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Executive Functioning in Asperger's Disorder and Nonverbal Learning Disabilities: A Comparison of Developmental and Behavioral Characteristics

Nathan E. Kegel

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EXECUTIVE FUNCTIONING IN ASPERGER’S DISORDER AND NONVERBAL LEARNING DISABILITIES: A COMPARISON OF DEVELOPMENTAL AND BEHAVIORAL CHARACTERISTICS

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for
the degree of Doctor of Philosophy

By
Nathan E. Kegel, M.S.Ed.

December 2010
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Nathan E. Kegel

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EXECUTIVE FUNCTIONING IN ASPERGER’S DISORDER AND NONVERBAL LEARNING DISABILITIES: A COMPARISON OF DEVELOPMENTAL AND BEHAVIORAL CHARACTERISTICS
ABSTRACT

EXECUTIVE FUNCTIONING IN ASPERGER’S DISORDER AND NONVERBAL LEARNING DISABILITIES: A COMPARISON OF DEVELOPMENTAL AND BEHAVIORAL CHARACTERISTICS

By
Nathan E. Kegel

December 2010

Dissertation supervised by Jeffrey A. Miller, Ph.D., ABPP

Autism spectrum disorders (ASD) are a broad classification of pervasive developmental disorders characterized by impairments in the development of reciprocal social and communication skills, abnormal language development, and a restricted repertoire of behaviors and interests. Evidence suggests that individuals with ASD also experience deficits in executive functioning, particularly cognitive flexibility. Deficits in cognitive flexibility have been related to the presence of repetitive behaviors and interests in adults with ASD. The goal of this study was to extend these findings to children and adolescents with Asperger’s Disorder. In addition, this study examined comparisons in executive functioning between children and adolescents with Asperger’s Disorder and those with nonverbal learning disability (NVLD), a similar syndrome generally thought
to lack repetitive and stereotyped behaviors characteristic of Asperger’s Disorder. It was hypothesized that children and adolescents with Asperger’s Disorder would perform more poorly on measures of cognitive flexibility/shifting and planning than those with NVLD. Group differences in other domains of executive functioning (e.g. inhibition and working memory) are not expected. Finally, it was hypothesized that cross-sectional age comparisons would reveal a greater discrepancy between adolescents (age range 13-18) with Asperger’s Disorder and NVLD than children (age range 8-12) on measures of cognitive flexibility/shifting, with the Asperger’s Disorder groups performing more poorly in both cases. Groups of children and adolescents with Asperger’s Disorder (n = 26) and NVLD (n = 25) were compared on measures of executive functioning. Results indicated a statistically significant relationship between repetitive behaviors and shifting behaviors in children and adolescents with Asperger’s Disorder. In addition, children and adolescents with Asperger’s Disorder demonstrated greater impairment in shifting behavior on a parent report of executive functioning compared to those with NVLD. Cross-sectional age comparisons did not reveal significant differences between groups. Although children and adolescents in these groups are diagnostically similar, those with Asperger’s Disorder demonstrated significant deficits in cognitive flexibility/shifting compared to those with NVLD. Implications of these findings and recommendations for future research were discussed.
DEDICATION

To my parents, Bill and Celeste, who have always stressed the importance of hard work and the value of education, both of which were essential to my pursuit and completion of graduate school. I sincerely appreciate everything you have done for me and I am truly grateful to be your son.
ACKNOWLEDGEMENTS

I would like to thank the members of my dissertation committee for their guidance throughout this long process. To my chair and academic advisor, Dr. Jeff Miller, thank you for your ongoing support throughout my graduate studies. You have provided me with invaluable academic and professional guidance that will no doubt serve me well as I begin my career. To Dr. Sharon Arffa, you have been integral in shaping my interests and professional development. I appreciate your years of supervision that broadened my thinking and covered a wide range of interesting topics and issues in our field. To Dr. Ara Schmitt, thank you for your thoughtful and insightful feedback as I progressed through this project. Your encouragement and ideas have been much appreciated. Finally, I would like to acknowledge The Watson Institute for allowing me access to the database used in this research project. Your organization does an outstanding job of providing a multitude of beneficial services to children, adolescents, and young adults with developmental disabilities.
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CHAPTER I

Introduction

Autism spectrum disorders (ASD) are characterized by impairments in the development of reciprocal social and communication skills, abnormal language development, and a restricted repertoire of behaviors and interests. Recent prevalence studies conducted by the Centers for Disease Control and Prevention (CDCP) have shown the current rate of ASD to be approximately 1 in 150 (Autism and Developmental Disabilities Monitoring Network, 2007). This represents a significant increase in the number of children identified with ASD compared to previously conducted prevalence studies (Fombonne, 2003; Fombonne & du Mazaubrun, 1992; Powell, Edwards, Edwards, Pandit, Sungum-Paliwal, & Whitehouse, 2000). In addition, the number of students served under the Individuals with Disabilities Education Act (IDEA; 2004) eligibility category of Autism has steadily increased from 2,896 students in 1991 to 165,522 students in 2004 (U.S. Department of Education, 2005). The increasing prevalence of ASD has resulted in a greater need for accurate diagnostic assessment, and ultimately individually tailored interventions.

In addition to impairments in reciprocal social and communication skills, and a restricted pattern of behaviors and interests, individuals with ASD often exhibit difficulties in executive functioning (Bennetto, Pennington, & Rogers, 1996; Lopez, Lincoln, Ozonoff, & Lai, 2005; Luna, Garver, Urban, Lazar, & Sweeney, 2004; Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff & McEvoy, 1994; Ozonoff, Pennington, & Rogers, 1991; Ozonoff, Strayer, McMahon, Filloux & 1994; Szatmari, Tuff, Finlayson, & Bartolucci, 1990). Executive functioning is a cognitive construct that
refers to an individual’s ability to maintain an appropriate problem solving set in order to guide goal-oriented behavior (Tsatsanis, 2005). Executive functioning includes skills such as planning, organization, inhibition, cognitive flexibility, self-monitoring, and use of working memory (Baddeley, 1986; Goldman-Rakic, 1987; Pennington, 1994).

**Executive Functioning**

Executive functioning represents a set of skills critical to functioning in the natural environment. Component skills of executive functioning may work independently or in conjunction with each other to facilitate functioning during activities involving novel problem solving, multistep task completion, and self-assessment of performance. Executive functioning also plays a crucial role in social and behavioral functioning. Individuals with deficits in executive functioning may exhibit increased rigidity, have difficulty shifting from one topic of conversation to another, and may experience increased emotional lability (Lezak, Howieson, & Loring, 2004). These implications for cognitive and behavioral functioning make executive functioning an important area for assessment and subsequent intervention planning.

Accurate assessment of executive functioning and subsequent treatment planning are often complicated by the wide range of functioning and uneven skill development of children with ASD (Loveland & Tunali-Kotoski, 2005; Simeonsson, Huntington, Brent, & Balant, 2001; VanMeter, Fein, Waterhouse, & Allen, 1997). Furthermore, assessment of components of executive functioning is highly dependent upon the developmental level of the individual. This is particularly true for children and adolescents, as they are believed to experience spurts in the development of various components of executive functioning at different points in time. This study will apply relevant theories and
research in order to examine executive functioning in individuals with ASD, taking into account diagnostic characteristics and developmental levels in the formulation of hypotheses.

**Theoretical conceptualizations.** The development of theoretical perspectives on executive functioning has been critical to increasing understanding of this complex construct. As theoretical conceptualizations of executive functioning have emerged over time, many have provided extensions to previous theory, while others have offered competing viewpoints. Several early models of executive functioning proposed unitary systems that operate under a “central” or “supervisory” process (Baddeley, 1986; Luria, 1981; Norman & Shallice, 1986). Most notably, Luria (1981) proposed a unitary system where self-regulation was the key outcome of effective executive functioning. In addition, Norman and Shallice’s Supervisory Attentional System (SAS; 1981) presents a relatively unified system that oversees cognitive and behavioral processes in the regulation of behavior. Under the SAS, routine control is accomplished by over-learning and eventually allowing information to become automatic. The supervisory-executive system represents a second level of control necessary when solving logical problems, planning, and correcting unexpected errors. While the early version of the SAS model presented a predominantly unitary viewpoint of executive functioning, more recent versions have moved more towards differentiation and fractionation (Miyake et al., 2000).

Recent conceptualizations have moved away from the unitary model, instead treating executive functioning as a construct made up of separate but related components. For example, Pennington and Ozonoff (1996) endorse the presence of a cluster of weakly
coupled functions converging upon “planning or programming future actions, holding those plans or programs on-line until executed, and inhibiting irrelevant actions” (p. 55). Other models representing a fractionated approach have attempted to categorize components of executive functioning according to associated neuroanatomical locations. For example, Zelazo and Muller (2002) propose a model of executive functioning that distinguishes between “hot” and “cool” aspects. Under their model, “hot” aspects represent affective or emotionally driven processes associated with the ventral and medial prefrontal cortex, while “cool” aspects are associated with abstract problem-solving skills more likely mediated by the dorsolateral prefrontal cortex. This type of model may be especially useful in clarifying the roles of specific executive functions in clinical disorders, such as ASD (Hongwanishkul, Happaney, Lee, & Zelazo, 2005).

**Executive Functioning in Autism Spectrum Disorders**

Deficits in executive functioning in individuals with ASD have been the subject of considerable empirical investigation. Individuals with ASD have been shown to perform more poorly than typical controls in several domains of executive functioning including working memory (Bennetto et al., 1996), planning (Prior & Hoffman, 1990), and cognitive flexibility (Bennetto et al., 1996; Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff, Pennington, & Rogers, 1991; Ozonoff & McEvoy, 1994; Ozonoff, Strayer, McMahon, Filloux & 1994; Szatmari, Finlayson, & Bartolucci, 1990).

Furthermore, impairments in domains of executive functioning occur in subjects of varying age ranges, from children (Goldberg, Mostofsky, Cutting, Mahone, Astor, Denckla, & Landa, 2005; McEvoy, Rogers, & Pennington, 1993; Prior & Hoffman, 1990; Yerys, Hepburn, Pennington, & Rogers, 2007), to adolescents (Luna, Garver, Urban,
Lazar, & Sweeney, 2004; Ozonoff & McEvoy, 1994; South, Ozonoff, & McMahon, 2007), to adults (Bogte, Flamma, van der Meere, & van Engeland, 2008; Lopez et al., 2005; Rumsey, 1985; Rumsey & Hamburger, 1988). This evidence suggests that deficits in domains of executive functioning in individuals with ASD are present, to some extent, at various points across the lifespan.

**Application of developmental theory.** The fractionated yet interrelated nature of components of executive functioning can make it difficult to understand the developmental course of specific components, and executive functioning in general. For example, a child’s ability to successfully utilize planning skills on a Tower task, involving the stepwise arrangement of colored balls on pegs, may be dependent upon his or her ability to inhibit incorrect moves. In general, development of executive functioning is non-linear, and appears to coincide with maturation of the prefrontal cortex, specifically increased myelination and cellular differentiation (Cummings, 1993; Hale, Bronik, & Fry, 1997; Yakovlev & Lecours, 1967). Developmental theory suggests that executive functions emerge during the first several years of life (Diamond, 1988) and experience notable spurts in development in late childhood and early adolescence (Luna et al., 2004), with adult levels of performance on some tasks being reached by approximately 12 years of age (V. Anderson, P. Anderson, Northam, Jacobs, & Catroppa, 2001; Chelune & Baer, 1986; Welsh, Pennington, & Grossier, 1991; Zelazo & Muller, 2003).

Examination of executive functioning in individuals with ASD at various stages of development has yielded mixed results, with studies using samples of adolescents and adults appearing more consistent than studies using younger children. Several studies
(e.g. Griffith, Pennington, Wehner, & Rogers, 1999; Rutherford & Rogers, 2003; Yerys, Hepburn, Pennington, & Rogers, 2007) have failed to find evidence of executive impairment in preschoolers and young children with ASD compared to typically developing controls. Longitudinal and cross-sectional research on older children and adolescents with ASD indicates significant impairments in executive functioning in the groups with ASD (Luna et al., 2004; Ozonoff & McEvoy, 1994). There is also evidence that performance on neuropsychological tests of executive functioning reaches a developmental ceiling for adolescents with ASD (Ozonoff & McEvoy, 1994). Overall, it appears that, as individuals with ASD progress through childhood and adolescence, their deficits in executive functioning become more pronounced compared to typically developing controls.

Executive Function Theory of Autism Spectrum Disorders. According to the Executive Function Theory, the primary symptoms of ASD are a manifestation of deficits in executive control over behavior (Joseph, 1999). Central to this theory, is the belief that these deficits are the result of abnormalities of the prefrontal cortex and the interconnections between cortical and subcortical brain structures (Joseph, 1999; Pennington & Ozonoff, 1996). Under the framework of the Executive Function Theory, studies have attempted to examine the relationship between executive functioning and the social impairments (Landa & Goldberg, 2005), language impairments (Joseph, McGrath, & Tager-Flusberg, 2005; Landa & Goldberg, 2005), and repetitive behaviors (Lopez et al., 2005) characteristic of ASD. Efforts to apply Executive Function Theory to social and language impairments have been met with mixed results (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002; Joseph et al., 2005; Landa & Goldberg, 2005); however, the
relationship between executive functioning and repetitive behaviors and interests appears to be stronger (Lopez et al., 2005). Considering these results, the primary use of the Executive Function Theory of ASD may be in the examination and explanation of repetitive behaviors and interests.

**Rourke’s Model of Nonverbal Learning Disabilities**

The primary neuropsychological characteristic of Nonverbal Learning Disability (NVLD) is significantly better performance on measures of verbal IQ compared to nonverbal IQ (Pennington, 2009). NVLD features a constellation of strengths and weaknesses consistent with this discrepancy. Rourke proposed a model of NVLD that includes primary deficits in nonverbal aspects of functioning, such as visual-spatial organization, nonverbal problem solving, psychomotor coordination, and tactile perception (Rourke, 1995; Rourke, Ahmad, Collins, B. A. Hayman-Abello, S. E. Hayman-Abello, & Warriner, 2002). Other deficits include difficulty understanding pragmatic aspects of language, social perception, and social judgment. On the other hand, strengths in verbal rote memory, selective and sustained attention for simple verbal material, and well-developed receptive language skills are often observed in individuals with NVLD. The cognitive and behavioral profile of individuals with NVLD is strikingly similar to that of individuals with Asperger’s Disorder, a classification of ASD (Gunter, Ghaziuddin, & Ellis, 2002; Rourke et al., 2002).

Rourke’s model of NVLD is based on a theory of brain functioning that suggests progressive left-right lateralization of functions throughout development. According to this concept, the right hemisphere is principally responsible for visual-spatial skills, whereas the left hemisphere manages language functioning (Rourke, 1988). This initial
model was used by Rourke to explain the strengths and weaknesses he observed in individuals with NVLD. Under this model of left-right lateralization, it has been found that individuals with NVLD appear to demonstrate behaviors indicative of right hemisphere deficits (Myklebust, 1975; Rourke, 1989; Rourke, 1995; Rourke et al., 2002).

Rourke later expanded upon his model of right hemisphere dysfunction by acknowledging the role of white matter in the cognitive and behavioral presentation of individuals with NVLD (Rourke, 1995; Rourke et al., 2002). White matter fibers are connections that serve as communication pathways between regions of the brain. According to Rourke’s “white matter model,” damage to these connections would lead to dysfunction in communication to the right hemisphere (Rourke, 1995). Rourke’s model expanded upon previous theories of hemispheric localization by illustrating the potential importance of white matter connectivity in the cognitive and behavioral deficits of NVLD.

**Critical Analysis of Relevant Literature**

Much of the research examining executive functioning in ASD, particularly early studies, utilized predominantly adult subjects (Bogte et al., 2008; Lopez et al., 2005; Rumsey, 1985; Rumsey & Hamburger, 1990). More recently, the focus has shifted towards children and adolescents. Any examination of executive functioning in children and adolescents must be viewed in the context of developmental theory. Development of executive functioning is generally believed to follow a nonlinear progression involving spurts in development at various points during childhood and adolescence (Chelune & Baer, 1986; Welsh, Pennington, & Grossier, 1991; Zelazo & Muller, 2003). As a result, comparisons between children and adolescents with ASD and typically developing
controls should take into account the age range of the sample. Attempting to make comparisons between subjects of a narrow age range in the context of developmental theory of executive functioning is ideal. This has often not been the case in many studies of executive functioning in ASD. Several studies have incorporated wide age ranges of participants, from children to adolescents and occasionally extending to adults (Brian, Tipper, Weaver, & Bryson, 2003; Kleinhans, Akshoomoff, & Delis, 2005; Ozonoff et al., 2004; Szatmari et al., 1990). Alternatively, use of a cross-sectional design to separate participants into more finite age ranges adhering to developmental theory of executive functioning would allow for more accurate and meaningful comparisons between children and adolescents with ASD and typically developing controls.

The extensive study of executive functioning in individuals with ASD over the past several years has led to the establishment of an executive profile of impaired cognitive flexibility and planning with relatively intact inhibition (Kleinhans, Akshoomoff, & Delis, 2005; Ozonoff et al., 2004). Under the framework of the Executive Function Theory, the establishment of an executive profile has facilitated the exploration of the relationship between components of executive functioning and the social, communicative, and repetitive behavioral manifestations of ASD. In particular, deficits in cognitive flexibility appear to be closely related to restricted and repetitive patterns of behaviors and interests characteristic of ASD (Lopez, Lincoln, Ozonoff, & Lai, 2005). On the other hand, attempts to establish a relationship between executive functioning and the social and language impairments characteristic of ASD have been less successful (Joseph et al., 2005; Landa & Goldberg, 2005).
The neuropsychological and behavioral profile of NVLD is remarkably similar to that of ASD, particularly Asperger’s Disorder (Rourke et al., 2002). In fact, some have suggested the possibility of classifying NVLD as a variant of Asperger’s Disorder due to the similar characteristics of the two conditions (Pennington, 1991; Rourke, 1995; Rourke, et al., 2002). These similarities include general strengths on verbal tasks accompanied by weaknesses in visual-spatial skills and deficits in social perception, judgment, and interaction skills that sometimes lead to social withdrawal (Rourke, 1995).

Despite the many similarities between NVLD and Asperger’s Disorder, the primary distinction between the two conditions appears to rest on the presentation of restricted and repetitive behaviors and interests. Rourke’s model (1988, 1995) does not include restricted and repetitive behaviors and interests as a characteristic of NVLD. Since Rourke’s proposed model of NVLD, it has become generally accepted that individuals with NVLD lack stereotypic restricted and repetitive behaviors and interests that are a key feature of Asperger’s Disorder (Rourke & Tsatsanis, 2000; Stein, Klin, & Miller, 2004). Given the relationship between executive functioning, particularly cognitive flexibility, and repetitive behaviors and interests, it might be expected that individuals with NVLD would not exhibit the same executive profile as individuals with Asperger’s Disorder. Specifically, it is possible that individuals with NVLD lack deficits in cognitive flexibility that appears to underlie the presentation of restricted and repetitive behaviors and interests characteristic of ASD. However, despite their neuropsychological similarities, direct comparisons of executive functioning in individuals with Asperger’s Disorder versus NVLD are lacking in the literature.
**Problem Statement**

Individuals with ASD often present with deficits in executive functioning, specifically cognitive flexibility (Bennetto et al., 1996; Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff, Pennington, & Rogers, 1991; Ozonoff & McEvoy, 1994; Ozonoff, Strayer, McMahon, Filloux & 1994; Szatmari, Finlayson, & Bartolucci, 1990) and planning (Hughes et al., 1994; Ozonoff & McEvoy, 1994; Prior & Hoffman, 1990). On the other hand, inhibition (Goldberg et al., 2005; Ozonoff & Strayer, 1997) and working memory (Hughes et al., 1994; Ozonoff & Strayer, 2001; Russell et al., 1996) appear relatively intact when compared to control groups. Furthermore, deficits in cognitive flexibility appear to be closely related to restricted and repetitive patterns of behaviors and interests characteristic of ASD (Lopez, Lincoln, Ozonoff, & Lai, 2005).

