at Time 3; instead, other variables such as expressive language ability and adaptive functioning appear to have an important function in explaining the variance in performance on certain tests of EF in school-aged children with HFA.

Discussion

Overview of Results

Results of EF Measures

One of the primary goals of the current study was to examine tasks of EF that included performance-based measures, as well as parent report of EF at home, in a well-characterized sample of school-aged children with HFA. On the performance-based measures of EF, largest deficits were found on task of cognitive flexibility (Animal Sorting), planning (Tower), and a basic task of attention and verbal memory (Digits Forward). Our findings are consistent with the previous literature, which has shown deficits on the Animal Sorting subtest of the NEPSY-II (Korkman, Kirk, & Kemp, 2007), on different variations of the Tower task (Hughes et al., 1994; Bennetto et al., 1996; Geurts et al., 2004; Joseph et al., 2005; Ozonoff & Jensen, 1999b; Ozonoff & McEvoy, 1994; Pellicano, Maybery, Durkin, & Maley, 2006; Verte, Geurts, Roeyers, Oosterlaan, & Sergeant, 2005), and on a task of simple verbal memory (Schuh & Eigsti, 2012).

Based on previous literature, we also expected to see significant group deficits on the WCST, a second task of cognitive flexibility that measures a participant's ability to shift set between categories. However, in the current sample, only 13% of participants showed clinically significant perseveration errors on the WCST. One possible explanation for the discrepancy in performance between the WCST and Animal Sorting subtests is the small sample size on the WCST. The WCST had only 8 participants, compared to 20 on the Animal Sorting subtest; therefore, the results on that particular test were limited. Results on the remaining performance-based measures of EF were fairly consistent with the previous literature, with few participants exhibiting deficits on an examiner-administered version of the Stroop Test (Inhibition) (Ozonoff & Jensen,

1999b), Digits Backward (Lopez, Lincoln, Ozonoff, & Lai, 2005), and on tasks of verbal fluency (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009).

When examining parent report of everyday tasks of EF, we expected to find largest deficits on the Shift scale (Gioia, Isquith, Kenworthy, & Barton, 2002). Our findings were consistent with our initial hypothesis, where parents of children with ASDs reported that their child had clinically significant difficulties in shifting focus between activities. Unlike the previous study, we also found deficits on the Initiation, Working Memory, and Inhibition scales of the BRIEF. These deficits occurred in more than one third of our sample, a finding not previously reported.

Previous literature has pointed out that laboratory studies of EF may be useful for disentangling specific components of EF, but with the trade-off of losing ecological validity (Kenworthy et al., 2008). The BRIEF is thought to be a measure of the application of EF in more complex social situations based on parent report of a child's behavior at home. Based on the theoretical nature of the BRIEF, we hypothesized that there would be an overlap in performance on tasks that directly measure one component of EF in the laboratory, such as inhibition, and parent report of more complex uses of inhibition at home. However, in fact, our findings suggested that there was very little overlap between the measures. There are several interpretations of this finding. We had hypothesized that the BRIEF Inhibition scale would measure the same cognitive process involved in completing a Stroop-based inhibition task in the laboratory; however, the results suggest that these two measures may in fact be measuring different processes. For example, questions included in the Inhibition scale measure verbal and social intrusiveness and a lack of awareness of personal safety. A child's ability to stop him or

herself from interrupting other children could be attributed to either impulsivity, or to a lack of social awareness that they shouldn't interrupt others, a distinction that is not made on this measure. As a result, the BRIEF Inhibition scale may be measuring something fundamentally different than a Stroop task.

In addition, differences in results between laboratory tests of EF and everyday tasks of EF could be because the measure of everyday tasks of EF used in the current study relied solely on parent report of behavior within the home environment. It would be useful for future research to examine behaviors in different environments, such as teacher report of EF at school or the use of more complex laboratory measurements of EF with greater task demands. These types of measures could potentially account for differences in findings between parent report on the BRIEF and laboratory tasks of EF.

