EXECUTIVE FUNCTIONING AND ATTENTION AS PREDITORS OF FUNCTIONAL OUTCOMES IN ADOLESCENTS WITH AUTISM SPECTRUM DISORDERS

by

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Abstract

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by impairments in communication and socialization, as well as by repetitive and stereotyped behaviours and interests. The ASD phenotype is also characterized by impairments in cognition. A growing body of literature points to attention and executive functioning as being key elements of cognition that are impaired in individuals with ASD. It is very possible that these cognitive difficulties are related to the functional deficits in academic achievement, daily living skills and socialization that are experienced by individuals with ASD throughout their lifetime. Associations between these cognitive and functional abilities have been identified in TD populations; however, this relationship is not well understood in ASD. This is especially true for *adolescents* with ASD who are a vastly understudied population within the field. The research in this thesis aimed to investigate the nature of cognitive and functional impairments in high-functioning adolescents with ASD, and to better understand the relationship between these deficits. This study made use of a multi-method approach, by obtaining behavioural and parent-report data related to cognition and functioning for both ASD and TD populations. The results indicated that adolescents with ASD may have some impairment in executive functioning, particularly with shifting and planning abilities, and score significantly lower than TD adolescents on measures of academic achievement, adaptive behaviour and social skills. Surprisingly, no evidence was found for attentional deficits in the ASD group. Multiple regression analyses did not reveal any significant predictive relationships of attention and executive functioning with academic ability, adaptive behaviour, or social skills. Limitations of this research are discussed. The results may lend themselves to the development of theoretical frameworks for understanding functional abilities in adolescents with ASD.

Co-Authorship

The research reported in this thesis was completed in conjunction with a larger study on attention and executive functioning in adolescents with autism spectrum disorder. My supervisor, Dr. Elizabeth Kelley, and Dr. Daryl Wilson assume primary responsibility for formulating the idea for the larger study; however, I assume shared responsibility for the formulation, conceptualization and design of the research reported in this thesis. I assume responsibility for the execution of this thesis research, which is shared with Rosaria Furlano who is also completing her Master's under the supervision of Dr. Kelley. Finally, I assume primary responsibility for the write-up of this thesis with the assistance of Dr. Kelley.

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Chapter 1

Introduction

Individuals with autism spectrum disorder (ASD) face lifelong struggles with regards to academic achievement, daily living and socialization (Seltzer, Shattuck, Abbeduto, & Greenberg, 2004). Unfortunately, although much has been done to understand these functional deficits in ASD, research regarding the underlying cognitive deficits that might explain these impairments continues to be limited. Attention and executive functioning are two components of cognition that could help to explain the functional impairments experienced by individuals with ASD. Attention and executive functioning are respectively lower- and higher-order cognitive processes important for retrieving information from the environment, processing that information, and developing, assessing, and executing a plan to act based on the information in an efficient way. There is a growing body of research to suggest that components of both attention and executive functioning are impaired in individuals with ASD as compared to their typically developing (TD) counterparts; however, evidence regarding the nature of these delays is not clear (Corbett & Constantine, 2006; Dye & Bavelier, 2010; Sweeney, Takarae, Macmillan, Luna, & Minshew, 2004). Furthermore, very little research has focused on how these cognitive processes influence functional outcomes in individuals with ASD. The relationship between cognition and functioning in ASD becomes especially relevant when we consider the period of adolescence. During this time the brain undergoes a burst of development in areas that have been linked to attention and executive functioning (Luna et al., 2001; Stuss, 2011). Furthermore, adolescence is a period of time when one works to develop the functional skills that will help them to be successful as they leave high school and transition into adulthood. By better clarifying the nature of cognitive and functional impairments in adolescents with ASD and by better understanding the relationships between these abilities, it may become possible to develop a theoretical model that can help to explain functional impairments experienced by individuals with ASD that may be the result of cognitive deficits associated with, but separate from, diagnostic symptoms. Furthermore, with deeper understanding of these relationships it will become possible to develop effective interventions that target the underlying roots of functional impairment.