Individuals with NVLD exhibit many of the same neuropsychological and behavioral characteristics as individuals with ASD, particularly Asperger’s Disorder. Given the similarities between NVLD and Asperger’s Disorder, it is often difficult to differentiate the two diagnostically. Executive functioning of individuals with NVLD has not been as thoroughly researched as it has in subjects with ASD, and it is not clear if consistent deficits are present in this group. Comparisons of executive functioning of individuals with ASD and NVLD may reveal differences between the two groups, and provide clinicians with useful information when formulating diagnoses and designing treatment interventions.
Research Questions

1. Which component of executive functioning will relate to repetitive and stereotyped behaviors and interests characteristic of children and adolescents with Asperger’s Disorder?

   Hypothesis 1: Performance of children and adolescents with Asperger’s Disorder on tasks of cognitive flexibility/set-shifting will have a negative relationship with repetitive and stereotyped behaviors and interests.

   Hypothesis 2: Behavioral ratings of cognitive flexibility/shifting will have a positive relationship with repetitive and stereotyped behaviors and interests.

2. Which executive function(s) will differentiate children and adolescents with Asperger’s Disorder from those with NVLD?

   Hypothesis 3: Children and adolescents with Asperger’s Disorder will perform significantly more poorly than those with NVLD in their ability to use cognitive flexibility/set shifting on measures of executive functioning.

   Hypothesis 4: Children and adolescents with Asperger’s Disorder will not differ significantly from those with NVLD in their performance on measures of inhibition.

   Hypothesis 5: Children and adolescents with Asperger’s Disorder will not differ significantly from those with NVLD in their performance on measures of working memory.
Hypothesis 6: Children and adolescents with Asperger’s Disorder will perform significantly more poorly than those with NVLD in their ability to use planning on measures of executive functioning.

3. How will a cross-sectional division based on age affect comparison of executive functioning between subgroups of children (age range 8-12) and adolescents (age range 13-18) with Asperger’s Disorder and NVLD?

Hypothesis 7: Adolescents with Asperger’s Disorder (age range 13-18) will demonstrate weaker performance than children with Asperger’s Disorder (age range 8-12) on measures of cognitive flexibility/set-shifting relative to age-matched participants with NVLD.

Hypothesis 8: No significant interaction will be present between age group and diagnostic category on measures of inhibition.

Hypothesis 9: No significant interaction will be present between age group and diagnostic category on a measure of working memory.

Hypothesis 10: Adolescents with Asperger’s Disorder (age range 13-18) will demonstrate weaker performance than children with Asperger’s Disorder (age range 8-12) on measures of planning relative to age-matched participants with NVLD.
CHAPTER II

Literature Review

Background and History

Autism spectrum disorders (ASD) are a broad classification of pervasive developmental disorders typically characterized by impairments in social interaction, communication skills, and restrictive and repetitive interests and activities. The general term “autism” was first used by Swiss psychiatrist Eugen Bleuler in 1911 to describe the loss of contact with reality experienced by individuals with schizophrenia (Bleuler, 1911/1950, as cited in Klinger, Dawson, & Renner, 2003). It was not until the 1940’s that the hallmark symptoms of impaired social interactions, abnormal communication skills, and restricted and repetitive interests were described outside of the context of schizophrenia. Leo Kanner (1943, as cited in Klinger et al., 2003) described his observations of a group of children who exhibited a lack of social awareness, deviance in language characterized by delays in acquisition, echolalia, mutism, and pronoun reversals, accompanied by a desire to engage in ritualistic behaviors and routines. In 1944, Hans Asperger described a group of children similar to those Kanner observed, with the absence of impaired language skills. The children in Asperger’s case study exhibited strong vocabularies and grammatical abilities, but continued to display difficulties in social interactions and conversation skills (Asperger, 1944/1991, as cited in Klinger et al., 2003). The identification of individuals who lacked the typical language impairment seen in autism eventually led to the development of a separate diagnostic label of Asperger’s Disorder for individuals displaying those characteristics.
Along with socialization, communication, and behavioral deficits, Kanner (1943, as cited in Klinger et al., 2003) also noted several cognitive characteristics of the group he observed. He determined that the individuals demonstrated specific strengths on various parts of IQ tests, particularly those that test rote memory and copying, rather than comprehension of abstract verbal concepts. This finding led him to conclude that individuals with autism were not mentally retarded, but instead performed poorly on some mental measures due to motivational factors. Subsequent observations and research have shown that, when developmentally appropriate measures are used, the majority of individuals with autism score in the mentally retarded range (Rutter, Bailey, Bolton, & Le Couteur, 1994). It is important to note that, when cognitive abilities are considered in terms of the broader classification of ASD, including conditions such as Asperger’s Disorder and Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS), a much more varied range of ability is observed (Bailey, Palferman, Heavey, & Le Couteur, 1998).

**Diagnosis and Classification**

The classification of ASD’s includes a number of conditions that share similar characteristic deficits in social functioning, atypical communication, and restrictive and repetitive behaviors and interests. ASD’s fit into the broader classification of Pervasive Developmental Disorders (PDD) that include several disorders in which a developmental delay or regression of previously acquired skills occurs. What follows is a brief review of accepted diagnostic criteria for common ASD’s and other PDD’s.

**Autistic Disorder.** According to the current standards of the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision* (DSM-IV-TR;
APA, 2000), a traditional diagnosis of Autistic Disorder requires the presence of a threshold of symptoms from a triad of general characteristics including (1) impairments in social interaction, (2) impairments in communication, and (3) restricted and repetitive interests and activities. Impairments in social interaction include characteristics such as an inability to utilize nonverbal behavior (i.e. eye contact, facial expressions, and gestures) during social interactions, failure to develop age appropriate peer relationships, a lack of spontaneous seeking to share enjoyment, interests, or achievements with others, and a lack of social or emotional reciprocity. Impairments in communication can be represented by a delay or lack of spoken language, impairments in the ability to initiate and sustain conversation, stereotyped and repetitive use of language or idiosyncratic language, and a lack of developmentally appropriate make-believe play. Restrictive and repetitive interests are indicated by an abnormal preoccupation with one or more stereotyped pattern of interest, inflexible routines and rituals, repetitive motor mannerisms, and a preoccupation with parts of objects.

The level of cognitive functioning for individuals with Autistic Disorder varies greatly. The terms low-functioning (IQ < 70) and high-functioning (IQ >70) autism are frequently used in the literature to characterize subgroups based on level of intellectual ability (Tsatsanis, 2005). Specific intellectual profiles for individuals with Autistic Disorder have been reviewed extensively, and it is typically found that rote memory and visual-spatial processing are well preserved and frequently a strength (Ghaziuddin & Mountain-Kimchi, 2004; Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995; Lincoln, Allen, & Kilman, 1995; Mayes & Calhoun, 2003).
**Asperger’s Disorder.** Hans Asperger’s original description of the syndrome that would one day bear his name included deficits in social interaction accompanied by what appeared to be intact language and cognitive abilities. The current DSM-IV-TR criteria for Asperger’s Disorder include the following: (1) impairments in social interaction such as poor use of nonverbal gestures (e.g. eye contact, facial expression, body postures), failure to develop developmentally appropriate peer relationships, and lack of spontaneous seeking of social or emotional reciprocity; (2) restricted repetitive and stereotyped patterns of interests and behaviors such as preoccupation with subjects of interest abnormal in either intensity or focus, inflexible adherence to specific, nonfunctional routines or rituals, stereotyped and repetitive motor movements, and persistent preoccupation with parts of objects; (3) no clinically significant delay in language, and (4) no clinically significant delay in cognitive development or in the development of age-appropriate self-help skills, adaptive behavior, and curiosity about the environment in childhood (APA, 2000).

The intellectual profiles of individuals with Asperger’s Disorder point to a pattern of better verbal relative to poorer perceptual organizational skills overall (Ghaziuddin & Mountain-Kimchi, 2004; Lincoln, Courchesne, Allen, Hanson, & Ene, 1998; Ozonoff, South, & Miller, 2000). The cognitive profile as measured by standardized instruments indicates a significant discrepancy between verbal IQ (VIQ) and performance IQ (PIQ), with VIQ > PIQ on average for individuals with Asperger’s Disorder (Ghaziuddin & Mountain-Kimchi, 2004; Klin et al., 1995).

**High Functioning Autism vs. Asperger’s Disorder.** Accurate classification of ASD is complicated by the fact that individuals with ASD can display considerable
behavioral and cognitive heterogeneity. One of the most difficult distinctions is between high functioning autism (HFA) and Asperger’s Disorder. HFA is generally defined as those individuals who meet the DSM-IV-TR criteria for Autistic Disorder, and have a full scale IQ of over 70 (Ghaziuddin & Mountain-Kimchi, 2004; Ozonoff, Pennington, & Rogers, 1991). Several clinical features have been shown to distinguish HFA from Asperger’s Disorder including motor clumsiness, pedantic speech, and cognitive factors. Individuals with HFA typically lack the VIQ-PIQ discrepancy seen in Asperger’s, with the latter demonstrating better verbal than performance IQ (Ghaziuddin & Mountain-Kimchi, 2004). Ghaziuddin and Mountain-Kimchi also noted that individuals with Asperger’s Syndrome tend to possess higher full scale IQ’s than those with HFA. These authors do, however, caution that both groups contained subjects with scores more characteristic of the other group. Observations such as these serve as a reminder that, although there appear to be some trends in characterization of cognitive abilities of individuals with ASD, the considerable variability that exists within this population must always be taken into account when conducting assessments.

**Other Pervasive Developmental Disorders.** Rett’s Disorder and Childhood Disintegrative Disorder are two forms of PDD that appear to be far less common than Autistic Disorder or Asperger’s Disorder. These disorders involve similar loss of skills following a period of apparently typical development. Rett’s Disorder is reported only in females and includes loss of previously acquired purposeful hand skills leading to the development of stereotyped hand movements, loss of social engagement skills, development of poor gait or trunk movements, and evidence of severe psychomotor retardation (APA, 2000). Childhood Disintegrative Disorder is marked by a loss of
previously acquired expressive or receptive language, social skills or adaptive behavior, bowel or bladder control, play, or motor skills (APA, 2000).

The DSM-IV-TR designates the diagnosis of Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS) when there are noted severe and pervasive impairments in the development of reciprocal social interactions associated with impairment in either verbal or nonverbal communication skills or with the presence of stereotyped behaviors, interests, and activities, but the criteria is not met for a specific Pervasive Developmental Disorder (APA, 2000).

Prevalence

Epidemiological studies of ASD have been conducted since the 1960’s and have found varying prevalence rates of the disorder. In a review of ASD prevalence studies, Fombonne (2003) noted that studies published after 2000 revealed average prevalence rates of approximately 1 per 166 compared to rates of 1 per 1,000 in previous studies. Recent studies from the Centers for Disease Control and Prevention (CDCP) have found prevalence rates of ASD of approximately 1 per 150 (Autism and Developmental Disabilities Monitoring Network, 2007). This data suggests an overall increase in the number of children identified with ASD.

Not surprisingly, the number of children with ASD served in special education programs has increased as well. The number of students served under the Individuals with Disabilities Education Act (IDEA; 2004) eligibility category of Autism has steadily increased from 2,896 students in 1991 to 165,522 students in 2004 (U.S. Department of Education, 2005). In addition, Kohrt (2004) reported that, in a survey of school psychologists, 95% of respondents indicated an increase in the number of students with
ASD on their caseloads. Given the increase in the number of students served by special education, accurate assessment is necessary for appropriate identification and effective treatment planning.

**Executive Functioning**

Executive functioning is a cognitive construct used to describe an individual’s ability to maintain an appropriate problem solving set in order to guide future (goal-directed) behavior (Tsatsanis, 2005), including planning, organization, inhibition, cognitive flexibility, focused attention, self-monitoring, and use of working memory (Baddeley, 1986; Goldman-Rakic, 1987; Pennington, 1994). Executive functions are critical higher order processes that act globally, affecting many aspects of cognitive functioning. Thus, impairments in executive functioning can directly lead to cognitive deficits by compromising strategies to initiating, planning, or carrying out cognitive tasks, or by adversely affecting monitoring of performance (Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Goldberg, 2001). Conversely, individuals with cognitive impairments may often continue to successfully function independently in social and vocational domains when executive functioning abilities remain intact (Lezak, Howieson, & Loring, 2004).

Executive functioning is a multidimensional construct consisting of specific skills (cognitive flexibility, focused attention, inhibition, planning, organization, and self-monitoring), some of which are related or dependent upon one another. For example, Tower tasks, such as the Tower of Hanoi (Welsh, Pennington, Ozonoff, Rouse, & McCabe, 1990) and Tower of London (Shallice, 1988), involving the arrangement of colored discs or balls on a series of pegs, are primarily used as a measure to examine an
individual’s ability to plan a sequence of moves to successfully achieve an outcome. In addition to planning, this task also appears to involve working memory as the individual is required to maintain a representation of the potential move while considering its consequences (Ozonoff, South, & Provencal, 2005). Thus, successful completion of Tower tasks is dependent, at least to some extent, on an individual’s ability to employ working memory in conjunction with planning strategies.

Another complicating factor in the measurement of executive functioning is the interaction of executive processes with non-executive processes. Using the previous example of Tower tasks, it is apparent that an individual’s spatial ability or motor skills may also play a role in successful completion of the task (Pennington & Ozonoff, 1996). As a result, it is important to consider the extent to which other cognitive processes contribute to, and interact with, the executive processes that are purported to be involved in assessment measures.

**Components of executive functioning.** Many models of executive functioning identify and define its hypothesized component processes in different ways (e.g. Borkowski & Muthukrishna, 1992; Butterfield & Albertson, 1995; Zelazo, Carter, Reznick, & Frye, 1997). For the purposes of this review, brief explanations will be provided for four commonly agreed upon elements of executive functioning: cognitive flexibility, inhibition, working memory, and planning.

**Cognitive flexibility.** Cognitive flexibility is generally defined as the component of executive functioning that involves cognitive and behavioral adaptation to the changing demands of complex environments (Hughes, Graham, & Grayson, 2004). This ability is a prominent trait of mature human behavior, and may be particularly important
in the social environment. Measures of cognitive flexibility typically attempt to impose changing rules and tasks demands on individuals, or may involve switching back-and-forth between equally important tasks.

**Inhibition.** Inhibition refers to the suppression of internal or external information that could potentially interfere with reaching a desired goal (Leon-Carrion, Garcia-Orza, & Perez-Santamaria, 2004). Tasks measuring inhibition generally require the examinee to ignore stimuli meant to interfere with their successful completion of the task. The stimulus to be ignored is often “prepotent”; it has the natural ability to draw the individual’s attention towards it (Hughes, Graham, & Grayson, 2004). Sometimes referred to as *resistance to* interference, many authors suggest that inhibition is a fundamental component of executive functioning, and that many executive impairments are a result of primary deficits in inhibition (Barkley, 1997).

**Working Memory.** Working memory involves holding information in an active state in order to utilize it for future goal-oriented action (Baddeley, 1986; Hughes, Graham, & Grayson, 2004). Current models of working memory emphasize multiple components that involve separate but related systems and processes that function together in order to complete working memory tasks (e.g. Baddeley, 2003). Measures of working memory often present the examinee with progressively larger amounts of information that requires some sort of mental manipulation before producing a response.

**Planning.** In the context of executive functioning, planning involves the fluent production of an efficient strategy meant to achieve a goal. In order to generate a successful plan, an individual must organize their cognitive and behavioral resources in order to obtain a goal that may not be the immediate consequence of a single action.
Neuropsychological measures of planning often prompt examinees to arrange simple objects (e.g. discs or balls) in a designated pattern involving the coordination of correct moves in order to reach the desired goal.

**Neuroanatomy of executive functioning.** The cognitive components of executive functioning (e.g. cognitive flexibility, working memory, planning, etc.) are typically believed to reside in the frontal lobe of the brain (Eslinger, 1996; Kolb & Whishaw, 2003; Lezak et al., 2004; Zelazo & Muller, 2002). Executive functioning was first linked to the frontal lobe when patients with frontal lobe damage presented with behaviors and cognitive difficulties that are now commonly associated with deficits in executive functioning. Lezak and colleagues (2004) describe the following five general deficits in executive functioning that are frequently observed in patients with frontal lobe damage:

1.) Difficulty initiating tasks and decreased spontaneity, as well as decreased fluency of responses

2.) Difficulties making mental or behavioral shifts, whether they are shifts in attention, changes in movement, or flexibility in attitude. These difficulties may also appear behaviorally as perseveration or rigidity

3.) Deficits in stopping or modulating ongoing behavior that may appear as disinhibition or impulsivity

4.) Deficient self-awareness or self-monitoring that may result in an inability to recognize errors, appreciate the impact one has on others, and difficulty assessing social situations appropriately

5.) Concrete thinking and a general deficit in abstract thinking that may appear as
a tendency to attach literal meanings to objects, experiences, and behavior

Individuals with compromised frontal lobe functioning may exhibit more complex and multidimensional deficits as a result of the reciprocal cortical and subcortical connections to other areas of the brain (Kolb & Whishaw, 2003; Zelazo & Muller, 2002).

**Prefrontal Cortex.** Within the frontal lobe, components of executive functioning have been linked specifically to areas of the prefrontal cortex, including the dorsolateral prefrontal cortex and the orbitofrontal cortex (Zelazo & Muller, 2002). The prefrontal cortex is the region of the cerebral cortex anterior to the premotor cortex. It comprises between a quarter and a third of the overall surface area of the cerebral cortex (Fuster, 1989). The dorsolateral prefrontal cortex and the orbitofrontal cortex are two distinct areas of the prefrontal cortex associated with specific functionality.

**Dorsolateral Prefrontal Cortex.** The dorsolateral prefrontal cortex is located in the region of the prefrontal cortex anterior to the premotor cortex (Kolb & Whishaw, 2003). The dorsolateral prefrontal cortex has connections to a number of brain regions including the posterior temporal, parietal, and occipital lobes, as well the basal ganglia. These connections establish the dorsolateral prefrontal cortex as an important center for the integration of sensory information and regulation of intellectual function and action (Zelazo & Muller, 2002).

**Orbitofrontal Cortex.** The orbitofrontal cortex is represented by an area that consists of the orbital and medial regions of the prefrontal cortex. The orbitofrontal cortex is generally implicated in the integration of affective information and regulation of behavior because of its strong connections to the amygdala and other parts of the limbic
system (Zelazo & Muller, 2003). The orbitofrontal cortex is also strongly connected to the neighboring dorsolateral prefrontal cortex.