Overall the results of the performance-based measures of EF were consistent with previous studies of children and adolescents with HFA. In our sample, school-aged children with a well-documented history of an ASD performed worse on tasks of cognitive flexibility, planning, and basic attention and memory. Furthermore, parent report of everyday tasks of EF at home showed that children had largest difficulties in their ability to shift from one situation, activity, or aspect of a problem to another based on their environmental circumstances, a finding that the current study replicated. In addition, parents of children in the current study reported difficulties in initiation, working memory, and inhibition. The current study was unable to compare performance to a control group. As a result, it remains unclear if our findings on the BRIEF are ASD specific, or more broadly associated with children with clinical disorders. This result

should be further studied while comparing school-aged children with HFA to an applicable control group, such as children with ADHD or learning disabilities.

The Relationship between EF and Developmental and Diagnostic Factors

The second goal of the current study was to compare performance on tasks of EF to relevant developmental and diagnostic factors in children with ASDs. There was a significant positive relationship between performance on Digits Forward and nonverbal IQ, and Digits Forward and verbal IQ. There was also a significant positive relationship between Digits Backward and nonverbal IQ. These relationships should be interpreted cautiously, because the Digits Forward and Digits Backward subtests come from the same measure as the child's IQ, and the DAS-II has high internal consistency reliability. There were no other significant relationships between performance-based tasks of EF and IQ, and between the scales of the BRIEF and IQ. The results from the current study indicate that there is very little overlap between task performance in EF and IQ, which is similar to the literature on typically developing children that showed task performance of EF to be somewhat independent of intelligence (Espy, Kaufmann, & Glisky, 2001).

The results of the current study yielded a significant relationship between adaptive functioning and EF. Parent report of EF on six out of the eight subscales of the BRIEF was significantly correlated with the Social score on the Vineland-II. In addition, the Working Memory scale of the BRIEF was inversely related to all three subscales of the Vineland-II (Social, Communication, and Daily Living). When examining performance-based measures of EF, only the Tower and Digits Forward subtests were significantly correlated with language ability on the Vineland-II. The results suggest that behavioral tasks of planning and memory may be positively related to communicative

skills on the Vineland-II. Also, parents who report that their child has difficulty applying EF skills while at home also report these same children as having difficulty engaging others socially while in similar environments.

It has been shown that performance on tasks of EF is related to social skills, such as those measured on tasks of Theory of Mind in children with ASDs. Since then, studies have directly measured a link between EF and clinical tools that measure social impairment in children with ASDs (ADOS, ADI). However, results from these studies have lacked consistency, with two studies failing to find a significant relationship between EF and social ability (Joseph & Tager-Flusberg, 2004) and one study finding a significant negative relationship between semantic fluency and a composite social score from the ADI and ADOS (Kenworthy, Black, Harrison, Rosa, & Wallace, 2009). In addition, these three studies failed to use similar measures of EF or the same measures of social ability. In an attempt to clarify the literature, the current study utilized EF tests from two of the previous studies, subtests from the NEPSY and parent report on the BRIEF. In addition, symptoms of ASD were measured in three distinct ways, through parent report of behavior at home, graduate student clinician's judgment of behavior during the assessment, and based on brief behavioral observation on the ADOS.

Unlike the previous studies, the current study found that the social score on the ADOS was negatively correlated with cognitive flexibility on the Animal Sorting subtest, planning on the Tower, and basic attention and memory on Digits Forward. While there was a negative relationship between semantic fluency and social scores on the ADOS, where children who performed better on a task of semantic fluency had less social impairment on the ADOS, this finding failed to reach significance ($r = -0.29$, $p > .05$). A

significant negative relationship between planning ability and social symptoms associated with ASDs was also found based on parent report with the SRS and clinician's judgment on the CARS. Previous literature suggested an inverse relationship between planning ability and communication symptoms on the ADOS, a finding that was also replicated in the current study. ADOS communication scores, similar to ADOS social scores, were also negatively related to cognitive flexibility on Animal Sorting and basic memory and attention on Digits Forward. In the current study, repetitive behaviors, as measured by the ADOS were not significantly correlated with laboratory tasks of EF; however, the majority of the correlations were in the negative direction. Future studies should employ a repetitive behavior specific measure, such as the Repetitive Behavior Scale, to assess for a possible relationship to tasks of EF, because the timeframe to observe repetitive behaviors is limited to the amount of time it takes to administer the ADOS and therefore may not capture the frequency or severity of some repetitive behaviors.