Attention and Executive Functioning in Development

Executive functions are a set of higher-order cognitive abilities associated with problem solving and goal-directed behaviour, which are skills that are imperative to helping us function from day to day. While there is no concrete definition of executive functioning that is agreed upon in the literature, there is general consensus that the main components of executive functioning include inhibition, shifting, working memory and planning (Best, Miller, & Jones, 2009). A common underlying element of each of these components that categorizes them as executive functions is that they function to change the probability of future actions. More specifically, inhibition is the prevention of a response to a change in the environment such that a different response may then be made that is more in line with the goal to be attained. Shifting refers to the disengagement and reengagement of attention to a new stimulus in order to further respond to it. Working memory is the maintenance of several pieces of information in the mind so that they might be used together in formulating an action, and finally, planning refers to the use of information to organize a plan that can then be acted upon to achieve a goal. Each of these skills is essential to helping us better function in our world as they allow us to conceptualize information, organize it, and then act efficiently according to it.

There is a good degree of overlap between how we conceptualize executive functioning and attention, which is often described as being composed of four components: the ability to initiate, sustain, inhibit, and shift attention (Lyon & Krasnegor, 1996). These similarities suggest an association between attention and executive functioning in which attention may help to direct some of the higher-order components of executive functioning and, more importantly, guide our everyday behaviour (Steele, Cornish, Karmiloff-Smith, & Scerif, 2012). Where attention differs is that its components function as responses to environmental events immediately after the event has occurred, rather than as a planned set of actions. As such, initiating and sustaining attention simply refer to the engagement and maintenance of attention towards a stimulus. Inhibition and shifting refer to the prevention or change of attention in response to environmental changes without a link to future action planning. In other words, attention is a bottom-up process of cognitive control, involving more reflexive responses as a primary reaction to information, while executive functioning works in a top-down manner in order to somewhat inhibit and modulate reflexive responses.

The components of executive functioning and attention have variable developmental trajectories throughout childhood and adolescence, and even continue to develop into adulthood. Executive functioning is localized primarily to certain areas of the frontal lobes, which undergo developmental spurts early in childhood and again in adolescence (Stuss, 2011). Specifically, the frontal lobes undergo a great deal of myelination in adolescence, and experience-dependent synaptic pruning reduces synaptic density in the frontal lobes throughout adolescence (Blakemore & Choudhury, 2006). Similar changes also occur during adolescence in various areas of the brain to which attentional abilities have been localized (Keehn, Muller, & Townsend, 2013). In line with these neurological changes, there is also a fair amount of evidence for behavioural changes throughout adolescence. With regards to executive functioning, skills such as inhibition, shifting, working memory, and planning have all been shown to improve throughout adolescence (Crone, 2009). For example, Leon-Carrion, Garcia-Orza, and Perez-Santamaria (2004) had children and adolescents 6 to 17 years of age and of average intelligence complete a computerized inhibition task and compared their performance. They found that participants made clear improvement in performance until age 17. Additionally, Luciana, Conklin, Cooper and Yarger (2005) investigated performance on nonverbal working memory and planning tasks of increasing difficulties in individuals 9 to 20 years of age. The results from this study demonstrated that the executive control to perform these tasks as they increased in organizational demands developed over time such that simpler tasks of working memory were accurately completed by the age of 12, while tasks requiring strategic organization did not fully develop until about 17 years of age. With regards to cognitive shifting abilities, Somsen (2007) used a card-sorting task to evaluate changes in performance in individuals between 6 and 18 years of age. Somsen found that while the general ability to form concepts about categorization of cards developed from 6 to 11 years of age, the ability to integrate feedback into performance and shift between rules continued to improve through to 18 years of age.