**Development of executive functioning.** The cognitive skills that comprise executive functioning follow different developmental trajectories, making a general discussion of development of executive functioning difficult (Anderson, Northam, Hendy, & Wrennall, 2001). Zelazo and Muller (2003) emphasize several key points that have been highlighted because of developmental research on executive functioning including:

1.) Executive functioning emerges early in development, likely around the end of the first year of life (Diamond, 1988)

2.) Executive functioning develops across a wide range of ages, with critical changes taking place between approximately two and five years of age

3.) Adult levels of executive functioning on many tasks may be reached at approximately 12 years of age

4.) Performance on some measures of executive functioning continues to change into adulthood

It appears clear that specific executive functions emerge at different stages in development, and may interact with each other in complex ways at various points of the developmental trajectory (V. Anderson, P. Anderson, & Lajoie, 1996; Barkley, 1996). The developmental trajectory of executive skills should also be considered nonlinear, and appears to coincide with development of the prefrontal cortex, specifically increased myelination and cellular differentiation (Cummings, 1993; Hale, Bronik, & Fry, 1997; Yakovlev & Lecours, 1967).
Several studies have attempted to examine the performance on specific executive functioning tasks from a developmental perspective (e.g. Anderson et al., 2001; Davidson, Amso, Anderson, & Diamond, 2006). For example, Davidson and colleagues (2006) looked at several aspects of executive functioning (e.g. inhibition, working memory, cognitive flexibility) in a sample of children from age four to thirteen. They found that even young children possess the ability to inhibit dominant responses, however, their ability to exercise inhibition decreased more dramatically than older children when task demands increased. A similar effect was found during working memory tasks. Other studies have demonstrated that performance on tests of inhibition ultimately depends on demands of the task, and appears to improve dramatically around 10 years of age, with near adult performance at approximately 12 years of age (Leon-Carrion, Garcia-Orza, Perez-Santamaria, 2004).

In terms of cognitive flexibility, Davidson and colleagues (2006) found that children were still not performing at adult levels even by age 13. In addition, tasks measuring cognitive flexibility showed a much longer progression in development than inhibition. However, other studies have found adult level performance on tests of cognitive flexibility in 10-year-olds (Chelune & Baer, 1986; Welsh, Pennington, & Grossier, 1991). Stability in performance on tests of cognitive flexibility has also been noted throughout adolescence, indicating maturation on these tasks by late childhood (Anderson et al., 2001). The mixed evidence in developmental studies of executive functioning could be due to a number of factors, including differential task demands on tests purported to measure the same construct, difficulty isolating individual components.
of executive functioning, and the influence of lower order skills (e.g. receptive language, fine motor skills, visual perception) on executive functioning.

**Theoretical conceptualizations of executive functioning.** The complexity of the executive functioning construct has given rise to a long line of theoretical perspectives. As theoretical conceptualizations of executive functioning have emerged over time, many have provided extensions to previous theory, while others have offered competing viewpoints. Theoretical models of executive functioning range from unitary systems that operate under a “central” or “supervisory” process (Baddeley, 1986; Norman & Shallice, 1986), to systems that propose fractionated but related components that function in a temporal or sequential manner (Fuster, 2002; Zelazo et al., 1997). What follows is a brief review of several prominent theoretical conceptualizations relevant to the current examination of executive functioning in ASD.

**Luria’s theory.** Any review of theoretical perspectives of executive functioning would be incomplete without mention of the contributions of Russian psychologist Alexander Luria. According to Luria, the primary roles of the frontal lobes are related to programming, monitoring, and regulating behavior. The self-regulation of behavior is accomplished through verbal mediation of purposeful activity (Luria, 1981). Over the course of development, verbal mediation eventually becomes internalized, providing a child with a system of regulating behavior. Luria’s empirical work has demonstrated developmental improvements showing a peak between the ages of four and seven in children’s ability to plan, monitor, and regulate behavior. Several classic tests of executive functioning in children have been developed through Luria’s work, including
the Go/No Go test, which examines inhibition as it requires the child either execute or withhold a response based on target stimuli.

**Supervisory Attentional System.** Norman and Shallice (1986) expanded on Luria’s idea that the frontal lobes are central to self-regulation. Under Supervisory Attentional System (SAS) theory, cognitive and behavioral processes are organized into schemas that help in the eventual regulation of behavior. Two levels of neuropsychological control mediate control over behavioral schemas. Routine control is accomplished by over-learning and eventually allowing information to become automatic. The supervisory-executive system represents a second level of control necessary when solving logical problems, planning, and correcting unexpected errors. Along these lines, impairments in the supervisory system would result in increased likelihood of lower level, habitual schemas, while decreasing the ability to utilize higher level novel problem solving skills.

**Pennington and Ozonoff’s Model.** More recent conceptualizations have move away from the unitary model, instead treating executive functioning as a construct made up of separate but related components. For example, Pennington and Ozonoff (1996) endorse the presence of a cluster of weakly coupled functions converging upon “planning or programming future actions, holding those plans or programs on-line until executed, and inhibiting irrelevant actions” (p. 55). Pennington and Ozonoff base their theoretical perspective on clinical findings in patients with frontal lobe damage where only specific component skills are affected, leaving general intelligence preserved.

**Zelazo’s Model.** Zelazo and colleagues (1997) conceptualize executive functioning as a macrostructure consisting of executive subfunctions that work together
in order to accomplish the goal of solving problems. They identify four distinct, but temporally related, stages of problem-solving: problem representation, planning, execution, and evaluation. This type of temporal model allows for the identification of locations in the sequence where failures of executive functioning took place. Zelazo believes the integration of individual processes along a temporal continuum does not rely solely on the prefrontal cortex, and likely involves recruitment of other areas of the brain.

“Hot” and “cool” executive functions. Recent research on the functions of the ventral and medial regions of the prefrontal cortex suggests that executive functioning may operate differently depending on environmental contexts or demands (e.g., Bechara, 2004; Clark, Cools, & Robbins, 2004; Miller & Cohen, 2001). Along the lines of this research, Zelazo and Muller (2002) propose a model of executive functioning that distinguishes between “hot” and “cool” aspects. Under their model, “hot” aspects represent affective or emotionally driven processes associated with the ventral and medial prefrontal cortex, while “cool” aspects are associated with abstract problem-solving skills more likely mediated by the dorsolateral prefrontal cortex. In most cases tasks or situations involving executive functioning call upon both hot and cool executive functions in some combination. Nonetheless, this emerging theoretical perspective encourages researchers to adopt a broader perspective on executive functioning that incorporates affective and emotional elements, and may eventually lead to increased clarification of the role of executive functioning in clinical disorders, such as ASD (Hongwanishkul, Happaney, Lee, & Zelazo, 2005).
Research on executive functioning in individuals with ASD began in 1985 with Rumsey’s examination of response perseveration tendencies of adults with Autistic Disorder (Rumsey, 1985). This work led to exploration and elaboration of several aspects of executive functioning in individuals with ASD. In a review of the literature, Pennington and Ozonoff (1996) reported that 13 of 14 studies demonstrated impaired performance on at least one executive functioning task in ASD. Deficits were found in 25 of the 32 executive tasks used across those empirical studies. Many of these studies corroborated earlier findings of perseverative responses and errors (Bennetto, Pennington, & Rogers, 1996; Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff, Pennington, & Rogers, 1991; Ozonoff & McEvoy, 1994; Szatmari, Finlayson, & Bartolucci, 1990), while others provided evidence for dysfunctions in working memory (Bennetto et al., 1996), planning (Prior & Hoffman, 1990), and flexibility (Ozonoff, Strayer, McMahon, Filloux & 1994).

**Early associations between ASD and executive functioning.** Several studies predating Rumsey’s study in 1985 described impairments that appear to overlap with the construct now referred to as executive functioning. Studies examining ASD from a behavioral standpoint found patterns of perseveration and inflexibility. Using operant conditioning, Lovaas and Schreibman (1971) found that a control group of normal children typically attended to multiple cues during learning, while children with ASD often appeared to be more focused on only a small number of cues that were often irrelevant to the learning situation. For example, children with Autistic Disorder learning to discriminate between male and female dolls were reported to focus on clothing details,
such as the presence of a belt, while non-autistic children focused on features of the head region (Schreibman & Lovaas, 1973). Koegel and Schreibman (1977) found that children with Autistic Disorder continued to respond to only one stimulus dimension after hundreds of trials in which responding to the cue was not reinforced. These studies, although conducted from a more behaviorist perspective, provided an early foundation for future investigations of some behavioral characteristics in ASD related to executive functioning.

The early work of Hermelin and O’Connor (1970) studying cognition in individuals with Autistic Disorder revealed a phenomenon that theorists studying executive functioning would later call perseveration. They stated that subjects with ASD tended to persist on responses rather than selecting an alternative one (Hermelin & O’Connor, 1970). Corroborating these results, Frith (1972) found that children with Autistic Disorder engaged in strict rule adherence when sequencing stimuli, ordering them in repetitive and rule-bound patterns more often than controls. In an investigation of maze solving strategies, Boucher (1977) noted a tendency of children with Autistic Disorder to utilize one solution to solve the maze even when presented with alternate correct solutions. Ability-matched normal controls frequently alternated maze solutions between potential correct choices. When novel solutions were presented to subjects on later trials, children with Autistic Disorder remained less likely than normal controls to try the new maze solution (Boucher, 1977). Although the aim of these early studies was not solely focused on executive functioning, they provided a critical background for the theory and methodology behind subsequent studies specifically targeting aspects of the construct.
Damasio and Maurer’s (1978) observation that individuals with ASD displayed some behaviors that were similar to those of persons with frontal lobe damage spawned neuropsychology’s attention to ASD. Behaviors common to individuals with ASD and those frontal lobe damage included difficulties switching between tasks, planning immediate and future activities, and acquiring and modulating social rules (Damasio & Maurer, 1978). The parallel behaviors in the two groups suggested that some of the executive impairments observed in individuals with ASD might have been the result of specific neurological damage or abnormality. This link between brain and behavior paved the way for subsequent study of executive function and ASD from a neuropsychological perspective.

**Early empirical studies of executive functioning in ASD.** Rumsey’s work (1985) was the first to formally target possible executive dysfunction in individuals with ASD using the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948) to demonstrate deficits in cognitive flexibility in a sample of adult men with HFA. The WCST is a conceptual problem-solving task involving four stimulus cards placed in front of a subject. A response deck featuring cards, each with a unique combination of the three stimulus dimensions, is given to the subject, who is then instructed to place each card in front of one of the stimulus cards. The subject is told whether each response is correct or incorrect according to a principle, but is not told what sorting principle was in effect or if that principle will change. Individuals with HFA, defined by Rumsey as meeting the diagnostic criteria for autism according to the *Diagnostic and Statistical Manual of Mental Disorders, Third Edition* (DSM-III; APA, 1980) along with Verbal and Performance IQ’s of 80 or above as measured by the Wechsler Adult Intelligence Scale
(WAIS; Wechsler, 1955), demonstrated significant perseveration, sorting by previously correct rules, despite feedback that their strategies were incorrect. Follow-up studies demonstrated that individuals with HFA sorted significantly fewer WCST categories than age-matched controls, and that the pattern of deficit for individuals with HFA was not a consequence of learning disorders when matched controls were a group of individuals with severe dyslexia (Rumsey and Hamburger, 1988; Rumsey and Hamburger, 1990). Rumsey’s findings served as a catalyst for subsequent studies searching for relationships between behaviors associated with ASD, such as perseveration, and performance on tests of executive functioning.

Prior and Hoffman (1990) found results similar to those of Rumsey on a modified version of the WCST (Nelson, 1976) in a pediatric population. All ambiguous cards were removed from the deck and subjects were explicitly told when to shift set. Despite such modifications, the children with Autistic Disorder made significantly more errors and perseverative responses than controls. This study also examined planning ability of children with Autistic Disorder using the Milner Maze Test (Milner, 1965), and perceptual organization and visual memory using the Rey-Osterrieth Complex Figure Design Copying Test (Rey, 1959). The Milner Maze Test requires the subject to discover and remember one correct path leading from the lower left-hand corner to the upper right-hand corner of the array. In the Rey Complex Figure Test, the subject is presented with a complex figure, 2 blank sheets of paper, and colored pencils. The subject is asked to copy the complex figure using different colored pencils for each minute until the drawing is complete. After a delay of three minutes, during which time the examiner talks to the subject about topics of personal interest, the subject is given the second sheet of paper
and asked to draw the design from memory. Significant differences were noted in number of errors and completion time of the Milner Maze, with the autistic group demonstrating deficits in planning and difficulty learning from mistakes. Significant group differences were not noted in the copy time or copy score of the Rey Complex Figure Test, but rather in the recall score, indicating that the children with Autistic Disorder demonstrated an intact ability to plan and organize as effectively as the normal control group, but have difficulty storing and retrieving this information in a coherent manner. However, it is likely that the visual-spatial demands of the Rey Complex Figure Test, often considered an area of strength for many individuals with Autistic Disorder (Hoffman & Prior, 1982), resulted in their unimpaired performance on this task. The authors did note that perseveration of lines and a tendency to recall smaller details of the figure were common characteristics of the reproductions of the children with Autistic Disorder (Prior and Hoffman, 1990).

Szatmari and colleagues (1990) used the WCST to compare a group of children with Asperger’s Disorder and a group of children with HFA to a control group from an outpatient population that consisted of individuals with Attention-Deficit/Hyperactivity Disorder (ADHD) or Conduct Disorder (Szatmari, Tuff, Finlayson, & Barolucci, 1990). Two interesting characteristics are noted in the subject selection of this study: (1) the inclusion of both an HFA group and an Asperger’s Disorder group; and (2) that the control group was made up of a population that has often been shown to have executive dysfunctions. The authors reported no significant differences between the HFA and Asperger’s Disorder group on many of the neurocognitive measures (e.g. verbal and nonverbal IQ, facial recognition task, visual motor integration test) used, however,
discriminant function analysis revealed discrepancies between the two groups on both perseverative errors and total errors of the WCST. The HFA group committed a greater percentage of perseverative errors and total errors than the Asperger’s Disorder group. Despite this difference, the authors combined both autism spectrum groups in their comparison with the outpatient control group, and found that the ASD group continued to commit more perseverative errors and complete fewer categories on the WCST than the outpatient control group. These findings suggest that the pattern of deficits in executive functioning in individuals with ASD is unique when compared to other conditions that typically evidence deficits in executive functioning.

In a study comparing children and adolescents with HFA to a clinical control group matched on verbal IQ, age, sex, and socioeconomic status (25% of whom also met the criteria for ADHD), Ozonoff and colleagues (1991) confirmed previous findings that individuals with HFA commit significantly more perseverative errors than matched clinical controls (Ozonoff, Pennington, & Rogers, 1991). Individuals with HFA also committed significantly fewer failures to maintain cognitive set than the control group. Maintaining cognitive set involves persisting with an effective strategy when solving a problem, and is logically independent and conceptually opposite to perseveration, which can be thought of as persistence of the same ineffective strategy. The study also found that the group with HFA performed significantly more poorly on the Tower of Hanoi, which was the best predictor of group membership compared to a number of other variables (e.g. theory of mind, emotion perception, and spatial abilities). Ozonoff and McEvoy (1994) followed this group over time and demonstrated that deficits on the
Tower of Hanoi and the WCST were either stable, or tended to show a slight decline, relative to controls over a 2.5-year period.

In an effort to extend the age-range of existing studies, McEvoy and colleagues (1993) conducted the first investigation of executive functions in preschool-age children with ASD using developmentally simple measures of prefrontal function (McEvoy, Rogers, & Pennington, 1993). A spatial reversal task involved a hidden object in one of two identical wells outside the subject’s vision. The location of the hidden object remained the same until the subject successfully located it on four consecutive trials after which time the location was changed to the other well. Successful performance on this task requires flexibility and set-shifting. The sample of children with Autistic Disorder made significantly more perseverative errors than age-matched controls. Combined with previous studies of adults and older children, the findings of this study appear to indicate that perseveration on measures of executive functioning is present throughout the lifespan of individuals with ASD.

Taken together, these early studies began to shed light on some of the strengths and weaknesses in executive functioning of individuals with ASD. Specifically, fairly consistent tendencies of individuals with ASD to perseverate on tasks of cognitive flexibility were noted along with deficits in planning on tower and maze tasks, while early evidence suggests that working memory was spared. The findings of these early studies would continue to be expanded upon by later research using more specific measures and improved methodology to begin to establish a profile of executive functioning for individuals with ASD.
Components of executive functioning and ASD. Although many early studies provided evidence for deficits in executive functioning in autism, their results are somewhat clouded by imprecise methods and instrument selection. Because executive functioning is a multidimensional construct consisting of a number of distinct but interrelated skills, specific component analysis can be difficult when the chosen instruments measure several aspects of executive functioning. For example, the vast majority of early studies utilized the WCST, which is often considered a test of cognitive flexibility, however, other cognitive processes, such as categorization, response inhibition, and selective attention, also appear critical for successful performance (Ozonoff, South, & Provencal, 2005). As a result, subsequent research has focused on more precise measurement of specific components of executive functioning.

Cognitive flexibility and inhibition. Ozonoff, South, and Provencal (2005) describe a component process analysis approach to examining executive functioning and autism, in which the complex cognitive functions of executive functioning are broken into the basic operations that underlie them. Component process analysis is a central methodological strategy of the information processing approach, described by Ozonoff, South, and Provencal (2005) as a broad framework for understanding the sequence of mental operations involved in the performance of cognitive tasks. Thus, this approach allows for a more detailed and precise exploration of a construct like executive functioning.

Cognitive flexibility is perhaps the most extensively studied component of executive functioning in individuals with ASD, likely due to the overwhelming clinical evidence indicating repetitive behaviors and interests in individuals on the autism
spectrum. However, much of the foundational work in this area has failed to take into account the contribution of inhibition into the demands of the task, most commonly the WCST. To illustrate the component process analysis approach, Ozonoff and colleagues (1994) designed a Go-NoGo task to examine the contributions of inhibition and flexibility (Ozonoff, Strayer, McMahon, & Filloux, 1994). The study compared a group of children and adolescents with HFA, defined as meeting the criteria for either Autistic Disorder or Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS) according to the DSM-III-R, and having a Full Scale IQ of 70 or above as measured by the Wechsler Intelligence Scale for Children, Third Edition (WISC-III; Wechsler, 1991), with an age and IQ-matched group with Tourette’s Syndrome and a developmentally typical control group. The Go-NoGo task was computer-administered and involved the presentation of two stimuli, a red circle and a red square, at regular intervals between presentation of the next stimuli. The subject was informed which of the two stimuli were the “Go” trial requiring a response, and which were the “NoGo” trial requiring inhibition of a response. The Go-NoGo task consisted of three phases: (1) a “neutral inhibition” phase in which the Go stimulus did not change; (2) a “prepotent inhibition” phase in which the Go and NoGo stimuli from the first phase switched roles, requiring subjects to inhibit prepotent responses; and (3) a “flexibility” phase involving random assignment of the Go and NoGo stimuli. The final condition required subjects to switch back and forth from responding to a stimulus to inhibiting response to that same stimulus. The performances of the children with HFA were significantly slower and the HFA group made significantly more errors than the comparison group in the both the flexibility condition and the prepotent inhibition condition, while no significant group differences
were noted on the neutral inhibition task. The authors noted that the demands of the prepotent inhibition condition may have involved flexibility as well, accounting for the observed impairment in the ASD group. By designing a task meant to dissociate two related executive functions (flexibility and inhibition) Ozonoff and colleagues were able to conclude with more certainty the extent to which each separate executive function was impaired in children with ASD.