Kenworthy and colleagues (2009) examined the relationship between parent report of EF on the BRIEF and combined ADOS and ADI scores. Her results suggested that there were no relationships between the BRIEF and social impairment, but that behavior regulation problems were associated with more communication symptoms and with more repetitive behaviors. The current study examined the BRIEF more thoroughly by using the individual subscales of the BRIEF instead of the composite Behavioral Regulation Index, which is composed of the Inhibit, Shift, and Emotional Control scales. Consistent with Kenworthy (2009), there was no significant relationship between social symptoms on the ADOS and parent report of EF. However, the current study failed to replicate her finding that behavior regulation was associated with more communication

impairment on the ADOS and with more repetitive behaviors. The only significant relationship between social symptoms in the current sample and parent report of EF was on the SRS. These results could be interpreted in two ways. One possible interpretation is that parents of children with HFA who report a higher degree of social impairment at home on the SRS also rate their child as being more impaired across a variety of measures. A second possible interpretation is that the SRS and BRIEF may be measuring similar behaviors that require both social skills and EF and, therefore, children whose parents report them as doing poorly on one measure are consistently reporting deficits on similar behaviors on the second measure.

Early Predictors of the Development of EF

The third goal of the current study was to examine early developmental and diagnostic factors that could predict performance on tasks of EF in school-aged children with HFA. Two related lines of research in the field of autism were expanded upon in the current study. Previous research had examined early predictors of outcome in children first diagnosed with an ASD in early childhood and how EF may be a positive predictor of performance on certain tasks of social skills, such as Theory of Mind (TOM). The current study aimed to capitalize on its unique longitudinal design by examining how developmental precursors, such as motor skills and language acquisition, may predict the development of executive functioning, which has been related to performance on tasks of important social skills in individuals with ASDs (e.g., TOM, joint attention, imitation, and emotional control).

Developmental data were collected from the participants when they were at the approximate ages of 2 and 4, and were used to predict performance on laboratory tasks of

EF when the children were of school-age (8-10 years). The results of the study indicated that fine motor ability at age 2 significantly predicted performance on tasks of inhibition, planning, working memory, and simple memory and attention. In the current sample, the attainment of early fine motor abilities positively predicted performance on multiple tasks of EF in later development. The early attainment of motor skills has been shown to be a positive predictor of outcome in other studies of children with ASDs (Sutera et al., 2007) and with other clinical populations (Murray et al., 2006). Surprisingly, expressive language ability at this early age was not found to be a positive indicator of later performance on tasks of EF. A possible explanation is the lack of variance in expressive language abilities at Time 1. Given the limited variance of this variable and the small sample size, the current study may not have been able to detect small differences in language abilities that could account for variations in performance on EF tasks at Time 3.

When examining the same predictor variables at Time 2, the results of the regression analyses no longer found that fine motor skills positively predicted EF task performance at Time 3. At Time 2, other measures, such as a child's expressive language ability and adaptive functioning appeared to be more positive predictors of outcome. Differences in findings from Time 1 to Time 2 could be accounted for by an increased amount of variance within the sample of children by the Time 2 evaluation on variables other than motor measures, which may be directly related to the intervention services that they may have received. All children in the current sample were referred for early intervention services following their Time 1 evaluation. By the time they were evaluated at Time 2, the majority of children had received services through their local Birth to Three providers. Many of these services included weekly instruction with an early

intervention associate, as well as weekly occupational or speech and language services. As a result, children who were responsive to intervention may have seen significant improvements in their developmental skills between the Time 1 and Time 2 evaluations, whereas children who continued to have deficits in speech and adaptive functioning after receiving intensive early intervention services, may continue on a developmental trajectory that is marked with delays in multiple areas of functioning, including EF.

Limitations

The current study has several important limitations. As mentioned previously, the sample size of the current study was small and ranged from 17-20 on most of the EF measures. The small sample size is concerning because it limits the amount of power that the study has to detect significant differences while running statistical analyses. Post-hoc analyses with the program G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that for linear regression analyses with a sample size of 20 and 4 predictor variables, the likelihood of measuring a large difference (effect size = 0.4) was 46%. As a result, it is unlikely that the current analyses had enough power to measure a small or medium sized difference in the current sample (Cohen, 1992). The sample size on the WCST was the smallest (n = 8) and as a result, this measure was not included in most analyses and interpretation of the data was severely limited. A second concern with the small sample size is how well the results of the study can be generalized to a larger population. The current study chose to use a well-defined sample of children with HFA. As a result, these findings cannot be applied to children with autism who have nonverbal IQs below 70 or those who are nonverbal.