Similar to executive functioning, different components of attention emerge and develop at different times throughout childhood and adolescence. Factor analysis using performance scores on various attention measures has shown that young children have developed attentional abilities in selective/sustained attention and executive attention, but more distinct components of attention emerge in adolescence and adulthood (Steele et al., 2012). In a study of children, 7 to 17 years of age, and adults, 18 to 22 years of age, Dye and Bavelier (2010) noted that performance on different computerized attention tasks continues to develop through adolescence and into adulthood. Specifically, they noted that while visual orienting, spatial-temporal tracking, and attentional refractory ability all are generally developed at various points throughout childhood, spatial-temporal tracking and attentional refractory ability continue to improve into early adulthood. This finding is in line with reports that the most reflexive elements of attention such as visual orienting become fully developed within young children, but that more volitional attentional abilities such as disengaging and shifting attention may continue to develop at least into adolescence (Ristic & Kingstone, 2008; Wainwright & Bryson, 2002; Waszak, Li & Hommel, 2010).

In addition to performance on behavioural tasks, measures such as eye-tracking tasks have been useful in providing biological correlates for understanding the development of executive functioning and attentional abilities. Such tasks make use of saccadic movement, or quick movements made by the eyes, to gain a better understanding of how quickly and accurately an individual is capable of orientating visual attention and controlling their responses to visual stimuli. To assess basic attention, such as the fundamental reflexive components of attention, studies typically make use of a Prosaccade task (Paolozza, Titman, Brien, Munoz, & Reynolds, 2013), which measures simple reflexive orientation and fixation of attention in response to a stimulus onset. Assessing higher-order executive functioning abilities often makes use of an Antisaccade task (Paolozza et al., 2013), which measures inhibitory control as individuals are required to make an eye movement in the opposite direction of a stimulus. Delayed-Memory tasks (Paolozza et al., 2013), which require individuals to remember the locations of a series of stimuli and then accurately direct attention towards their locations following a period of delay from their onset, are also typically used to assess working memory and planning components of executive control. It has generally been reported that while the ability to perform on all of these types of tasks is present in infancy and early childhood, the more reflexive attentional occulomotor activities stabilize in development during infancy or early childhood, and the executive functioning components of saccadic movement continue to develop throughout adolescence (Luna, Velanova, & Geier, 2008). More specifically, research investigating Prosaccade and Antisaccade responses and brain activity through fMRI scanning of individuals ages 8 to 30 demonstrated that, while Prosaccade performance was already at peak performance by the beginning of this age range, Antisaccade performance continued to improve through adolescence which coincided with age-related changes in brain development (Luna et al., 2001).

Functional Implications of Attention and Executive Functioning Abilities

Both attention and executive functioning have been shown to make important contributions to the development of functional abilities in TD individuals. Functional abilities refer to the various behavioural skills that one develops over time that allows one to interact with his/her environment in an efficient and meaningful way and gain independence. Such abilities tend to include attributes such as academic achievement, social skills and adaptive behaviour, with adaptive behaviour including the aptitude to carry out day-to-day tasks such as interacting in the community, communicating effectively, performing self-care tasks, and coping.

Attention has been indicated as playing a critical role in facilitating prosocial behaviour in TD children in kindergarten and first grade, such that children who have more social difficulties have a harder time shifting attention and that the ability to shift attention significantly predicts sharing behaviour (Wilson, 2003). It is suggested that the inability to effectively shift attention interferes with the opportunity to learn from important social information in the child's environment. More specifically, when a child becomes fixated on a certain object and is not reflexively disengaging and orienting attention to different stimuli in their environment, it becomes easy to miss certain social cues such as facial expressions, body language, or environmental stimuli that provide an important context for social interaction. Failure to perceive and process such cues can interfere with both the process of learning from social information in the environment and the ability to carry out social interactions in an effective way.