Ozonoff and Strayer (1997) conducted a study to isolate inhibitory operations using a Stop-Signal measure to examine voluntary motor response and a Negative Priming task to measure cognitive inhibitory mechanisms. The Stop-Signal task required subjects to categorize words as either animals or objects by pressing corresponding keys on a response box, with the presence of an auditory signal indicating that responses to the primary task should be inhibited on that trial. The Negative Priming task involved the presentation of a string of five letters, and required subjects to determine whether the second and fourth letters were the same or different. On some trials, the second and fourth letters were the same as the distractor stimuli from the previous trial. They found that subjects with Autistic Disorder were unimpaired on either task compared to age- and IQ-matched normal controls.

These results were more recently confirmed by Brian and colleagues (2003) using a different computer administered negative priming task involving two conditions: (1) a prime display in which the presentation of a target stimulus followed by the presentation of the target and a distractor and (2) a probe display in which the target shared some characteristic of the previously ignored distractor (e.g. color or location). Results indicated that the ability of individuals with ASD (HFA, Asperger’s Disorder, and PDD-
NOS) to selectively direct inhibition to task-relevant stimulus features was intact.

Furthermore, the irrelevant perceptual feature of color actually facilitated performance, improving inhibition ability of individuals with ASD (Brian, Tipper, Weaver, & Bryson, 2003).

Other studies (Hughes, Russell, & Robbins, 1994; Ozonoff, Cook, Coon, Dawson, Joseph, Klin et al., 2004; Turner, 1997) have also attempted to isolate the component processes of cognitive flexibility and inhibition using the Intradimensional-Extradimensional (ID/ED) subtest of the Cambridge Neuropsychological Test Automated Battery (CANTAB; Cambridge Cognition, 1996). The ID/ED is a computerized set-shifting task that measures flexibility while controlling for other cognitive processes. Participants are first trained with stimuli made up of colored shapes and lines, and learn, through trial and error with computerized feedback, to respond to the shape as opposed to the line. In the intradimensional task, new shapes and lines are presented, but shape remains the criteria for response. This task measures perceptual flexibility necessary to shift within cognitive set. In the extradimensional task, the line becomes the relevant stimuli and the shape is now irrelevant. This task demands conceptual flexibility necessary to shift from one concept to another. In comparison to matched controls, individuals with ASD and mental retardation demonstrate intact performance on tasks measuring discrimination learning, inhibitory control, and intradimensional shifting, but impairment in extradimensional shifting (Hughes, Russell, & Robbins, 1994). Turner (1997) also found extradimensional shifting deficits in individuals with ASD and mental retardation, but not in participants with ASD of normal IQ. In another recent study using the ID/ED subtest to assess flexibility, Ozonoff and colleagues (2004) found that
individuals with ASD demonstrated intact intradimensional shifting, but were significantly more impaired than controls on the measure of extradimensional shifting, regardless of IQ across an age range of 6 to 47 years.

The more precise methods and instrument selection of these studies has clarified some of the results of studies that preceded them. In particular, they continued to confirm deficits in cognitive flexibility, while indicating a general pattern of more intact inhibition in individuals with ASD. However, it appears that, when the demands of the inhibition task require cognitive flexibility, as is the case with the prepotent condition of Ozonoff and colleagues’ Go-NoGo task, performance of individuals with ASD is impaired.

In addition to set shifting, another form of flexibility that has been studied in individuals with autism spectrum disorders is attention shifting. Courchesne, Akshoomoff, and Ciesielski (1990) compared a group of adults with autism to an age and IQ matched control sample on a task that measured shifting of attention between sensory modalities. Subjects were told to monitor either an auditory or visual modality until a distractor target was identified, at which time they were to switch to the other modality to find targets. There were no group differences noted between the group with ASD and the control group on the first task, which required no shifting. However, performance of the group with autism was significantly below that of controls on the task that involved rapid shifting of attention between auditory and visual channels. The group with ASD had significantly more difficulty disengaging from prior targets, instead continuing to respond to the previous modality.
Wainwright-Sharp and Bryson (1993) examined attention shifting in adolescents and adults with HFA using a visuospatial orienting task that presented subjects with a cue indicating where attention should be focused just prior to the presentation of the target. The target was either in the box the cue indicated, in the opposite box that the cue indicated, or in both boxes, rendering the cue uninformative. Individuals with HFA were found to take longer than controls to disengage attention from the cue and move it to the appropriate location indicated.

Similar deficits in attention shifting have been found in children with autism spectrum disorders. Rinehart and colleagues (2001) used a global-local task in which stimuli were large digits composed of smaller digits (Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001). Targets could appear at either the global or local level, requiring shifting of attention between stimulus dimensions. The children with ASD were slower, as compared to a group of typically developing age, gender, and IQ matched controls, to find global targets when the previous stimulus was at the local level. These results suggest that children with autism have difficulty shifting attention between processing levels.

The observed impairments of individuals with ASD in the ability to shift attention are not surprising since it is highly dependent upon cognitive flexibility, which has previously been shown to be impaired. Therefore, these findings corroborate earlier findings indicating impaired cognitive flexibility in individuals with ASD.

**Working memory.** Working memory refers to the ability to maintain information in an activated, online state to guide cognitive processing (Baddeley, 1986), and is necessary for the completion of many higher-order problem-solving tasks. Working
memory tasks generally require the individual to simultaneously attend to, recall, and act on presented information and stimuli. This component of executive functioning has been studied fairly extensively in individuals with ASD using a number of tasks such as Tower tasks (Tower of Hanoi, Tower of London) and verbal working memory tasks including those involving counting and sentence span tasks.

Clinical observations suggest that many individuals with ASD possess the ability to utilize rote memory strategies or procedural mechanisms to achieve learning, while presenting with deficits in abstraction and generalization (Tsatsanis, 2005). Empirical evidence has confirmed these observations. Bennetto, Pennington, and Rogers (1996) compared adolescents and adults with HFA to age and IQ matched controls on verbal working memory tasks involving counting and sentence span tasks, as well as tests of declarative memory involving rote short-term memory, verbal long-term memory, and recognition tasks. They found that the group with HFA was significantly more impaired on tasks involving working memory, but performed similarly to controls on the measures of declarative memory. However, Tsatsanis (2005) notes that the tasks used in this study rely more heavily aspects of episodic memory such as the use of learning episodes that are not central to the target, memory for source, and memory for temporal order. This observation indicates difficulty in measuring components often executive functioning that often involve other cognitive processes, and suggests the need for an analysis based on component skill processes like the one proposed by Ozonoff, South, and Provencal (2005).

In another study of working memory and ASD, Russell, Jarrold, and Henry (1996) compared a group of children with Autistic Disorder and a group of children with
moderate learning difficulties to matched controls on measures of verbal working memory such as a dice counting task, a sentence span test, and an odd-man-out task. They found that the children with Autistic Disorder and children with learning difficulties performed significantly more poorly on all tasks, but that no significant difference existed between the two comparison groups. These findings led the authors to conclude that working memory deficits were not exclusive to Autistic Disorder, but were more likely a result of deficits in information processing associated with levels of intellectual functioning.

Ozonoff and Strayer (2001) compared children with HFA to children with Tourette’s Disorder and matched controls on several working memory tasks. In the running memory task the participants were presented with one of four colored shapes and asked to determine whether the shape appeared in the preceding trial (one-back condition) or the penultimate trial (two-back condition). In the spatial memory-span task, participants were presented with a series of one, three, or five colored shapes, and then asked to determine the location of a target shape after the removal of the original sequence of shapes. The box search task required participants to select one of six colored boxes in order to find the three “treasures” under each box. The authors predicted that performance of the HFA group would be specifically more impaired on tasks of verbal working memory (running memory task) than on nonverbal working memory (spatial memory span task). However, this prediction was not confirmed, as they found no significant group differences across the tasks of working memory, and also noted significant correlations between performance and both age and IQ.
The inconsistent results found in working memory studies on individuals with ASD may be due to the use of working memory measures that tapped other executive functions. For instance, organization has a clear role in working memory tasks, as individuals are often required to hold presented information in an active state, and then organize it according to a given set of rules before responding (e.g. Letter-Number Sequencing subtest of the WISC-IV). In addition, Goel and Grafman (1995) suggested that Tower tasks are primarily a measure of planning ability and cognitive flexibility rather than working memory. These findings further confirm the need for more precise component analysis when examining processes related to executive functioning in children with ASD.

**Planning and organization.** Planning involves the identification and organization of steps and elements needed to carry out an intention or achieve a goal (Lezak, Howieson, & Loring, 2004). There are a number of component skills involved in planning including conceptualizing changes, entertaining alternative possibilities, and foreseeing consequences of actions. In terms of executive functions, exercising inhibitory control and utilizing working memory appear to be conceptually tied to an individual’s ability to plan effectively. A number of researchers have examined the role of planning in their examination of EF and autism. Deficits in planning have been observed on the Stockings of Cambridge subtest of the CANTAB. This subtest is a computerized version of the Tower of London task involving three colored balls that must be arranged to match a target configuration. Variables that factor in to the overall efficiency of performance include number of moves and time to complete each trial. Children with autism failed to show age related improvement in planning efficiency (Ozonoff et al., 2004).
Deficits in organization are often observed in individuals with ASD, but empirical investigations of organizational ability appear with far less frequency in the literature than other components of executive functioning. Organization is conceptually linked with planning, and involves many of the same basic processes. Deficits in organization of individuals with ASD are suggested by their difficulty copying and integrating component parts of the Rey Complex Figure Test (Rumsey & Hamburger, 1988), a task heavily reliant upon visual-spatial organization. Verbal organization deficits are also reported in individuals with HFA (Tager-Flusberg, 1991). In their study of children with HFA, defined as having a Full Scale IQ of 70 or above, and Asperger’s Disorder, Kenworthy and colleagues (2005) revealed prominent deficits in organization (Kenworthy, Black, Wallace, Ahluvalia, Wagner, & Sirian, 2005). While there were no significant discrepancies between the HFA group and the Asperger’s group, the combined group of individuals with ASD was reported to have clinically significant levels of disorganization according to parent ratings of the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). In addition, the combined HFA/Asperger’s group displayed deficits in organization on visual problem solving problem-solving tasks. They performed significantly more poorly on the Rey Complex Figure Test than on the Beery-Buktenica Test of Visual-Motor Integration, a visual-spatial task far less reliant upon organization.

While the research base for planning and organization is less established and less comprehensive than that of other executive functions, the existing results point to impairment in these abilities. The impairment of organization and planning abilities in
individuals with ASD likely plays a significant role in difficulties these individuals face in academic and vocational tasks.

**Clarifying the executive profile in ASD.** More recent studies exploring executive functioning and ASD have attempted to identify an executive profile of strengths and weaknesses by incorporating multiple measures for separate executive functions, or by using established neuropsychological batteries such as the Cambridge Neuropsychological Test Automated Battery (CANTAB) and the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001). By simultaneously using multiple measures, researchers are able to determine with more certainty specific executive impairments of the subject group they are testing, and relate these impairments to behaviors characteristic of autism spectrum disorders including social impairments (Landa & Goldberg, 2005), language impairments (Joseph, McGrath, and Tager-Flusberg, 2005; Landa & Goldberg, 2005), and restrictive, repetitive behaviors (Lopez, Lincoln, Ozonoff, & Lai, 2005).

Ozonoff and Jensen (1999) attempted to compare executive profiles in three development disorders: Autistic Disorder, Tourette’s Disorder, and Attention-Deficit/Hyperactivity Disorder (ADHD). This study incorporated the Stroop Color-Word Test (Stroop, 1935) as a measure of inhibition, along with the commonly used WCST and Tower of Hanoi, as measures of cognitive flexibility and planning respectively, to establish a more thorough executive profile. The Stroop Color-Word Test features a list of color words in which the ink is a different color than the printed word (e.g. the word “green” is printed in red ink), and the subject is required to name the color of ink, while inhibiting the natural urge to read the word. The children with ASD were significantly
more impaired on the WCST and Tower of Hanoi tasks than on the Stroop Color-Word Test when compared to the group with Tourette’s Disorder, ADHD, and typically developing control group. Moreover, the groups with ADHD and Tourette’s Disorder were impaired relative to the group with ASD on the Stroop Color-Word task. This led the authors to conclude that children with autism were impaired in their cognitive flexibility and planning, while inhibition was relatively intact, corroborating previous findings. Subsequently, a similar executive profile was obtained by Ozonoff and colleagues (2004) using subtests of the CANTAB. In addition, this study added the dimension of further establishing unique characteristics of executive functioning by demonstrating that children with ADHD and Tourette’s Disorder differed in their executive profile from the ASD group.

A subsequent study attempting to clarify the executive profile (Goldberg, Mostofsky, Cutting, Mahone, Astor, Denckla, & Landa, 2005) demonstrated findings in impaired spatial working memory and unimpaired planning and set-shifting in children with HFA compared to controls on tasks of the CANTAB. The researchers also noted unimpaired inhibition on the Stroop Color and Word Test. When comparing these results with age and IQ-matched children with ADHD, the authors found similar deficits in spatial working memory, with no significant differences between the two groups on inhibition, planning, or set-shifting. These results are in contrast to the findings of Ozonoff and colleagues (2004) indicating significant impairment in planning and set-shifting of individuals with Autistic Disorder in relation to those with ADHD. In addition, it has been noted that individuals with ASD are generally unimpaired on measures of inhibition relative to those with ADHD (Ozonoff & Jensen, 1999; Ozonoff et
al., 2004). The differences in results could have been the result of Goldberg and colleagues use of an apparently slightly higher functioning group of individuals with Autistic Disorder.

Another more recent study utilized several subtests from the D-KEFS in order to establish a fairly thorough and comprehensive profile of executive functioning in adolescents and adults with HFA and Asperger’s Disorder (Kleinhans, Akshoomoff, & Delis, 2005). In order to assess aspects of executive functioning such as cognitive switching, verbal and nonverbal fluency, and inhibition, the authors chose the Color-Word Interference Test, Trail Making Test, Verbal Fluency Test, and Design Fluency Test from the D-KEFS. The D-KEFS test administration procedures include several adaptations to these commonly used neuropsychological tests that are meant to increase sensitivity to subtle deficits in executive functioning. The Color-Word Interference Test includes modifications of the traditional Stroop task that now includes a new switching condition instructing the examiner to switch between saying the color of ink a color-word is printed in, and reading what the word says. The Trail Making Test is comprised of five testing conditions: visual scanning, number sequencing, letter sequencing, number-letter switching, and motor speed. The primary measure of executive function is the number-letter switching condition, which is considered to be a measure of cognitive flexibility, and requires the examinee to switch back and forth between connecting numbers and letters in a sequence. The other four conditions are considered to be baseline components of the number-letter switching condition. The Verbal Fluency test is comprised of three conditions: (1) letter fluency requires the examinee to generate as many words as they can think of that begin with a target letter in 60 seconds; (2) the category fluency instructs
the examinee to name as many items from a given category as they can in 60 seconds; and (3) the category switching condition requires the examinee to name as many items as they can in 60 seconds by alternating between two given categories. The Design Fluency is also made up of three conditions: filled dots, empty dots, and switching. In each condition, the examinee is asked to draw different designs for 60 seconds using only four straight lines to connect the dots. The authors compared the performance of the group with ASD to age-corrected scaled scores provided by the D-KEFS national normative database. Results indicated that participants with ASD performed significantly below the predicted average score on the overall executive function composite. The most consistent deficit was found on measures of verbal fluency that required cognitive switching and initiation of lexical retrieval strategies. Inhibition and inhibition/switching were found to be intact in this study. In addition, when examining differences between individuals with HFA and Asperger’s Disorder, no significant group differences were found on the executive functioning conditions of the individual tests.

The Trails and Color-Word subtests of the D-KEFS hold advantages over the traditional versions of those tests. Their expanded administration allows for a more precise look at other component skills that comprise such tasks, such as the involvement of motor skills in the Trails task. This level of analysis makes using the administration procedures of the D-KEFS appealing in the assessment of individuals with ASD. While this study did produce results similar to other studies attempting to establish an executive profile of in individuals with ASD, several drawbacks and opportunities for subsequent research are present. Most notably, individuals in the sample ranged in age from 14 to 42 years old, limiting the specificity of conclusions that can be drawn. The authors found no
significant differences between individuals with HFA and Asperger’s disorder, however, the sample size of 6 for each group was fairly small, and likely limits the power of statistical findings.

**Developmental characteristics of executive functioning and ASD.** Exploration of executive functioning at various points in the lifespan of individuals with ASD has yielded mixed results. A great deal of the executive functioning research in ASD has been conducted on samples of adolescents or adults. Many of these studies have produced consistent results, and have been critical in helping to establish an executive profile for ASD. However, results of studies conducted on younger samples, particularly preschool age children, have been inconsistent. For example, McEvoy and colleagues (1993) found executive impairments in disengaging and flexibly shifting attention on a spatial reversal task in a group of preschoolers with ASD. However, a similar study by Wehner and Rogers (1994; as cited in Pennington et al., 1997) with a younger group of preschoolers found no evidence of executive impairment on a similar developmentally appropriate task. Other studies of executive functioning with younger children have also found non-significant differences between typically developing controls and children with ASD (Griffith, Pennington, Wehner, & Rogers, 1999; Rutherford & Rogers, 2003; Yerys, Hepburn, Pennington, & Rogers, 2007). These results provide evidence to suggest that executive functioning in very young children with ASD may be similar to that of typically developing children.

Developmental theory suggests that executive functions emerge during the first several years of life (Diamond, 1988) and experience notable spurts in development in late childhood and early adolescence (Luna, Garver, Urban, Lazar, & Sweeney, 2004),
with adult levels of performance on some tasks being reached by approximately 12 years of age (Zelazo & Muller, 2003). This developmental framework may provide an explanation of the apparent inconsistencies in executive abilities of individuals with ASD compared to typically developing controls at different age levels. For example, the lack of evidence of executive dysfunction in preschoolers with ASD (Griffith, Pennington, Wehner, & Rogers, 1999; Rutherford & Rogers, 2003; Yerys, Hepburn, Pennington, & Rogers, 2007) may indicate that executive functioning is similarly underdeveloped in both groups at young ages.

Developmental exploration of executive functioning in older children and adolescents with ASD has been accomplished through longitudinal and cross-sectional studies. Ozonoff and McEvoy (1994) compared a group of children and adolescents with Autistic Disorder to a learning-disabled control group on measures of executive functioning at approximately 12 then 15 years of age. They found that the group with Autistic Disorder performed significantly worse on the WCST and the Tower of Hanoi, improved very little over time, and that performance on these tests appeared to reach a developmental ceiling compared to the learning-disabled group. Luna and colleagues (2004) found slightly different results using a cross-sectional design that examined performances of three age groups (8 to 12 year olds, 13 to 17 year olds, and 18 to 33 year olds) on an antisaccade test of response inhibition. Although many studies have indicated intact inhibitory control in ASD (Brian et al., 2003; Ozonoff et al., 2004; Ozonoff & Jensen, 1999; Ozonoff & Strayer, 1997), Luna and colleagues demonstrated impairments in inhibition for the group with ASD across development. However, the study noted that the developmental trajectory of individuals with ASD was similar to that of typically
developing controls. Results of these studies suggest that, while children with ASD appear to reach a developmental ceiling in cognitive flexibility and planning, they may experience developmental gains in inhibition during later childhood and adolescence. Overall, it appears that, as individuals with ASD progress through childhood and adolescence, their deficits in cognitive flexibility and planning become more pronounced compared to typically developing controls.