Given the larger study that the sample was selected from, a convenient control group could not be accessed. Therefore, the results from the current study may not be unique to children with HFA. In fact, it is possible that the findings on tasks of EF may be similar to the performance of other clinical samples, such as children with ADHD, on the same measures. One argument against this limitation is that previous research examining EF in different clinical groups have argued for a unique pattern of performance on tasks of EF in children and adolescents with ASDs (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Verte, Guerts, Roeyers, Oosterlaan, & Sergeant, 2005). This literature would support the notion that the findings in the current study may be unique to the characteristics of children with ASDs; however, this will need to be further explored in future research by using appropriate control groups to study precursors of EF longitudinally.

A third limitation in the current study was the use of parent report in measuring everyday tasks of EF. Previous literature has argued that laboratory tests of EF may lack ecological validity. As a result, the BRIEF has been used as a way to measure tasks of EF that a child engages in regularly when in a natural environment. However, the tradeoff of the BRIEF is that individual items that are meant to measure one specific cognitive process, such as inhibition, may be measuring multiple cognitive processes at once, making it difficult to tease out the cause of a particular deficit.

The current study attempted to correct for these issues by using both performance-based measures of EF and the BRIEF. The results of the study have shown that there is very little overlap on the individual indices of the BRIEF and laboratory measures of EF.

It remains unclear if parent report on the BRIEF is a reliable marker of everyday EF deficits in children with ASDs. One difficulty in interpreting the results of the BRIEF is that items on the BRIEF could be socially constrained and therefore parents who report severe social deficits for their children do so not only on measures of social engagement, such as the SRS, but also on measures of everyday tasks of EF. Therefore, the ratings on the BRIEF may be more indicative of social delays and not impairments in EF. Researchers are beginning to develop laboratory tasks that mimic or are more similar to everyday tasks of EF. These tests may be a useful intermediary between existing laboratory tasks that are highly controlled and parent report on the BRIEF, by allowing researchers to parse out areas of difficulty during more complex tasks of EF, while still in a controlled setting. For example, Kofman and colleagues (2008) developed a task to measure strategic planning that is similar to many school assignments, where children had to implement a strategic approach to finish a visual discrimination task. Kofman (2008) used this measure to show how children with ADHD have difficulties with strategic planning and suggested areas for possible intervention that directly apply to academic functioning.

Conclusion

The current study demonstrated that children with ASDs consistently display deficits on some tasks of EF. Furthermore, performance on laboratory-based measures of EF was not related to parent report of everyday tasks of EF in the home environment. In the study, some tasks of EF were directly related to measures of adaptive functioning and ASD specific deficits in social skills, communication, and the presence of repetitive behaviors. This result further supported the idea that deficits in EF may be related to the

core social and communication deficits typically viewed in children with ASDs. When analyzing the development of EF, the current study showed that motor development in toddlers was a positive predictor of EF task performance in school-aged children with HFA. This finding did not hold true when analyzing similar predictors of performance when the children were approximately 4 years old, at which time other predictors, such as expressive language and adaptive skills, were significant.

This study contributed to the literature by examining the developmental predictors of EF. EF has been shown to be important for the development of a variety of social skills and academic functioning; however, until the present study, researchers had not examined other factors that may contribute to the development and maintenance of EF in children with ASDs. The results from the current study indicate the importance of obtaining information about motor milestones and skills in young children as they relate to the development of other areas of functioning in adolescence. These results highlight an area of potential focus for treatment by early intervention providers.

The cause of the relationship between motor skills and EF remains unclear. However, because early motor skills have been implemented in multiple studies as a positive predictor of outcome, its contribution to developmental trajectories warrants further investigation. It is possible that motor skills, such as using a pincer grasp and walking, may be markers of the overall integrity of a child's central nervous system. Therefore, delays in motor milestones may be more indicative of a larger problem with a child's neural development, and perhaps frontal lobe functioning, as it relates to tasks of EF. A second possible interpretation is that motor skills allow a child to interact in their social environment by moving from person to person and being able to manipulate

objects, such as toys. These abilities facilitate the development of language and social skills that become necessary for the development of EF in later life. It is clear, however, that once children begin receiving early intervention, those with lingering delays in expressive language and adaptive functioning may continue to show delayed functioning in other areas, such as EF. Taken together, the current study highlights the need for early intervention in order to address delays in motor skills, language, and adaptive functioning that could potentially impact a child's development of EF in adolescence.

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Table 1

Study Criteria and Participant Flow Chart

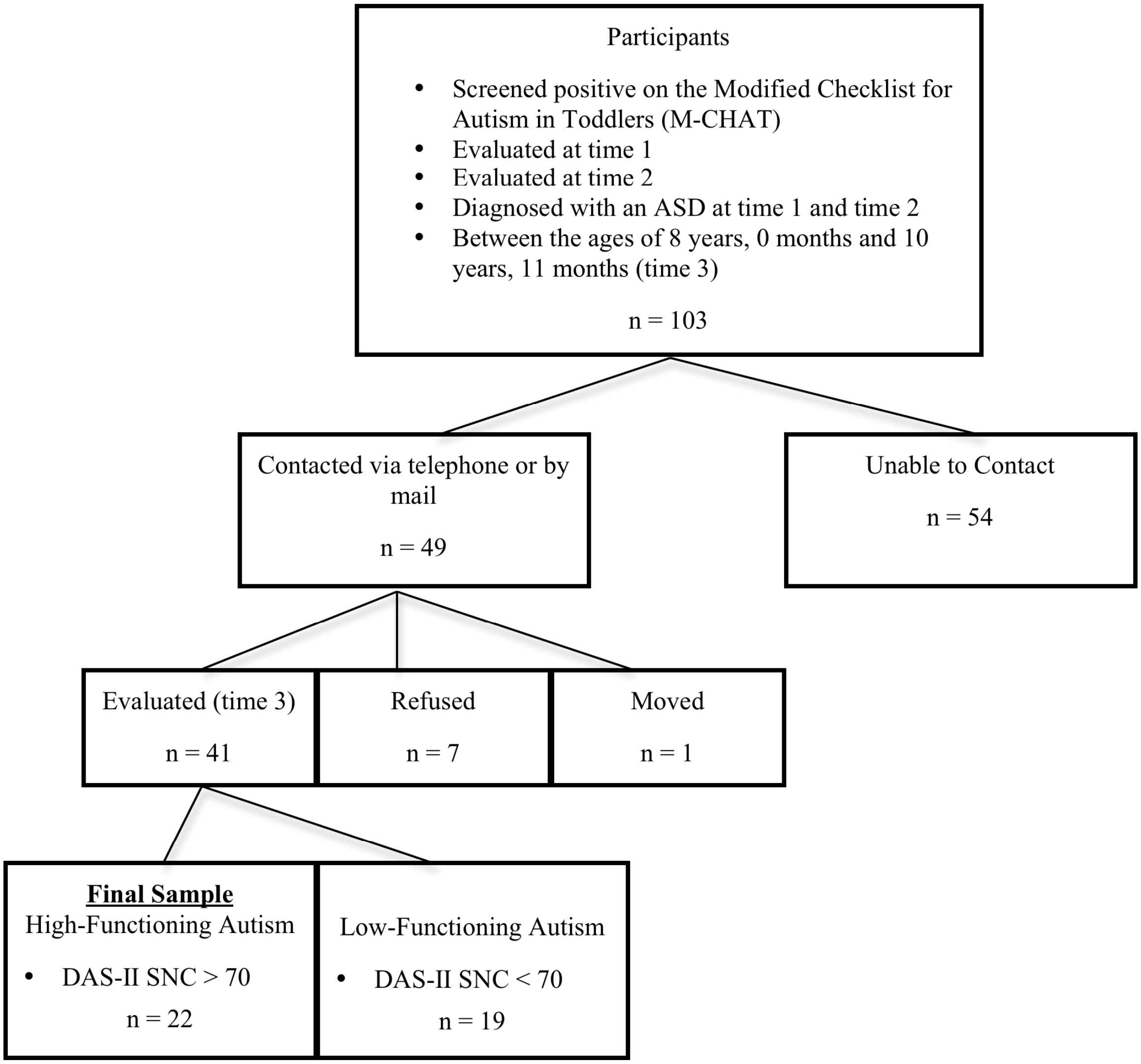

Table 2

Participant Demographic Information

n = 22	Time 1	Time 2	Time 3
Age in Months			
Mean (SD)	27.0 (3.3)	54.1 (11.2)	118.8 (10.0)
Gender (n)			
Male	18		
Female	4		
Ethnicity (n)			
White	20		
Black	1		
Asian/Pacific Islander	1		
Diagnosis (n)			
Autistic Disorder	17	15	
PDD-NOS	5	7	
Mullen Mean T-Score (SD)			
Fine Motor	30.5 (8.0)	33.1 (11.5)	
Visual Reception	33.2 (8.1)	39.2 (19.3)	
Receptive Language	23.4 (7.9)	33.0 (14.7)	
Expressive Language	24.7 (6.4)	31.3 (12.2)	
DAS-II* Standard Score (SD)			
Special Nonverbal Composite			101.2 (15.3)
Verbal			96.5 (20.7)
General Conceptual Ability			99.8 (16.9)
CARS* (SD)			
Total Score	32.7 (3.1)	28.9 (4.2)	28.0 (4.7)
ADOS* (SD)			
Severity Score	7.0 (2.3)	6.5 (1.6)	6.1 (2.9)

* Differential Ability Scales - Second Edition (DAS-II), Childhood Autism Rating Scales (CARS), Autism Diagnostic Observation Schedule (ADOS)

Table 3

Measures Collected at each Time Point

	Time 1 17-37 months	Time 2 41-69 months	Time 3 8-10 years
Cognitive	Mullen	Mullen	DAS-II
Adaptive Function	Vineland	Vineland	Vineland-II
ASD Symptoms	ADOS CARS SRS	ADOS CARS SRS	ADOS CARS SRS
Executive Function			NEPSY-II Animal Sorting NEPSY-II Inhibition NEPSY-II Word Generation NEPSY Tower BRIEF WCST DAS-II Digits Forward DAS-II Digits Backward