Executive Function Theory of ASD. The executive function theory of ASD has evolved over the past several decades beginning with the early qualitative and behavioral observations (Boucher, 1977; Damasio & Maurer, 1978; Frith, 1972; Hermelin & O’Connor, 1970; Schreibman & Lovaas, 1973) to recent investigations revealing a more thorough executive profile (Goldberg et al., 2005; Kleinhans, Akshoomoff, & Delis, 2005; Ozonoff & Jensen, 1999; Ozonoff et al., 2004). The executive function theory views the symptoms of ASD as a manifestation of primary deficits in executive control over behavior (Joseph, 1999). According to this theory, deficits in executive function in individuals with ASD is believed to be the result of abnormalities of the prefrontal cortex and the connections between its interconnected cortical and subcortical brain structures (Joseph, 1999; Pennington & Ozonoff, 1996).

The establishment of an executive profile in ASD of impaired cognitive flexibility and planning with relatively intact inhibition (Kleinhans, Akshoomoff, & Delis, 2005; Ozonoff et al., 2004) is important to executive function theory for several reasons. First, it provides evidence that differentiates specific executive deficits of individuals with ASD from other disorders with known executive dysfunction. Several researchers have found that individuals with ASD have a unique pattern of executive functioning
compared to those with ADHD and Tourette’s Disorder (Ozonoff & Jensen, 1999; Ozonoff et al., 2004). In addition, clarification of the executive profile has facilitated the exploration of the relationship between components of executive functioning and the social, communicative, and repetitive behavioral manifestations of ASD.

**Executive functioning and social impairments.** Landa and Goldberg (2005) examined the relationship between the executive functioning profile observed on the CANTAB and social functioning in their sample of children with HFA. To examine social functioning, individuals were administered the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2001) and the Autism Diagnostic Interview—Revised (ADI-R: Lord, Rutter, & LeCouteur, 1994). No correlational relationship was found between the Social Domain scores of the ADOS or ADI on any of the measures of executive functioning.

**Executive functioning and language impairments.** In an effort to establish a relationship between language ability and executive functions in verbal children with Autistic Disorder, Joseph, McGrath, and Tager-Flusberg (2005) assembled a battery of neuropsychological tests measuring working memory (Block Span; Isaacs & Vargha-Khadem, 1989), planning (NEPSY Tower; Korkman, Kirk, & Kemp, 1998), and a combined working memory and inhibition task (NEPSY Knock-Tap; Korkman et al, 1998). The Block Span task requires the examinee to repeat a series of block taps performed by the examiner in both a forward and backward condition, the NEPSY Tower task is similar to other previously discussed Tower tasks involving arrangement of colored balls on a series of three pegs, and the NEPSY Knock-Tap task requires examinees to knock their knuckles on the table when the examiner tapped with a flat
palm and vice versa. Language level was assessed using the Peabody Picture Vocabulary Test (PPVT-III; Dunn & Dunn, 1997) and the Expressive Vocabulary Test (EVT; Williams, 1997). Results of the executive functioning measures indicated that the participants with Autistic Disorder were impaired on the measures of working memory, inhibition, and planning compared to a typically developing control group. Concerning language level, it was found that there was no correlation between executive performance and language ability within the group with Autistic Disorder.

In another study relating language functioning to an executive profile, Landa and Goldberg (2005) utilized several subtests of the CANTAB in conjunction with two subtests from the Clinical Evaluation of Language Fundamentals-Revised (CELF-R; Semel, Wiig, & Secord, 1987) (Landa & Goldberg, 2005). The Formulated Sentences subtest measures the ability to form grammatically correct sentences based on the presentation of an increasingly more complex stimulus word accompanied by a picture. The subject is instructed to construct a sentence that uses the target word or words and tells about the picture. This subtest assesses comprehension and interpretation of metaphoric expressions and figures of speech. The Spatial Working Memory, Stockings of Cambridge, and Intradimensional/Extradimensional tasks from the CANTAB were used to examine working memory, planning, and cognitive flexibility respectively. A group of children with HFA was compared to a typically developing control group, with findings indicating that the group with HFA demonstrated deficits in expressive grammar, figurative language, spatial working memory, and planning. A mixed profile of set-shifting was obtained using the ID/ED task, with participants with HFA showing greater difficulty on the intradimensional shift task, involving perceptual shifting, but
enhanced performance on the extradimensional shift task, involving conceptual shifting, compared to controls. In addition, no significant correlations were found between any of the executive functions examined and language function.

*Executive functioning and restricted repetitive behaviors and interests.* Lopez and colleagues (2005) incorporated a variety of subtests from the D-KEFS in order to compare a comprehensive profile of executive functioning to the characteristic patterns of restrictive and repetitive behaviors in Autistic Disorder (Lopez, Lincoln, Ozonoff, & Lai, 2005). In addition to the previously described Trail Making, Color-Word, Verbal Fluency, and Design Fluency tasks, this study also included the WCST to more thoroughly examine perseveration, the Working Memory Index of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III), and the D-KEFS version of the Tower task involving arrangement of five discs of varying circumferences on three pegs. In order to examine the behavioral profile of their sample, the researchers collected data using the ADI, the ADOS, and the Gilliam Autism Rating Scale (GARS; Gilliam, 1995). Results of the executive battery were largely a replication of previous findings indicating impaired cognitive flexibility, increased perseveration, intact inhibition and working memory, and impaired nonverbal fluency when compared to typical controls. Strong positive correlations were found between cognitive flexibility and restrictive, repetitive behaviors; however, planning and fluency were not positively correlated with these behaviors. In addition, there were also moderately strong correlations between working memory and response inhibition and stereotyped behaviors.

This study provides a fairly comprehensive outline of executive functioning and working memory, and effectively relates these to the repetitive behavior profile of
individuals with Autistic Disorder. These findings provide an opportunity for future research in several areas. First, the sample used in this study was comprised of only adults with Autistic Disorder. An interesting direction of future research would be to expand these findings to a younger sample of children and adolescents. In addition, the inclusion of a group with Asperger’s Disorder would possibly provide evidence further discrepancy between ASD’s.

**Nonverbal Learning Disabilities**

The syndrome now referred to as nonverbal learning disability (NVLD) was first identified by Johnson and Myklebust (Myklebust, 1975) and later expanded upon by Rourke (1995). The primary neuropsychological characteristic of NVLD is a significant verbal IQ > non-verbal IQ discrepancy (Pennington, 2009). NVLD features a constellation of strengths and weaknesses in line with this discrepancy. Individuals with NVLD often present with strengths in verbal rote memory, selective and sustained attention for simple verbal material, and well-developed receptive language skills (Rourke, 1995). On the other hand, nonverbal aspects of functioning, such as visual-spatial organization, nonverbal problem solving, psychomotor coordination, and tactile perception are often impaired. Other deficits include difficulty understanding pragmatic aspects of language, social perception, and social judgment. Rourke (1995) also described academic weaknesses in graphomotor skills, reading comprehension, mechanical arithmetic, and science.

**Rourke’s Right Hemisphere and White Matter Models.** Rourke’s theory of NVLD is based largely on Goldberg and Costa’s (1981) theory of brain functioning that suggests progressive left-right lateralization of functions throughout development. Rouke
(1988) explained the strengths and weaknesses of NVLD in terms of right and left hemisphere functioning: the right hemisphere being principally responsible for visual-spatial skills, while language functioning is managed predominantly by the left hemisphere. He also added that the right hemisphere is more adept in processing novel information, while left hemisphere processing relies more heavily on established schemas (Rourke, 1988). Under this model of left-right lateralization, it has been found that individuals with NVLD appear to demonstrate right hemisphere deficits (Myklebust, 1975; Rourke, 1989; Rourke, 1995).

Rourke (1995) further expanded on this rather simplistic model of right hemisphere dysfunction by incorporating the apparent role of white matter in the cognitive and behavioral presentation of individuals with NVLD. White matter fibers are connections that serve as communication pathways between regions of the brain. Three principle types of white matter connections include: fibers that cross the midline of the brain and interconnect similar regions in the two cerebral hemispheres (commissural fibers); fibers that interconnect cortical regions of the same cerebral hemisphere (association fibers); and fibers that connect subcortical structures to the cerebral cortex (projection fibers). Rourke’s ‘white matter model’ proposes that NVLD may develop from extensive damage or compromises to commissural fibers and/or right hemisphere association fibers (Rourke, 1995). According to the “white matter model,” damage to these connections would lead to dysfunction in communication to the right hemisphere. Rourke argued that the right hemisphere is more affected by this disrupted communication than the left because it is made up of relatively more white matter and has longer communication links than the left hemisphere (Goldberg & Costa, 1981).
Rourke’s model expanded upon previous theories of hemispheric localization by illustrating the potential importance of white matter connectivity in the cognitive and behavioral deficits of NVLD.

**Developmental course.** There have been very few studies conducted on the developmental trajectory of NVLD. Strang and Rourke (1985) summarized retrospective case histories of children with NVLD, revealing greater delays in motor rather than language milestones, decreased exploratory activity, difficulties in pragmatic language, poor peer relations, and overreliance on parents. This early history is consistent with many of the strengths and weaknesses observed in children and adolescents with NVLD.

In a small adult follow-up study of children with NVLD, Rourke and colleagues (1986) found that all subjects continued to exhibit social and emotional difficulties. In addition, the study determined that subjects were working in jobs below their educational level. These results indicate that the deficits associated with NVLD may be present into adulthood. However, further research is needed in this area in order to obtain an accurate developmental course of NVLD symptoms across the lifespan.

**NVLD and executive functioning.** Given their weaknesses in visual-spatial organization and non-verbal problem solving (Rourke, 1989), it seems plausible that individuals with NVLD may exhibit deficits in executive functioning that are negatively affecting these skills. In fact, anecdotal and clinical reports have indicated multiple difficulties with executive functioning in this population (Tanguay, 2002; Thompson, 1997). Despite this apparent characteristic, relatively few formal studies have been conducted that directly address executive functioning of individuals with NVLD. Jing, Wang, Yang, and Chen (2004) examined several components of executive functioning in
children with NVLD. They found significant weaknesses in attentional control and cognitive shifting among children with NVLD compared to controls. The authors concluded that deficits in the right frontal lobe were contributing to poor performance of the NVLD group on a measure of selective auditory attention and cognitive shifting. This finding is consistent with Rourke’s model that suggests general weaknesses in right hemisphere functioning. However, it should be noted that the authors used the Wisconsin Card Sorting Test as a measure of cognitive shifting on a sample that was relatively young (ages ranged from 7.5 to 12.5). The deficits in cognitive shifting reported in this study should be interpreted with caution, as other studies have found that this skill does not reach adult levels until early adolescence (Anderson et al., 2001; Davidson et al., 2006). Other research examining executive functioning in children with NVLD points to deficits in visual-spatial working memory and visual imagery (Cornoldi, Rigoni, Tressoldi, & Vio, 1999). It is likely that the executive deficits noted in this study may be attributable to the well-documented weaknesses in visual-spatial skills of individuals with NVLD. It is clear that further research is needed in order to draw more definite conclusions regarding executive deficits in individuals with NVLD.

**NVLD and Autism Spectrum Disorders.** The neuropsychological profile and behavioral characteristics of NVLD is remarkably similar to those of Asperger’s Disorder (Rourke et al., 2002). In fact, some have suggested the possibility of classifying NVLD as a variant of Asperger’s Disorder due to the similar characteristics of the two conditions (Pennington, 1991; Rourke, 1995; Rourke, et al., 2002). Several of the key characteristics of NVLD according to Rourke (1988, 1995) that are also indicative of Asperger’s Disorder include:
1.) General strengths in verbal tasks (e.g. verbal rote memory and receptive language) accompanied by significant weaknesses in visual-spatial skills often measured by a verbal IQ > non-verbal IQ discrepancy on measures of cognitive functioning

2.) Distinct speech patterns that include little or no speech prosody, excessive verbosity, and lack of pragmatic understanding

3.) Deficits in social perception, judgment, and interaction skills that sometimes leads to social withdrawal

Strang and Rourke (1985) examined retrospective case histories of children with NVLD and found several characteristics that overlap with HFA and/or Asperger’s Disorder including hyperlexia, difficulties in pragmatic language, and poor peer relations. It is apparent that the NVLD profile is present in many children with Asperger’s Disorder; however, it remains a topic of considerable debate whether or not the overlap between ASD and NVLD is significant enough to warrant separate diagnostic categories (Pennington, 2009).

Despite the many similarities between NVLD and Asperger’s Disorder, the primary distinction between the two conditions appears to rest on the presentation of restricted and repetitive behaviors and interests. Rourke’s model (1988, 1995) does not include restricted and repetitive behaviors and interests as a characteristic of NVLD. Since Rourke’s proposed model of NVLD, it has become generally accepted that individuals with NVLD lack stereotypic restricted and repetitive behaviors and interests that are a key feature of Asperger’s Disorder (Rourke & Tsatsanis, 2000; Stein, Klin, & Miller, 2004). Although this characteristic appears to be important in the differentiation
of NVLD from Asperger’s Disorder, more research is needed in order to clarify the neuropsychological similarities and differences between the two conditions.

Summary and Conclusions

The evidence base for the relationship between executive dysfunction and autism spectrum disorders is vast. Consistent evidence points to a general impairment in cognitive flexibility and a tendency to exhibit perseverative responses on measures like the WCST (Bennetto, Pennington, & Rogers, 1996; Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff, Pennington, & Rogers, 1991; Ozonoff & McEvoy, 1994; Rumsey and Hamburger, 1988; Szatmari, Finlayson, & Bartolucci, 1990). When component process analysis is used to parse apart the seemingly connected domains of flexibility and inhibition, a profile of impaired flexibility and intact inhibition emerges (Brian et al., 2003; Ozonoff et al., 1994; Ozonoff & Strayer, 1997; Ozonoff et al., 2004; Turner, 1997). Deficits in planning on Tower tasks also appear to be present (Ozonoff et al., 2004; Ozonoff & McEvoy, 1994; Prior & Hoffman, 1990).

Several recent studies have examined the relationship between the emerging executive function profile and the behavioral characteristics of ASD. Attempts to establish links between executive dysfunction and the social and language deficits of ASD have been unsuccessful (Joseph et al., 2005; Landa & Goldberg, 2005). However, efforts to relate deficits in executive functioning to restricted and repetitive behaviors characteristic of ASD have been met with more success. For example, Lopez and colleagues (2005) found strong positive correlations between deficits in cognitive flexibility and restrictive, repetitive patterns of behavior characteristic of individuals with ASD. These studies indicate that the executive function theory of ASD may be more
useful in explaining stereotyped repetitive behaviors than social and language impairments.

Nonverbal learning disability is a syndrome identified by strengths in verbal rote memorization and deficits in visual-spatial skills, a cognitive profile very similar to that of Asperger’s Disorder. Individuals with NVLD also often exhibit deficits in social perception and judgment. Given the similarities between NVLD and ASD, particularly Asperger’s Disorder, it is often difficult to differentiate the two diagnostically. The primary means of distinguishing ASD from NVLD relies on the presentation of restricted and repetitive behaviors and interests, a feature that is absent from the latter of the two. The restricted and repetitive behaviors characteristic of ASD appear to be closely related to deficits in executive functioning, specifically cognitive flexibility. Executive functioning of individuals with NVLD has not been as thoroughly researched as it has in subjects with ASD, and it is not clear if consistent deficits are present in this group. Comparisons of executive functioning of individuals with ASD and NVLD may reveal differences between the two groups, and provide clinicians with useful information when formulating diagnoses and designing treatment interventions.
CHAPTER III

Methods

Participants

Participants were children and adolescents ages 8 to 18 assessed in an outpatient neuropsychology clinic at The Watson Institute in Sewickley, PA. Children and adolescents in the sample were referred for neuropsychological evaluation in order to obtain diagnostic clarification and appropriate treatment recommendations. Participants were diagnosed with ASD by a licensed psychologist using accepted criteria of the DSM-IV-TR (APA, 2000). Exclusionary criterion was a diagnosis of mental retardation.

Children and adolescents diagnosed with ASD who were identified for participation in the study were compared to a sample of children and adolescents ages 8 to 18 diagnosed with NVLD according to Rourke’s model. Exclusionary criteria were a comorbid ASD diagnosis or a diagnosis of mental retardation.

All data on the participants used in this study was obtained from a pre-existing database created and maintained at The Watson Institute. The database provided to the researcher included participants’ identification numbers, age, gender, primary diagnosis, secondary diagnosis (if applicable), and scores on chosen instruments. The database contained assessment results for approximately 200 participants with diagnoses of either ASD or NVLD.

Neuropsychological evaluation procedures at The Watson Institute follow a flexible battery. Information for the database was collected retrospectively through review of neuropsychological evaluation reports contained in participants’ charts. The database was updated and maintained by research assistants. All participants were
referred for clinical rather than research purposes. Parents completed informed consent procedures for assessment prior to initiation of the evaluation. All identifying information was removed from data prior to entry into the database.

Power Analysis

An a priori power analysis was conducted to determine the number of participants necessary to achieve adequate power. Power represents the probability that existing effects have a chance of producing statistical significance through data analysis (Tabachnick & Fidell, 2007). According to criteria discussed in Stevens 2002, power ≥ .80 is considered adequate for multivariate analyses with a medium effect size of .50 (Stevens, 2002). G*Power 3.1.0 (Faul, Erdfelder, Lang, & Buchner, 2007) was used to determine the number of participants necessary to achieve adequate power with medium effect sizes. For a multivariate analysis of variance (MANOVA) with two groups and seven response variables, a sample size of 38 participants is needed in order to achieve a medium effect size of .50 with adequate power of .80 at α = .05. Given the size of the database to be used for analysis, adequate power was expected for the current study.

Measures

Delis-Kaplan Executive Function System. The Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001) is a collection of nine classic neuropsychological tests measuring various components of executive functioning. Each test is designed to be a stand-alone measure that can be administered independently or in conjunction with other D-KEFS tests. The D-KEFS is designed for use with individuals ranging in age from 8 to 89. The D-KEFS was standardized on a nationally representative sample of 1,750 children, adolescents, and adults. Using data from the
2000 U.S. Census, the sample was stratified based on age, sex, race/ethnicity, years of education, and geographic region (Delis et al., 2001). The D-KEFS Verbal Fluency Test and D-KEFS Color-Word Interference Test will be used for the purposes of this study.

**D-KEFS Verbal Fluency Test.** The D-KEFS Verbal Fluency Test involves three conditions: Letter Fluency, Category Fluency, and Category Shifting. In the Letter Fluency condition, the participant is asked to generate words that begin with a designated letter (e.g., F, A, and S) as quickly as possible. The Category Fluency condition requires the participant to generate words that belong to a designated category (e.g., animals) as quickly as possible. In the last condition, Category Switching, the participant is asked to generate words, alternating between two different categories (e.g., fruit and furniture) as quickly as possible. There is a 60-second time limit for each condition. In addition, the participant is not permitted to use proper nouns and cannot give the same word with a different ending. The participant’s raw score for each condition is the total number of correct words in each 60-second interval. Additional scores can be obtained for repetition errors, set-loss errors, and switching accuracy for the Category Switching condition. The D-KEFS Verbal Fluency Test assesses the participant’s ability to produce words fluently in a phonemic format (Letter Fluency), from overlearned concepts (Category Fluency), and while shifting between overlearned concepts (Category Switching) (Delis et al., 2001).

Internal consistencies for the D-KEFS Verbal Fluency Test were obtained by comparing time intervals (i.e., first 15 seconds, second 15 seconds, etc.) for each condition. Internal consistencies for 8 to 19-year-olds ranged from moderate to high (.53 to .81) for the Letter Fluency and Category Fluency conditions. Values were slightly
lower for the Category Switching condition (.37 to .76). Test-retest correlations for the various conditions of the D-KEFS Verbal Fluency Test range from .53 to .70 (Delis et al., 2001).

Intercorrelations for the tasks of the D-KEFS Verbal Fluency Test reveal moderate associations (.40 to .55) between the Letter Fluency, Category Fluency, and Category Switching conditions for individuals ages 8 to 19. The Letter Fluency and Category Fluency conditions showed low negative correlations (-.14 to -.21) with Error Scores, indicating that the more errors (repetition and set loss) made, the higher the total score (i.e. faster completion time). However, the Category Switching condition displayed the opposite pattern, with low to moderate positive correlations (.04 to .22) between completion time and total errors. The authors suggest that the Category Switching condition requires better cognitive control and monitoring relative to the non-switching conditions (Delis et al., 2001).

In order to explore construct validity, performance on the D-KEFS Verbal Fluency Test was compared to performance on the California Verbal Learning Test – Second Edition (CVLT-II; Delis, Kaplan, Kramer, & Ober, 2000), a list-learning task involving both immediate and delayed recall. Correlations between the measures were low and positive (.32 to .38). These results indicate that the two tasks measure different constructs, but likely share some degree of variance due to the verbal nature of each task.

**D-KEFS Color-Word Interference Test.** The D-KEFS Color-Word Interference Test represents a modification to the classic Stroop Test (Stroop, 1935). It includes two baseline conditions: naming of color patches (Condition 1) and reading color-words printed in black ink (Condition 2). These baseline conditions are meant to measure
fundamental skills involved in the higher-order tasks. The Inhibition task requires the participant to inhibit their natural inclination to read words in order to name incongruent ink colors in which the words are printed (i.e. the word “red” is printed in blue ink). The Inhibition/Switching task requires the participant to switch back and forth between naming incongruent ink colors and reading words. Thus, this condition assesses both inhibition and cognitive flexibility. The participant’s raw score for each condition is the time (in seconds) in which it takes to name all stimuli on the page. Scores can also be obtained for the number of errors committed in each condition.

For the D-KEFS Color-Word Interference Test, a composite score can be obtained by combining the baseline Color Naming and Word Reading conditions. Spit-half correlation is computed by correlating performance on each of the conditions. Internal consistencies for the baseline conditions of the D-KEFS Color-Word Interference Test for 8 to 19-year-olds range from .62 to .79. Test-retest reliabilities for the four conditions of the D-KEFS Color-Word Interference Test are high, ranging from .77 to .90 (Delis et al., 2001).

Intercorrelations for the four conditions of the D-KEFS Color-Word Interference Test are moderate and positive (.41 to .57) for individuals ages 8 to 19. Error scores displayed positive correlations (.21 to .33) with the Inhibition and Inhibition/Switching conditions.

The Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtis, 1993) was compared to several tests of the D-KEFS, including the Inhibition and Inhibition/Switching conditions of the Color-Word Interference Test. Moderate negative correlations (-.31 to -.53) were found between the completion time on the Inhibition and
Inhibition/Switching conditions and the categories completed on the WCST. These finding indicate that faster completion times on the Inhibition and Inhibition/Switching conditions are associated with a greater number of categories completed on the WCST. The authors indicate that it is likely the D-KEFS and the WCST share some degree of variance while still contributing unique variance in the assessment of different aspects of executive functioning, but caution interpretation of the results of these comparisons due to small sample size \((n = 23)\) (Delis et al., 2001).

**Behavior Rating Inventory of Executive Function.** The Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) is a questionnaire designed to assess components of executive functioning in the home and school settings. It can be completed by parents and teachers of children ages 5 to 18 years. The form contains 86 items within eight theoretically derived clinical scales that measure different aspects of executive functioning: Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor (Gioia et al., 2000). The clinical scales form two Indexes, Behavioral Regulation and Metacognition, and an overall Global Executive Function Composite. Validity scales measuring Inconsistency and Negativity are also included.

Participants (i.e., parents) are asked to determine if the child performs each behavior *Never* (N), *Sometimes* (S), or *Often* (O). The participant’s rating corresponds to a numbers (i.e., 1 for *Never*, 2 for *Sometimes*, and 3 for *Often*) that are summed for each clinical scale to obtain a raw score. Raw scores are then converted into \(T\) Scores for each clinical scale, Index, and Composite.
The BRIEF was standardized on a nationally representative sample of 1,419 children and adolescents. Key demographic variables included in the sampling procedure were: gender, socioeconomic status (SES) ethnicity, age, and geographical population density (Gioia et al., 2000).

Internal consistency for the BRIEF is generally high, ranging from .80 to .98. Interrater reliability between parent and teacher ratings are generally moderate (mean $r = .32$). The strength of the relationship between these ratings is likely influenced by the differing demands of the home and school environments (Gioia et al., 2000). Test-retest reliabilities for the clinical scales of the BRIEF are generally high (.76-.85).

Content validity for the BRIEF was obtained through agreement among several pediatric neuropsychologists as to the fit of each item within the intended scale. Items were retained if they achieved high interrater agreement among the expert raters. Construct validity was examined by determining the convergent and discriminant validity of the BRIEF with other related and unrelated measures. In general, the clinical scales of the BRIEF showed convergent and divergent validity with broad-based behavioral rating scales such as the Child Behavior Checklist (CBCL; Achenbach, 1991) and Behavior Assessment System for Children (BASC; Reynolds & Kamphaus, 1992). Executive functions, as measured by the BRIEF, had the strongest positive correlations with measures of behavioral functioning (e.g. CBCL Attention Problems Scale, BASC Hyperactivity and Aggression Scales), and generally correlated less strongly or not at all with measures of emotional functioning (e.g. CBCL Somatic Complains and Withdrawn Scales, BASC Anxiety Scale).
**Gilliam Asperger’s Disorder Scale.** The Gilliam Asperger’s Disorder Scale (GADS; Gilliam, 2001) is a 32-item behavioral rating scale used to help identify individuals with Asperger’s Disorder. The GADS is indicated for use in individuals ages 3 through 22 who are suspected of having characteristics indicative of Asperger’s Disorder. It was normed on a sample of 371 individuals who were previously diagnosed with Asperger’s Disorder. The rating scale is intended to be administered to anyone who has direct, sustained contact with the referred individual.

The respondent is asked to rate the individual’s behavior according to a 0-to-3 Likert scale representing increasing frequency of behavior. A rating of “0” indicates that the individual has *Never* performed the behavior in question. A rating of “1” indicates that the frequency of observation of the behavior is *Seldom* (i.e., 1 to 2 times in a 6-hour period). A rating of “2” is given when the behavior is observed *Sometimes* (i.e., 3 to 4 times in a 6-hour period). Finally, a rating of “3” is given when the behavior is observed *Frequently* (i.e., at least 5 times in a 6-hour period).

The GADS is comprised of four subscales. The Social Interaction subscale is made up of items that describe social interactive behaviors, expression of communicative intent, and cognitive and emotional behaviors. The Restricted Patterns of Behavior subscale measures restricted and stereotyped behaviors that are characteristic of Asperger’s Disorder. The Cognitive Patterns subscale is comprised of items assessing speech, language, and cognitive skills. Finally, the Pragmatic Skills subscale contains items concerned with the individual’s ability to understand and use language in the social context. Raw scores are obtained for each subscale based on the respondent’s ratings. The raw scores are then converted into scaled scores for each subscale. The subscale scaled
scores are summed in order to obtain the Asperger’s Disorder Quotient (reported as a standard score). An Interpretation Guide is also provided in order to estimate the probability of Asperger’s Disorder (e.g., Low/Not Probable, Borderline, High/Probable).

The GADS demonstrates moderate to strong estimates of internal consistency (.70 to .87) for the core subscales (Gilliam, 2001). Test-retest reliabilities were adequate, ranging from .71 to .93. In addition, assessment of interrater reliability revealed strong and statistically significant correlations (.72 to .89) between parent and teacher ratings on the GADS.

To ensure face validity, the items of the GADS were developed using the definitions of Asperger’s Disorder from the DSM-IV-TR (APA, 2000) and the International Classification of Diseases and Related Health Problems-Tenth Edition (ICD-10; World Health Organization, 1992). A thorough review of the literature was also conducted, as well as a review of existing instruments designed to assess Asperger’s Disorder (Gilliam, 2001). Criterion validity was assessed by comparing the GADS to the GARS (Gilliam, 1995). Correlations between the two instruments were generally moderate (.50 to .70), indicating that the measures are related, but still contribute unique information about the individual being assessed (Gilliam, 2001). Concurrent criterion-prediction validity among different diagnostic groups was examined using discriminant analysis. Results indicated that the Asperger’s Disorder group was significantly higher on all subscales, and that discriminant analysis revealed correct group categorization 83% of the time.
Research Design

This study utilized correlational techniques as well as multivariate analyses in order to examine relationships between variables. Independent variables were diagnostic category and participants’ age. Diagnostic categories for analyses were Asperger’s Disorder and NVLD. Dependent variables included restricted and repetitive behaviors and interests, cognitive flexibility/set-shifting, inhibition, working memory, and planning. Table 1 presents each construct of interest with applicable dependent measure(s).

Table 1

<table>
<thead>
<tr>
<th>Construct</th>
<th>Measure(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Flexibility</td>
<td>D-KEFS Verbal Fluency Category Switching</td>
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<tr>
<td></td>
<td>D-KEFS Verbal Fluency Switching Accuracy</td>
</tr>
<tr>
<td></td>
<td>D-KEFS Color-Word Inhibition/Switching</td>
</tr>
<tr>
<td></td>
<td>BRIEF Shift</td>
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<tr>
<td>Inhibition</td>
<td>D-KEFS Color-Word Inhibition</td>
</tr>
<tr>
<td></td>
<td>BRIEF Inhibit</td>
</tr>
<tr>
<td>Working Memory</td>
<td>BRIEF Working Memory</td>
</tr>
<tr>
<td>Planning</td>
<td>BRIEF Plan/Organize</td>
</tr>
<tr>
<td>Restricted Stereotyped Behavior</td>
<td>GADS Restricted Patterns of Behavior subscale</td>
</tr>
</tbody>
</table>

*Note.* D-KEFS = Delis-Kaplan Executive Function System; BRIEF = Behavior Rating Inventory of Executive Functioning
Restricted and repetitive behaviors and interests were measured by the Restricted Patterns of Behavior Scale of the GADS (Gilliam, 2001). Cognitive flexibility/set shifting were operationalized using scaled scores on the Category Switching condition of the D-KEFS Verbal Fluency Test (Delis et al., 2001), scaled scores on the Inhibition/Switching condition of the D-KEFS Color-Word Interference Test (Delis et al., 2001), and T-scores on the Shift Scale of the BRIEF (Gioia et al., 2000). Inhibition was measured using scaled scores on the Inhibition condition of the D-KEFS Color-Word Interference Test (Delis et al., 2001) and T-scores on the Inhibition Scale of the BRIEF (Gioia et al., 2000). Working memory and planning were operationalized using T-scores on the Working Memory and Planning Scales of the BRIEF (Gioia et al., 2000).

**Procedures**

Participants in this study were children and adolescents assessed at an outpatient neuropsychology clinic. Participant data was extracted from a pre-existing de-identified database maintained by the clinic. Participants were included if they had either an ASD diagnosis or a diagnosis of NVLD, and completed all measures included in the research design. Exclusionary criterion was a diagnosis of mental retardation. The independent variable of age was examined using a cross-sectional procedure. Participants were divided into *child* (ages 8 to 12) and *adolescent* (ages 13 to 18) groups. Age ranges for these groups was determined by applying developmental theory that suggests notable spurts in the development of executive functioning in late childhood and early adolescence (Anderson et al., 2001; Luna et al., 2004), with adult levels of performance on some tasks being reached by approximately 12 years of age (Zelazo & Muller, 2003).
Data Analysis

Descriptive statistics and outliers. Analyses for this study were conducted using SPSS version 17.0. Means and standard deviations were calculated by group and total sample for all variables included in the study. Outliers are considered cases or data points that are extreme in value to the extent that they distort statistical results. In the case of this study, outliers were identified using several statistical methods. Mahalanobis distance is a value commonly used in multivariate statistics to detect cases that are outliers by comparing its value to a chi-square critical value (Tabachnick & Fidell, 2007). A large Mahalanobis distance indicates an observation is an outlier. Influential outliers were also identified using Cook’s Distance and differences in betas (DFBETAs). Cook’s Distance represents the amount of change in a regression coefficient if the case in question were omitted, thus highlighting which cases exert the most influence on the equation. Values for Cook’s Distance greater than one are considered large and warrant further examination of the case (Stevens, 2002). DFBETAs indicate the number of standard errors the regression coefficient changes when a given data point is deleted. DFBETAs greater than an absolute value of two should be investigated further to determine potential influence on the data analysis (Stevens, 2002).
Assumptions for multivariate analyses. Several statistical assumptions were important to consider when conducting the analyses in the current study. Assumptions applicable to all analyses in this study will be discussed in this section. Other assumptions that are specific to analyses for individual research questions will be addressed in subsequent sections.

Normality, linearity, and homoscedasticity. The assumption of normality is critical to most univariate and multivariate statistical analyses. Normality is the assumption that each variable and all linear combinations of the variables are normally distributed (Stevens, 2002; Tabachnick & Fidell, 2007). Screening for normality can be accomplished informally by simply examining histograms for each variable to be used in the analysis. Normality can be statistically tested using significance tests for skewness and kurtosis. Skewness represents the symmetry of the distribution, while kurtosis has to do with the peakedness of the distribution. Skewness and kurtosis values equal to zero indicate the variable is normally distributed. Absolute values greater than 1.5 are considered non-normal and should be considered for removal from the analyses.

Linearity means that there is a “straight-line” relationship between two variables, where one or both of the variables may be combinations of several variables (Tabachnick & Fidell, 2007). Linearity can be assessed by examining bivariate scatterplots and standardized residuals plotted against predicted values. When two variables are normally distributed and linearly related, the scatterplot will be oval-shaped (Tabachnick & Fidell, 2007). Furthermore, when the assumption of linearity is upheld, standardized residual values should scatter randomly around a horizontal line (Stevens, 2002).
The assumption of homoscedasticity (for ungrouped data) or homogeneity of variance (for grouped data) is that variability in scores for one continuous variable is approximately the same at all values of another continuous variable (Tabachnick & Fidell, 2007). Homoscedasticity is closely associated with the assumption of normality; when multivariate normality is achieved, the relationships between variables are homoscedastic. For grouped data, homogeneity of variance can be formally assessed using a number of methods, including the Box’s M test and Levene’s test of homogeneity of variance. Tests of homogeneity of variance are sensitive to sharp differences in group sizes as well as normality (Stevens, 2002).

**Independence of observations.** The independence assumption is that participant’s responses are unrelated. Data used in the current study was gathered from neuropsychological evaluations in which each participant was assessed individually. As a result, the independence assumption was satisfied for the current analyses.

**Multicollinearity.** Multicollinearity involves moderate to high intercorrelations among predictor variables (Stevens, 2002; Tabachnick & Fidell, 2007). Inclusion of predictor variables that are highly correlated leads to redundancy and can weaken the analysis. Stevens (2002) describes two methods for identifying multicollinearity. A bivariate correlation matrix can be created, with Pearson correlations greater than .80 considered examples of multicollinearity. Another way of determining multicollinearity involves examination of variance inflation factors for the predictors. Variance inflation factors exceeding 10 should be considered cause for concern (Stevens, 2002). When multicollinearity is detected, the researcher has the options of removing the variable with the highest variable proportion from analyses, combining collinear variables by averaging
their values, or computing principal components in order to use the components as predictors (Tabachnick & Fidell, 2007).

**Research question one analysis.** The first research question examined which components of executive functioning related to behaviors characteristic of Asperger’s Disorder, particularly repetitive and stereotyped behaviors and interests. Behaviors characteristic of Asperger’s Disorder were measured using the GADS. It was hypothesized that measures of shifting/cognitive flexibility would have the strongest negative relationships with a measure of repetitive and stereotyped behaviors and interests. In other words, high scores on measures of shifting/cognitive flexibility would be related to low scores on a measure of repetitive and stereotyped behaviors and interests. In addition, it was hypothesized that behavioral measures of shifting/cognitive flexibility would have a positive relationship with a measure of repetitive and stereotyped behaviors and interests. Along these lines, increased difficulty on tasks involving shifting in the natural environment would be associated with a higher number of repetitive behaviors. In order to examine relationships between variables, bivariate Pearson correlation coefficients ($r$) were calculated. Pearson correlations coefficients are a measure of effect size, and range from -1 to +1. A correlation of +1 indicates that as scores on one variable increase, scores on the other variable increase as well. A correlation of zero indicates no relationship between variables. A bivariate correlation matrix was used to depict strength and direction of relationships between variables.

**Correlation vs. causation.** When interpreting results of analyses utilizing bivariate correlation, it is important to remember that correlation does not equal causation. One of the most common errors when interpreting correlations is to assume
that a correlation implies a cause-and-effect relationship between two variables (Gravetter & Wallnau, 2004). The researcher must keep in mind that the results of bivariate correlation simply provide information about the strength and relationship between two variables.

**Research question two analyses.** Research question two was concerned with comparing executive functioning of children and adolescents with Asperger’s Disorder to those with NVLD. It was hypothesized that children and adolescents with Asperger’s Disorder would differ significantly from those with NVLD in their ability to use cognitive flexibility/set shifting and planning on both performance-based measures and parent ratings of executive functioning. Significant differences between diagnostic categories were not expected for other components of executive functioning (e.g. inhibition and working memory).

Examination of group differences on measures of executive functioning was accomplished using a one-way MANOVA. The independent variable, or factor, for this analysis was diagnostic category, with two levels: Asperger’s Disorder and NVLD. Dependent variables were various measures of the following components of executive functioning: cognitive flexibility/set shifting, inhibition, working memory, and planning. This MANOVA was used to determine if group means on multiple dependent variables differ significantly across groups. Significance was set at an $\alpha$ level of .05. Results of the MANOVA can be reported using a number of statistics, including Wilks’ Lambda and Pillai’s trace, depending on results of the Box’s M test.

Follow-up analyses to statistically significant MANOVAs provide a means for determining on which dependent variable(s) group differences lie. One method of
following-up a significant MANOVA is to conduct multiple analyses of variance (ANOVA) for each dependent variable. Type I error can be controlled across these multiple tests using Bonferroni approaches. The use of follow-up ANOVAs has been criticized by some because it does not take into account the multivariate nature of MANOVA, ignoring linear combinations of dependent variables inherent to MANOVA (Green & Salkind, 2005).

**Research question three analysis.** Research question three asked how age affects comparisons of executive functioning between children and adolescents with Asperger’s Disorders and NVLD. In order to incorporate age as an independent variable, a cross-sectional design was employed to separate children (ages 8 to 12) and adolescents (ages 13 to 18). It was hypothesized that adolescents with Asperger’s Disorder would demonstrate weaker performance than children with Asperger’s Disorder on measures of cognitive flexibility/set-shifting and planning relative to age-matched participants with NVLD.