Note. Mullen = Mullen Scales of Early Learning; DAS = Differential Abilities Scale; Vineland = Vineland Adaptive Behavior Scales; ADOS = Autism Diagnostic Observation Schedule; CARS = Childhood Autism Rating Scale; SRS = Social Responsiveness Scale; BRIEF = Behavior Rating Inventory of Executive Function; WCST = Wisconsin Card Sorting Test.

Table 4

Performance on Measures of Executive Function

	Sample Size	Minimum	Maximum	Mean	Standard Deviation
NEPSY Scaled Score					
Animal Sorting	20	3	13	7.1	2.7
Inhibition	19	3	14	10.0	3.3
Word Generation (FAS)	18	4	16	9.3	3.2
Word Generation (Semantic)	18	7	19	13.2	3.8
Tower	20	1	13	7.7	3.8
DAS-II T-Score					
Digits Forward	18	10	65	41.9	16.9
Digits Backward	17	33	60	47.2	8.1
WCST Standard Score					
Perseverative Errors	8	54	146	94.8	25.4
BRIEF T-Score					
Inhibit	17	42	78	61.0	11.7
Shift	17	39	84	60.8	13.9
Emotional Control	17	36	76	54.5	12.4
Initiate	17	43	75	58.7	9.6
Working Memory	17	40	76	59.9	10.9
Plan/Organize	17	42	80	58.9	10.8
Organization of Material	17	36	71	54.0	8.4
Monitor	17	41	75	59.4	9.4
Global Executive Composite	17	41	77	60.0	10.3

Table 5

Percentage of Participants with Clinically Significant Deficits on Measures of Executive Function

	Sample Size	Percentage
BRIEF		
Shift	17	41%
Initiation	17	41%
Working Memory	17	35%
Inhibition	17	35%
Plan / Organize	17	29%
Monitor	17	29%
Emotional Control	17	24%
Organization of Materials	17	12%
NEPSY		
Animal Sorting	20	30%
Tower	20	30%
Inhibition	19	11%
WG (Letter)	18	11%
WG (Semantic)	18	0%
DAS-II		
Digits Forward	18	28%
Digits Backward	17	6%
WCST		
Perseverative Errors	8	13%

Clinical cut-off = 1.5 standard deviations from the mean

Table 6

Correlations Among performance-based Measures of EF and Parent Report on the BRIEF