A factorial MANOVA was conducted in order to examine group differences on dependent measures of cognitive flexibility, inhibition, working memory, and planning. Independent variables, or factors, for the analysis were diagnostic category with two levels (Asperger’s Disorder and NVLD) and age with two levels (child and adolescent). The factorial MANOVA allows for analyses of main effects among variables and interaction effects between variables. Results of main and interaction effects were examined using Wilks’ Lambda. Follow-up examination of MANOVA results was accomplished using univariate ANOVAs and graphical depictions of results.
CHAPTER IV

Results

This chapter presents the findings of statistical analyses that were conducted to examine this study’s three research questions. The primary objectives of the research questions were to first, establish a relationship between executive functioning and repetitive behaviors in children and adolescents with Asperger’s Disorder. This was accomplished by constructing a bivariate correlation matrix of dependent variables for executive functioning (D-KEFS and BRIEF) and behaviors associated with Asperger’s Disorder (GADS). Next, executive functions of children and adolescents diagnosed with Asperger’s Disorder and NVLD were compared via MANOVA. Finally, the influence of age on these two groups was assessed using a cross-sectional design and second MANOVA. Prior to running these analyses, descriptive statistics were obtained and preliminary analyses were conducted in order to evaluate statistical assumptions.

Descriptive Statistics

The original clinic-referred database contained 221 children and adolescents who received either a diagnosis of an ASD or NVLD based on neuropsychological evaluation. For the purposes of this study, only individuals with a diagnosis of Asperger’s Disorder or NVLD, ranging in age from eight to 18 years, and with a Full Scale IQ of 70 or greater were included in the final sample. In addition, participants included in the final sample must have completed each of the dependent measures. These criteria led to a final sample size of 51 remaining for analysis. The sample consisted of 26 participants with a diagnosis of Asperger’s Disorder (mean age = 11.7) and 25 participants with a diagnosis of NVLD (mean age = 11.8). The Asperger’s Disorder group consisted of 77% males and
23% females, while the NVLD group was 56% male and 44% female. Several comorbid diagnoses were present in the sample, including 13 individuals with ADHD Combined Type, six individuals with ADHD Inattentive Type, 12 individuals with an anxiety disorder, and seven individuals with a depressive disorder. Means and standard deviations for the Asperger’s Disorder and NVLD groups on each of the dependent variables are reported in Table 2.

**Preliminary Analyses for Statistical Assumptions**

Prior to conducting formal analyses, the dataset was examined for outliers to ensure no cases were exerting undue influence on the analyses. Mahalanobis distances were obtained for each case and compared to a chi-square critical value of 26.13 (df = 8; p<0.001). There were no values exceeding the chi-square critical value, indicating no outliers according to this criterion. In addition, standardized DFBETAs and Cook’s Distances did not reveal any cases as outliers based on previously stated criteria.

The assumption of normality was assessed by visually examining histograms of the dependent variables and, more formally, by obtaining skewness and kurtosis values. All histograms appeared to demonstrate normal distribution and calculated values for skewness and kurtosis were within acceptable limits (i.e., less than an absolute value of 1.5), indicating normal distribution for each of the dependent variables. A summary of score ranges, skewness, and kurtosis for each of the dependent variables can be found in Table 2. Histograms depicting normal distributions for dependent variables are shown in Figure 1 for D-KEFS measures and Figure 2 for BRIEF measures.
Table 2

Mean, Standard Deviation, Range, Skewness, and Kurtosis for Dependent Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Asperger’s Disorder (n = 26)</th>
<th>NVLD (n = 25)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>D-KEFS VF-CS</td>
<td>9.31</td>
<td>5.01</td>
</tr>
<tr>
<td>D-KEFS CW-I</td>
<td>9.08</td>
<td>3.14</td>
</tr>
<tr>
<td>D-KEFS CW-I/S</td>
<td>9.00</td>
<td>3.87</td>
</tr>
<tr>
<td>BRIEF Inhibit</td>
<td>61.92</td>
<td>12.37</td>
</tr>
<tr>
<td>BRIEF Shift</td>
<td>72.31</td>
<td>12.67</td>
</tr>
<tr>
<td>BRIEF WM</td>
<td>67.04</td>
<td>11.71</td>
</tr>
<tr>
<td>BRIEF Plan</td>
<td>67.65</td>
<td>8.70</td>
</tr>
</tbody>
</table>

Note. D-KEFS = Delis-Kaplan Executive Function System; VF-CS = Verbal Fluency-Category Switching; VF-SA = Verbal Fluency-Switching Accuracy; CW-I = Color-Word Inhibition; CW-I/S = Color-Word Inhibition/Switching; BRIEF = Behavior Rating Inventory of Executive Functioning; WM = Working Memory; D-KEFS values reported as *scaled scores* (Mean = 10; SD = 3); BRIEF values reported as *T-scores* (Mean = 50; SD = 10).
Figure 1. Scaled score distributions for D-KEFS dependent measures.
Figure 2. T-score distributions for BRIEF dependent measures.
Linearity among all pairs of dependent variables was assessed via bivariate scatterplots for each level of independent variable (i.e. diagnostic category). Bivariate scatterplots for all dependent measures can be found in Figure 3 for the Asperger’s Disorder group and Figure 4 for the NVLD group. In addition, a bivariate correlation matrix of dependent variables was constructed as part of the analysis for research question one. Given the results of the bivariate scatterplots and correlation matrix, as well as the reasonably balanced distributions of the dependent variables, it is determined that the assumption of linearity was upheld. The assumptions of homoscedasticity and multicollinearity will be addressed separately when presenting results for applicable research questions.
Figure 3. Bivariate scatterplots of dependent measures for Asperger’s Disorder group.  

1 = D-KEFS Verbal Fluency Category Switching; 2 = D-KEFS Verbal Fluency Switching Accuracy; 3 = D-KEFS Color Word-Inhibition; 4 = D-KEFS Color Word Inhibition/Switching; 5 = BRIEF Inhibit; 6 = BRIEF Shift; 7 = BRIEF Working Memory; 8 = BRIEF Planning.
Figure 4. Bivariate scatterplots of dependent measures for NVLD group.

1 = D-KEFS Verbal Fluency Category Switching; 2 = D-KEFS Verbal Fluency Switching Accuracy; 3 = D-KEFS Color Word-Inhibition; 4 = D-KEFS Color Word Inhibition/Switching; 5 = BRIEF Inhibit; 6 = BRIEF Shift; 7 = BRIEF Working Memory; 8 = BRIEF Planning.
Research Question One Results

The first research question utilized a correlation matrix in order to examine relationships between executive functioning and the repetitive stereotypic behaviors characteristic of Asperger’s Disorder. The correlation matrix also allowed for the examination of multicollinearity for dependent variables that were used in subsequent multivariate analyses. Dependent measures included previously mentioned scales of the D-KEFS and BRIEF to assess executive functioning, and the four subscales of the GADS to assess behaviors characteristic of Asperger’s Disorder. Bivariate Pearson correlations for these measures are contained in Table 3.
Table 3

Pearson Correlations for Dependent Measures on the D-KEFS, BRIEF, and GADS

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. D-KEFS VF-CS</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. D-KEFS VF-SA</td>
<td>0.88**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. D-KEFS CW-I</td>
<td>0.32**</td>
<td>0.26*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. D-KEFS CW-I/S</td>
<td>0.22</td>
<td>0.18</td>
<td>0.64**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. BRIEF Inhibit</td>
<td>0.03</td>
<td>-0.02</td>
<td>0.04</td>
<td>0.14</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. BRIEF Shift</td>
<td>-0.02</td>
<td>-0.08</td>
<td>0.05</td>
<td>0.23</td>
<td>0.56**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. BRIEF WM</td>
<td>-0.16</td>
<td>-0.21</td>
<td>-0.27</td>
<td>0.09</td>
<td>0.43**</td>
<td>0.46**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. BRIEF Plan</td>
<td>0.09</td>
<td>-0.05</td>
<td>-0.09</td>
<td>0.11</td>
<td>0.33**</td>
<td>0.47**</td>
<td>0.72**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. GADS-Social</td>
<td>-0.32</td>
<td>-0.34</td>
<td>-0.22</td>
<td>-0.18</td>
<td>0.59**</td>
<td>0.53*</td>
<td>0.45*</td>
<td>0.61**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. GADS-Behavior</td>
<td>-0.34</td>
<td>-0.36</td>
<td>-0.29</td>
<td>-0.19</td>
<td>0.47*</td>
<td>0.45*</td>
<td>0.16</td>
<td>0.22</td>
<td>0.53**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. GADS-Cognitive</td>
<td>-0.24</td>
<td>-0.28</td>
<td>0.24</td>
<td>0.14</td>
<td>0.39</td>
<td>0.28</td>
<td>-0.09</td>
<td>-0.07</td>
<td>0.25</td>
<td>0.63**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12. GADS-Pragmatic</td>
<td>-0.35</td>
<td>-0.38</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.29</td>
<td>0.48*</td>
<td>0.10</td>
<td>0.14</td>
<td>0.51**</td>
<td>0.63**</td>
<td>0.33</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. D-KEFS = Delis-Kaplan Executive Function System; VF-CS = Verbal Fluency-Category Switching; VF-SA = Verbal Fluency-Switching Accuracy; CW-I = Color-Word Inhibition; CW-I/S = Color-Word Inhibition/Switching; BRIEF = Behavior Rating Inventory of Executive Functioning; WM = Working Memory. *p<.05; **p<.01
Based on bivariate Pearson correlations in Table 3, several statistically significant relationships are evident. Most notably, the BRIEF Shift scale is moderately correlated with the GADS-Social ($r = 0.53, p < .05$), GADS-Behavior ($r = 0.45, p < .05$), and GADS-Pragmatic ($r = 0.48, p < .05$) scales. Similar relationships are also found between the BRIEF Inhibit Scale and the GADS-Social ($r = 0.59, p < .01$) and GADS-Behavior ($r = 0.47, p < .05$) scales. There are no statistically significant relationships between clinical measures of executive functioning on the D-KEFS and behaviors associated with Asperger’s Disorder on the GADS. However, relationships between subscales of these measures generally tend to be modest and negative, indicating that lower scores on D-KEFS scales are associated with higher, more clinically significant, scores on GADS subscales. These findings, while not statistically significant, provide some support for the hypothesized negative relationship between performance on clinical measures of executive functioning and repetitive stereotyped behaviors as measured by the GADS Behavior scale.

**Research Question Two Results**

The comparison of executive functioning in children and adolescents with Asperger’s disorder versus those with NVLD was accomplished using a one-way MANOVA. Prior to running the MANOVA for research question two, several multivariate assumptions not already addressed in the preliminary analyses were examined. First, the Pearson correlation matrix presented in Table 3 was examined for collinearity among dependent variables. Tabachnick and Fidell (2007) suggest either omitting the variable with the highest variance proportion or computing the average of the collinear variables when correlations are high (.90 and higher). Table 3 indicates a
high degree of correlation between the two Verbal Fluency measures on the D-KEFS (Category Switching and Switching Accuracy; \( r = 0.88, p < .05 \)). As a result, these two variables were combined by computing the average of the two scores for each case, creating a new variable named D-KEFS Verbal Fluency Switching (\( M_{Asp} = 9.46(4.77), M_{NVLD} = 8.84(2.60) \)). Homogeneity of variance was evaluated using the Box’s M test. Result of the Box’s M test for this MANOVA was not significant (\( F(28, 8338) = 1.36, p < .05 \)), indicating the assumption of homogeneity of variance was upheld.

A one-way MANOVA was conducted with diagnostic category (Asperger’s Disorder and NVLD) as the independent variable and seven measures of executive functioning (D-KEFS Verbal Fluency Switching, Color-Word Inhibition, Color-Word Inhibition/Switching, and BRIEF Inhibit, Shift, Working Memory, Planning). Results indicate a significant main effect for diagnostic category, Wilks’ \( \lambda = 0.683, F(7, 43) = 2.85, p < .05 \) (see Table 4).

Table 4

<table>
<thead>
<tr>
<th>MANOVA for Executive Functions with Diagnosis as Independent Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
</tr>
<tr>
<td>Wilks’ Lambda</td>
</tr>
</tbody>
</table>

\*\( p < .05 \)

Given the significance of the MANOVA, univariate ANOVAs were conducted as follow-up analyses to determine which dependent variable(s) differed significantly between the two diagnostic groups. ANOVA results indicate that scores on the BRIEF Shift scale differ significantly based on diagnosis, \( F(1, 49) = 16.85, p < .001 \). Significant
differences based on diagnosis were not detected on any other dependent variable according to follow-up univariate ANOVAs. Refer to Table 5 for a summary of results from the univariate ANOVAs.

Table 5

*Summary for Follow-up ANOVAs with Diagnosis as Independent Variable*

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-KEFS VF-S</td>
<td>4.924</td>
<td>1</td>
<td>0.330</td>
<td>0.568</td>
</tr>
<tr>
<td>D-KEFS CW-I</td>
<td>0.715</td>
<td>1</td>
<td>0.082</td>
<td>0.776</td>
</tr>
<tr>
<td>D-KEFS CW-I/S</td>
<td>10.787</td>
<td>1</td>
<td>0.806</td>
<td>0.374</td>
</tr>
<tr>
<td>BRIEF Inhibit</td>
<td>453.194</td>
<td>1</td>
<td>2.618</td>
<td>0.112</td>
</tr>
<tr>
<td>BRIEF Shift</td>
<td>2939.861</td>
<td>1</td>
<td>16.848*</td>
<td>0.000</td>
</tr>
<tr>
<td>BRIEF WM</td>
<td>0.188</td>
<td>1</td>
<td>0.001</td>
<td>0.971</td>
</tr>
<tr>
<td>BRIEF Plan</td>
<td>60.228</td>
<td>1</td>
<td>0.504</td>
<td>0.481</td>
</tr>
</tbody>
</table>

Note. D-KEFS = Delis-Kaplan Executive Function System; VF-S = Verbal Fluency-Switching; CW-I = Color-Word Inhibition; CW-I/S = Color-Word Inhibition/Switching; BRIEF = Behavior Rating Inventory of Executive Functioning; WM = Working Memory. *p < .001

Figure 5 presents boxplots comparing scaled score distributions of the Asperger’s Disorder group and NVLD group on each of the dependent variables from the D-KEFS. Figure 6 displays boxplots comparing T-score distributions of the Asperger’s Disorder group and NVLD group on each of the dependent variables from the BRIEF. A reference line is included in Figure 6 at T-score of 65, indicating clinical significance according to the BRIEF manual (Gioia et al., 2000). Three out of four group means (Shift, Working Memory, Planning) exceed clinical significance for the Asperger’s Disorder group versus
only one out of four (Working Memory) for the NVLD group, with a statistically
significant group difference present for the BRIEF Shift scale as indicated by follow-up
univariate ANOVA.

Figure 5. D-KEFS scaled scores for Asperger’s Disorder and NVLD groups showing no
significant mean differences on any variable. VF = Verbal Fluency; CW = Color-Word.
Figure 6. BRIEF T-scores for Asperger’s Disorder and NVLD groups showing significant mean difference on Shift scale only. Reference line at $T$-score = 65 indicates clinical significance.
Research Question Three Results

Research question three expanded on the comparison of executive functioning in children and adolescents with Asperger’s Disorder and NVLD by adding age as a variable using a cross sectional approach. Groups were further separated by age into child (ages 8 to 12) and adolescent (ages 13 to 18) groups. Descriptive statistics for the age groups can be found in Table 6.

Table 6

Means and Standard Deviations for Dependent Measures Based on Age Group

<table>
<thead>
<tr>
<th>Measure</th>
<th>Asperger’s Disorder</th>
<th>NVLD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Child (n = 16)</td>
<td>Adolescent (n = 10)</td>
</tr>
<tr>
<td>D-KEFS VF-S</td>
<td>9.94  4.82</td>
<td>8.70  4.85</td>
</tr>
<tr>
<td>D-KEFS CW-I</td>
<td>9.31  2.89</td>
<td>8.70  3.62</td>
</tr>
<tr>
<td>D-KEFS CW-I/S</td>
<td>9.56  3.22</td>
<td>8.10  4.77</td>
</tr>
<tr>
<td>BRIEF Inhibit</td>
<td>61.25 12.95</td>
<td>63.00 11.95</td>
</tr>
<tr>
<td>BRIEF Shift</td>
<td>71.75 12.41</td>
<td>73.20 13.69</td>
</tr>
<tr>
<td>BRIEF WM</td>
<td>66.94 11.21</td>
<td>67.20 13.09</td>
</tr>
<tr>
<td>BRIEF Plan</td>
<td>66.94  9.64</td>
<td>68.80  7.29</td>
</tr>
</tbody>
</table>

Note. D-KEFS = Delis-Kaplan Executive Function System; VF-S = Verbal Fluency-Switching; CW-I = Color-Word Inhibition; CW-I/S = Color-Word Inhibition/Switching; BRIEF = Behavior Rating Inventory of Executive Functioning; WM = Working Memory; D-KEFS values reported as scaled scores (Mean = 10; SD = 3); BRIEF values reported as T-scores (Mean = 50; SD = 10).
The interaction between diagnosis and age group was assessed using MANOVA. Prior to running the MANOVA, the assumption of homogeneity of variance was again examined using the Box’s M test. Result of the Box’s M test for this MANOVA was not significant \((F(84, 3558) = 1.04, p < .05)\), indicating the assumption of homogeneity of variance was again upheld. Given the result of the Box’s M test, Wilks’ Lambda was used to determine the presence of significant interactions between diagnosis and age. Results of this MANOVA reveal no significant interaction between diagnosis and age group, Wilks’ \(\lambda = 0.871\), \(F(7, 41) = 0.869\), \(p = 0.539\) (See Table 7).

Table 7

**MANOVA for Interaction of Diagnosis with Age Group**

<table>
<thead>
<tr>
<th>Value</th>
<th>(F)</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
<th>(\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wilks’ Lambda</td>
<td>0.871</td>
<td>0.869</td>
<td>7</td>
<td>41</td>
<td>0.539</td>
</tr>
</tbody>
</table>

Despite the lack of statistically significant interactions, estimated marginal means for the two diagnostic categories at each age point were plotted for all dependent variables. Figures 7 to 9 present plots of estimated marginal means for each of the dependent variables on the D-KEFS.
Figure 7. Estimated marginal means for child and adolescent Asperger’s Disorder and NVLD groups on D-KEFS Verbal Fluency-Switching.

Figure 8. Estimated marginal means for child and adolescent Asperger’s Disorder and NVLD groups on D-KEFS Color-Word Inhibition.
Figure 9. Estimated marginal means for child and adolescent Asperger’s Disorder and NVLD groups on D-KEFS Color-Word Inhibition/Switching.

In the case of the D-KEFS Verbal Fluency-Switching variable, the Asperger’s Disorder child group performed better than the NVLD child group, with the reverse being true for the adolescent groups of the two diagnostic categories (see Figure 7). Scores on the D-KEFS Color-Word Inhibition and Color-Word Inhibition/Switching conditions followed a similar pattern from the child group to adolescent group, with the Asperger’s Disorder group performing slightly better than the NVLD group at both age classifications (see Figures 8 and 9).

Plots of estimated marginal means for the two diagnostic categories at each age point for BRIEF dependent variables were also constructed and are presented in Figures 10 to 13.
Figure 10. Estimated marginal means for child and adolescent Asperger’s Disorder and NVLD groups on the BRIEF Inhibit scale. Reference line at $T$-score = 65 indicates clinical significance.
**Figure 11.** Estimated marginal means for child and adolescent Asperger’s Disorder and NVLD groups on the BRIEF Shift scale. Reference line at $T$-score = 65 indicates clinical significance.
### BRIEF-Working Memory

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Mean T-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child (8-12)</td>
<td>70</td>
</tr>
<tr>
<td>Adolescent (13-18)</td>
<td>69</td>
</tr>
<tr>
<td>Asperger's Disorder</td>
<td>68</td>
</tr>
<tr>
<td>NVLD</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>65</td>
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<tr>
<td></td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>63</td>
</tr>
</tbody>
</table>

**Figure 12.** Estimated marginal means for child and adolescent Asperger’s Disorder and NVLD groups on the BRIEF Working Memory scale. Reference line at T-score = 65 indicates clinical significance.
**Figure 13.** Estimated marginal means for child and adolescent Asperger’s Disorder and NVLD groups on the BRIEF Planning scale. Reference line at $T$-score = 65 indicates clinical significance.

Mean scores on the BRIEF Inhibit scale remained relatively stable for children and adolescents with Asperger’s Disorder, with a slight decrease in mean scores (i.e., less clinically significant) in the NVLD group from child to adolescent designation (see Figure 10). The BRIEF Shift scale yielded a nearly parallel relationship when comparing group means, with the Asperger’s Disorder group reaching clinical significance at both age classifications (see Figure 11). Both the BRIEF Working Memory and Planning scales produced similar plots with the Asperger’s Disorder group exhibiting clinically significant behavior, compared to non-clinically significant behavior in the NVLD group, at the adolescent classification (see Figures 12 and 13).
CHAPTER V

Discussion

The primary goals of this study were to examine the relationships between components of executive functioning and behaviors associated with Asperger’s Disorder, and to compare children and adolescents with Asperger’s Disorder to those with NVLD on measures of executive functioning. This chapter will address the findings of the current study within the context of relevant theoretical background and extant literature. Implications and recommendations for future research will be discussed.

Summary of Results

Research question one. The first research question focused on the relationship between various components of executive functioning and behaviors characteristic of Asperger’s Disorder, particularly stereotypic and repetitive behaviors. It was hypothesized that a negative relationship would be present between performance on clinical measures of cognitive flexibility and severity of stereotypic and repetitive behaviors. On the other hand, positive correlations were expected between parent ratings of executive functioning and parent report of behaviors associated with Asperger’s Disorder.

Bivariate correlations revealed no statistically significant relationships between clinical measures of executive functioning and behaviors indicative of Asperger’s Disorder. Despite the lack of statistically significant findings, modest negative correlations were observed between clinical measures of inhibition and cognitive flexibility and behaviors associated with Asperger’s Disorder, particularly social and repetitive behavior. Put differently, a greater presence of social and behavioral
characteristics indicative of Asperger’s Disorder was associated with decreased performance on tasks of inhibition and cognitive flexibility.

In terms of parent ratings of executive functioning, results indicated that statistically significant positive correlations existed between executive functioning and behaviors associated with Asperger’s Disorder. In particular, difficulty utilizing shifting behaviors was positively correlated with the presence of repetitive and stereotyped behaviors. In other words, individuals who had difficulty performing tasks such as adjusting to new situations and using alternative problem-solving methods also had a tendency to demonstrate a higher degree of repetitive and stereotyped behaviors. This provides support for the hypothesized results of research question one.

**Research question two.** Comparison of executive functioning in children and adolescents with Asperger’s Disorder versus NVLD was the objective of the second research question. It was hypothesized that the groups would differ on measures of cognitive flexibility/set shifting and planning. There were no significant differences between the two groups on clinical measures of inhibition or cognitive flexibility. Likewise, there were no significant differences between the two groups on parent behavioral ratings of inhibition, working memory, or planning. However, a significant difference was present between the two groups in terms of parent ratings of shifting behavior, with the Asperger’s Disorder group demonstrating significantly more difficulty. Furthermore, when considering clinical significance of behavioral ratings, the Asperger’s Disorder group exceeded the cutoff for clinically significant behavior on three out of four domains (shifting, working memory, and planning) versus only one for the NVLD group (working memory).
**Research question three.** In order to address developmental questions related to executive functioning in Asperger’s Disorder and NVLD, research question three further divided the two diagnostic categories into child (ages 8 to 12) and adolescent (ages 13 to 18) groups. It was hypothesized that adolescents with Asperger’s Disorder would demonstrate weaker cognitive flexibility/set-shifting and planning than children with Asperger’s Disorder relative to age-matched groups of children and adolescents with NVLD. In other words, it was expected that the NVLD group would demonstrate a more positive trajectory in development of executive functioning from childhood to adolescence. The result would be a larger discrepancy in performance at adolescence favoring the NVLD group. This would be particularly relevant on measures of cognitive flexibility and planning. In terms of parent ratings of shifting and planning behavior, a negative trajectory was expected for the Asperger’s Disorder group from childhood to adolescence. Again, a larger discrepancy in ratings would be expected at adolescence, with the Asperger’s Disorder group demonstrating more behaviors indicative of executive dysfunction in the domains of shifting and planning.

Results indicated that there were no statistically significant interactions between diagnosis and age group on any measure of executive functioning. A qualitative examination of data for the performance-based measures indicated that children with Asperger’s Disorder outperformed children with NVLD on a verbal fluency measure involving cognitive flexibility, but the two groups were relatively similar at adolescence, with the NVLD group demonstrating slightly better performance. On both tasks of the D-KEFS Color-Word test, the first component involving purely inhibition with the second task incorporating both inhibition and cognitive flexibility, performance declined from
childhood to adolescence in a parallel manner, with the Asperger’s Disorder group actually performing slightly better in both cases. These findings did not provide support for the hypothesized results of the third research question.

As was the case for the performance-based measures of executive functioning, behavioral measures of executive functioning yielded no significant interaction between diagnosis and age group. Data was again examined qualitatively for possible trends. Behavioral ratings of inhibition indicated similar characteristics for the child subgroups of both the Asperger’s and NVLD groups. However, behavioral ratings of inhibition appear to improve (scores decrease) from childhood to adolescence for the NVLD group, whereas ratings remain stable between the two age-defined subgroups of the Asperger’s Disorder group. No group ratings exceeded clinical significance.

Similar patterns of behavioral ratings were observed for both working memory and planning. In each case, the child subgroup for each diagnostic category exceeded clinical significance, with the NVLD group actually demonstrating more impairment initially. However, the trend of improvement in behavioral ratings is again evident for the NVLD group as clinically significant behavior was no longer present for the adolescent subgroup for either planning or working memory. This trend was not apparent for the Asperger’s Disorder group, as adolescents demonstrated similar performance compared to their child counterparts and remained in the clinically significant range for behaviors associated with both planning and working memory.

An interesting and unique pattern emerges for ratings of shifting behavior. Both the child and adolescent Asperger’s Disorder groups demonstrated similar clinically significant behavior. On the other hand, the child and adolescent NVLD groups remained
well below the cutoff for clinical significance. The relationship between the two groups appears nearly parallel, with each diagnostic category demonstrating similar performance for both child and adolescent subgroups. This pattern does not provide support for the hypothesized results of research question three, which expected increased difficulty with shifting behavior for the Asperger’s Disorder group from childhood to adolescence as opposed to relatively stable, less impaired, behavior for the NVLD group. In fact, these findings provide further support for the hypothesized results of research question two, indicating the discrepancies in shifting behavior of individuals with Asperger’s Disorder and NVLD appear to be present at two points in development.

Conclusions

The current study explored behavioral and developmental characteristics of executive functioning in Asperger’s Disorder and NVLD. Hypothesized results of research questions were met with mixed findings. The following sections will present explanations and implications of the present findings in the context of theoretical perspectives and relevant existing literature.

Relationship between executive functioning and stereotypic behavior.

Examination of the relationship between executive functioning and the stereotypic repetitive behaviors and interests of children and adolescents with Asperger’s Disorder was essentially a modification of Lopez and colleagues (2005). In this existing study, relationships were found between deficits in cognitive flexibility on performance-based measures and the presence of restricted, repetitive behavior in adults with ASD. The current study utilized both performance-based measures and behavioral ratings of executive functioning with mixed results compared to research hypotheses and existing
literature. The expected negative relationship between performance on tasks of cognitive flexibility was present, but only modestly. On the other hand, significant positive relationships were found between behavioral ratings of shifting and repetitive behaviors. One explanation for these mixed results, which differ slightly from the findings of Lopez and colleagues (2005), may relate to differences in methodology between the two studies. Lopez and colleagues relied solely on performance-based measures of executive functioning and created composite variables that incorporated multiple measures of the same hypothesized construct. This design feature may have led to more reliable assessment of components of executive functioning, and ultimately increased the sensitivity and specificity in detecting relationships between cognitive flexibility and repetitive behavior.

Another explanation of the current findings, particularly the strong relationship between behavioral ratings of executive functioning and stereotypic behaviors, related to potential method variance inherent in this analysis. Method variance pertains to variance particularly related to methods used to obtain data (Campbell & Fiske, 1959). In this case, behavioral ratings of executive functioning and ratings of stereotypic behavior were both obtained via parent report. As a result, variables assessed share some degree of variance because the methods used to obtain them was the same (Spector & Brannick, 2010). Thus, the significant positive relationship between difficulty with shifting behavior and stereotypic behavior may have been influenced by common methods used.

The current findings also provided partial support for the Executive Function Theory of ASD, which proposes that deficits in executive functioning underlie behavioral characteristics of ASD (Joseph, 1999; Pennington & Ozonoff, 1996). Of course, the
correlational techniques employed in this study should not be used to suggest causation. However, behavioral manifestations of executive functioning measured by the BRIEF, particularly shifting behavior, do appear to relate to behavioral and social characteristics of Asperger’s Disorder. This relationship suggests the possibility of incorporating executive functioning training in treatment planning as a way to target stereotypic behaviors and social deficits associated with Asperger’s Disorder.

**Comparison of executive functioning in Asperger’s Disorder versus NVLD.**

Existing literature has established a profile of executive functioning in ASD of impaired cognitive flexibility (Bennetto et al., 1996; Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff, Pennington, & Rogers, 1991; Ozonoff & McEvoy, 1994; Ozonoff, Strayer, McMahon, Filloux & 1994; Szatmari, Finlayson, & Bartolucci, 1990) and planning (Hughes et al., 1994; Ozonoff & McEvoy, 1994; Prior & Hoffman, 1990). On the other hand, inhibition (Goldberg et al., 2005; Ozonoff & Strayer, 1997) and working memory (Hughes et al., 1994; Ozonoff & Strayer, 2001; Russell et al., 1996) appear relatively intact when compared to control groups. Research on executive functioning in children and adolescents with NVLD, the comparison group in the current study, is much less abundant. According to extant literature, weaknesses in attentional control (Jing et al., 2004) as well as visual-spatial working memory and visual imagery (Cornoldi et al., 1999) appear to be present when individuals with NVLD are compared to controls.

The establishment of an executive profile comprised of strengths and weaknesses in various component processes follows a theoretical conceptualization of executive functioning of fractionated but related components proposed by Pennington and Ozonoff (1996). This framework is central to the organization and methodology of the current
study, and facilitates interpretation of results that demonstrate partial corroboration of the existing executive profile. More specifically, results of performance-based measures of inhibition and cognitive flexibility yielded no support for the existing executive profile, nor did they reveal significant differences between individuals with Asperger’s Disorder and NVLD. However, behavioral ratings of executive functioning, as measured by the BRIEF, revealed a profile more consistent with extant findings in the literature. In particular, children and adolescents with Asperger’s Disorder demonstrated clinically significant difficulties in shifting and planning. As expected, these deficits were not seen in children and adolescents with NVLD. Neither group demonstrated deficits in inhibition, which was again consistent with existing literature (Goldberg et al., 2005; Ozonoff & Strayer, 1997). Interestingly, both groups exhibited clinically significant behaviors related to working memory.

One possible explanation for the increased sensitivity and specificity of the BRIEF in detecting unique executive profiles for Asperger’s Disorder and NVLD relates to the concept of “hot” and “cool” executive functions proposed by Zelazo and Muller (2002). Under their model, “hot” aspects represent affective or emotionally driven processes associated with the ventral and medial prefrontal cortex, while “cool” aspects are associated with abstract problem-solving skills more likely mediated by the dorsolateral prefrontal cortex. The current study employed varied assessment methods to potentially tap both “cool” (e.g., performance-based problem-solving tasks) and “hot” (e.g., behavioral ratings) aspects of executive functioning. The behavioral characteristics of Asperger’s Disorder, particularly repetitive and stereotyped behaviors and interests, may indicate that “hot” aspects of executive functioning are central to the disorder. This
may explain why the BRIEF Shift scale detected deficits in executive functioning, while clinical measures did not. These findings also illustrate the importance of incorporating ecologically valid behavioral assessments into neuropsychological evaluation of executive functioning. Using multiple assessment methods provides clinicians with useful information when formulating treatment plans and developing specific interventions.

**Developmental characteristics.** Developmental theory suggests that executive functions emerge during the first several years of life (Diamond, 1988) and experience notable spurts in development in late childhood and early adolescence (Luna et al., 2004), with adult levels of performance on some tasks being reached by approximately 12 years of age (V. Anderson, P. Anderson, Northam, Jacobs, & Catroppa, 2001; Chelune & Baer, 1986; Welsh, Pennington, & Grossier, 1991; Zelazo & Muller, 2003). Given the documented deficits in cognitive flexibility and planning in individuals with ASD, it was expected that the Asperger’s Disorder group would demonstrate a flattened developmental trajectory from childhood to adolescence compared to the NVLD group. These expected results were not statistically supported. However, qualitative examination of mean scores indicated mixed trends. Most notably, planning, as measured by the Planning subscale of the BRIEF, indicated similar clinically significant means for both child groups, with improved planning for the NVLD group at adolescence. The lack of statistically significant findings may have been related to the decreased group sample sizes following cross-sectional division. Additionally, a longitudinal design, when feasible, may be a preferred method for detecting developmental change.
Limitations

The goal of the current study was to expand upon findings of existing literature on executive functioning in ASD. This was accomplished methodologically in several ways. First, group comparisons were made between two very similar diagnostic categories, Asperger’s Disorder and NVLD. Comparisons between diagnostically similar groups provide an opportunity for unique and interesting findings with a potential to offer important information regarding differential diagnosis. In addition, this study utilized both performance-based measures and an ecologically valid behavioral rating scale completed by parents in order to measure executive functioning.

Despite these strengths, several limitations remain for the current study. First and foremost, research on executive functioning is often complicated by an inability to purely measure the intended component process (Blair, Zelazo, & Greenberg, 2005; Hughes & Graham, 2002). For example, the D-KEFS Color-Word Inhibition/Switching subtest requires the examinee to utilize both cognitive flexibility and inhibition, as was the case with the current study. This factor introduces extraneous variance that may have affected analyses. In addition, several key measures of the D-KEFS (e.g., Verbal Fluency – Category Switching) have been shown to have admittedly low to moderate reliability (Delis et al., 2001). Measures with low reliability can affect the results of analyses by making differences between variables more difficult to detect (Stevens, 1999).

Limitations related to sample characteristics and size were also apparent in the current study. A preexisting dataset from an outpatient neuropsychology clinic was used. Thus, the sample was non-random and included individuals primarily from the same geographical area. As such, the results of this study may be somewhat limited in their
generalization to broader populations. Additionally, while the sample size was adequate for initial comparisons between Asperger’s Disorder and NVLD groups, it became quite small when the groups were cross-sectioned by age. The small sample sizes in this analysis resulted in reduced power and likely limited the MANOVA’s ability to detect meaningful group differences.

Another limitation of the current study relates to the presence of comorbid diagnoses for both individuals in the Asperger’s and NVLD groups. Inclusion of individuals with comorbid diagnoses was necessary as the sample size would have been limited otherwise. However, including individuals with comorbid diagnoses introduces more error variance into analyses. This may be particularly relevant for the current study, as individuals with ADHD (Barkley, 1997; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002), depression (Austin et al., 1999; Emerson, Mollet, & Harrison, 2005), and anxiety (Yan, Wang, & Cui, 2007) have been found to have difficulties with various aspects of executive functioning. Although, research has indicated that individuals with ASD appear to have a unique executive functioning profile when compared to other clinical populations (Ozonoff & Jensen, 1999; Ozonoff et al., 2004).

Recommendations for Future Research

Research on executive functioning in ASD is extensive. The current study attempted to extend the findings of extant research by incorporating behavioral and developmental variables in comparison of two similar diagnostic categories, Asperger’s Disorder and NVLD. Future research can expand upon this study in several ways. First, the diagnostic criteria for ASD continues to evolve, and will likely change with the next revision of the DSM, possibly leading to the elimination of the Asperger’s Disorder
diagnosis in favor of a broad classification of ASD based on language ability. As a result, future research in this area may wish to utilize a broader sample of participants with ASD classified either by language ability or using language ability as a covariate.

Another possibility for expansion of research in this area relates to the handling of comorbid diagnoses. As mentioned previously, comorbid diagnoses were present in this study and may have influenced results. Ideally, the presence of comorbid diagnoses should be limited in order to provide more certainty when drawing conclusion about group characteristics. However, in the case of clinic-referred databases, it may not always be possible to eliminate comorbid diagnoses without limiting the sample size. Given a large enough sample size, examining the characteristics of individuals with comorbid diagnoses may provide useful information regarding specific neuropsychological effects of compounded disorders.

Future research should also consider extending behavioral ratings of executive functioning to other sources, such as teachers. Behavioral ratings, such as the BRIEF, provide a valuable source of information regarding executive functioning in the natural environment. Obtaining information on executive functioning from traditional performance-based measures, as well as from multiple sources across environments (i.e., home and school) allows clinicians to more thoroughly assess executive functioning in children and adolescents with ASD. Inclusion of teacher ratings in future studies will extend the current findings and may potentially inform treatment planning in the academic environment.
References


APPENDIX

DUQUESNE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
424 RANGOS BUILDING • PITTSBURGH PA 15282-0202

Dr. Paul Richer
Chair, Institutional Review Board
Human Protections Administrator
Phone (412) 396-5320 Fax (412) 396-5170
e-mail: irche@duq.edu

June 8, 2010

Dr. Jeffrey Miller:
School of Education
Duquesne University
Pittsburgh PA 15282

Dear Dr. Miller:

Re: Executive functioning in Asperger’s disorder and nonverbal learning disabilities: A comparison of developmental and behavioral characteristics (Protocol # 10-59)

Thank you for submitting the research protocol from your student, Mr. Nathan Kegel, to the IRB.

Based on the review of Dr. Rick Myer, IRB Representative, and my own review, your study is approved as Exempt based on 45-CODE OF FEDERAL REGULATIONS-46.101.b.4, regarding data without identifiers extracted records existing at this time.

This exempt approval pertains strictly to the research described in the protocol. If you and Mr. Kegel intend to make a change in the research, you must re-submit an amended proposal before proceeding. In addition, you should inform the IRB if any adverse events or procedural problems occur impacting subjects. In correspondence about the research, please refer to the protocol number shown after the title above.

Once the study is complete, provide our office with a short summary (one page) of your results for our records.

Thank you for contributing to Duquesne’s research endeavors.

Sincerely yours,

[Signature]
Paul Richer, Ph.D.

C: Dr. Rick Myer
Mr. Nathan Kegel
IRB Records