	BRIEF							
Performance Based Measures	Inhibit	Shift	Emotional Control	Initiate	Working Memory	Plan/Org	Org Materials	Monitor
WCST	0.06	0.27	0.11	0.20	-0.18	0.44	-0.61	-0.11
Animal Sorting	0.10	-0.08	0.19	-0.15	-0.01	-0.17	0.05	-0.01
Inhibition	0.11	0.48	0.09	0.19	0.08	0.12	-0.52	0.25
WG Letter	0.10	0.34	0.14	-0.08	0.09	-0.12	0.21	-0.03
WG Semantic	-0.39	0.05	-0.35	-0.47	-0.36	-0.65*	-0.04	-0.44
Tower	0.10	-0.21	0.08	-0.33	-0.51	-0.33	0.30	-0.34
Digits Forward	0.18	-0.14	-0.03	-0.19	-0.43	-0.08	0.27	0.01
Digits Backward	0.29	0.38	-0.07	0.37	0.17	0.18	0.21	0.47

* $p < .05$; ** $p < .01$

Table 7

Correlations Among Performance Based Measures of EF and Verbal and Nonverbal IQ

	WCST	Animal Sorting	Inhibition	WG Letter	WG Semantic	Tower	Digits Forward	Digits Backward
SNC	0.35	0.42	0.39	-0.02	-0.33	0.25	0.53*	0.62**
Verbal	-0.53	0.40	0.06	0.43	0.26	0.28	0.77**	0.41

* p < .05; ** p < .01; SNC = Special Nonverbal Composite (DAS-II); Verbal = Verbal Score (DAS-II)

Table 8

Correlations Among Measures of EF and Adaptive Functioning

	WCST	Animal Sorting	Inhibition	WG Letter	WG Semantic	Tower	Digits Forward	Digits Backward
Vineland - II								
Communication	-0.13	0.07	-0.20	0.33	0.42	0.64**	0.58*	0.15
Daily Living	-0.14	-0.06	-0.11	0.32	0.23	0.39	0.28	-0.05
Social	-0.32	-0.01	-0.39	0.14	0.38	0.45	0.21	-0.33

* $p < .05$; ** $p < .01$

Table 9

Correlations Among the Indices of the BRIEF and Adaptive Functioning

	Inhibit	Shift	Emotional Control	Initiate	Working Memory	Plan/Org	Org Materials	Monitor
Vineland - II								
Communication	-0.13	-0.36	-0.36	-0.40	-0.53*	-0.29	0.39	-0.27
Daily Living	-0.34	-0.39	-0.16	-0.41	-0.54*	-0.32	-0.04	-0.41
Social	-0.53*	-0.65**	-0.51*	-0.50*	-0.62*	-0.46	0.09	-0.63**

* $p < .05$; ** $p < .01$

Table 10

Correlations Among Tasks of EF and Measures of ASD Symptoms

	WCST	Animal Sorting	Inhibition	WG Letter	WG Semantic	Tower	Digits Forward	Digits Backward
ADOS								
Social	-0.24	-0.53*	0.01	-0.13	-0.29	-0.56*	-0.49*	-0.11
Communication	-0.31	-0.53*	-0.08	-0.17	-0.11	-0.45*	-0.61**	-0.32
Combined	-0.28	-0.55*	-0.03	-0.15	-0.23	-0.54*	-0.56*	-0.20
RRB	-0.06	-0.09	0.19	-0.14	-0.41	-0.28	-0.39	-0.01
SRS	0.34	-0.18	0.48	-0.14	-0.44	-0.65*	-0.29	0.18
CARS	0.29	-0.40	0.20	-0.36	-0.51*	-0.64**	-0.50*	-0.05

* $p < .05$; ** $p < .01$

Table 11

Correlations Among the Indices of the BRIEF and ASD Symptoms

	Inhibit	Shift	Emotional Control	Initiate	Working Memory	Plan/Org	Org Materials	Monitor
ADOS	-0.10	0.05	-0.23	0.36	0.21	0.27	-0.06	0.26
Social	-0.28	-0.01	-0.20	0.09	0.10	-0.07	-0.28	-0.04
Communication	-0.16	0.07	-0.12	0.21	0.10	0.18	-0.17	0.23
Combined	0.06	0.19	-0.031	0.31	0.34	0.17	-0.23	0.27
RRB	0.49	0.68**	0.26	0.73**	0.72**	0.68**	-0.10	0.68**
SRS	-0.05	0.20	0.14	0.20	0.25	0.20	-0.45	0.18

* $p < .05$; ** $p < .01$