Furthermore, attentional ability has been linked to academic achievement in TD children and adolescents. An analysis of six longitudinal data sets revealed that attentional abilities at the time of school entry, as measured by behavioural performance on a continuous performance task as well as by parent and teacher reports on standardized measures of attention, are one of the most important predictors of later academic success in mathematics and reading in children, as measured by standardized tests of academic achievement (Duncan et al., 2007). Additionally, Steele, Cornish, Karmiloff-Smith and Scerif (2012) assessed the attentional abilities of a group of children ranging from 3 to 6 years of age using measures of sustained and cued attention. When the academic achievement of these children was assessed 12 months later, it was found that attention predicted their achievement on standardized numeracy and literacy tests of achievement (Steele et al.). Attention has also been shown to play a critical role in the academic achievement of TD adolescents. Steinmayr, Ziegler and Trauble (2010) demonstrated that although IQ is a strong predictor of academic achievement, sustained attention ability moderates this relationship and explains a significant amount of variance in achievement above and beyond IQ in high-school students. Steinmayr, Ziegler and Trauble (2010) assert that it may not be enough to be able to apply the theories that one has learned in class when completing academic work, but that there needs to be continuous focus and concentration on the task in order to succeed in an academic environment.

There is also a substantial amount of support for the role of executive functioning in the development of social and academic skills (Best, Miller, & Jones, 2009). Rinsky and Hinshaw (2011) assessed the executive functioning abilities (including planning, working memory, and inhibition) of a group of girls with Attention Deficit/Hyperactivity disorder (ADHD) and a group of TD girls between 6 and 11 years of age, and followed up these same participants five years later with an assessment of their social skills using a number of parent- and teacher-report measures. The results of this study indicated that childhood planning and inhibition abilities were predictive of adolescent social skills above and beyond the effects of diagnosis, indicating that executive functioning is important to social skills development in both groups (Rinsky & Hinshaw). Such results suggest that for the development of social functioning it is important to be able to plan and organize responses in a social environment as well as to be able to inhibit inappropriate social reactions.

In a related study, Miller and Hinshaw (2010) assessed the academic achievement and adaptive behaviour of the same set of TD and ADHD girls at a five-year follow-up. For both groups, childhood planning and inhibition scores significantly predicted math (but not reading) scores. Miller and Hinshaw also found that executive functioning was predictive of later adaptive functioning, but only for the ADHD group. It is possible that executive functioning is especially important to the development of monitoring and conceptualization skills that are critical to comprehending and completing school work and carrying out daily activities. The results found by Miller and Hinshaw, as well as by Rinsky and Hinshaw (2011), are in agreement with correlational findings that link observational measurements of executive functioning, as well as teacher- and parent-report executive functioning measures to academic skills and social functioning in children (Charman, Carroll, & Sturge, 2001; Monette, Bigras, & Guay, 2011).

Furthermore, within TD adolescent populations different components of executive functioning have been found to be predictive of different academic abilities (i.e., conceptual flexibility predicts performance in reading and science while inhibition predicts success in mathematics and science) (Latzman, Elkovitch, Young, & Clark, 2010). Similar relationships between executive functioning and academics have also been identified in adults (Biederman et al., 2006). Beyond academic and social skills development, there is also some evidence for a relationship between executive functioning and adaptive behaviour in TD adults, such that self-reported executive functioning deficits were predictive of self- and other-reported daily functioning impairments (Barkley & Fischer, 2011).

In summary, attention and executive functioning are separate but related cognitive skills that are essential for obtaining information from one's environment, organizing that information and acting in a meaningful way based on that information. These abilities show different developmental trajectories, with most attentional aptitude fully developed to adult-like levels by middle to late childhood, and executive functioning skills experiencing a burst of development beginning in late childhood and continuing through adolescence. Although attention does develop earlier than executive functioning, there is evidence that improvements in attentional abilities, especially those beyond basic orientation of attention, continue to occur through adolescence (Dye & Bavelier, 2010). There is a growing body of evidence that indicates that both attention and executive functioning are linked to the development of both academic achievement and social functioning in TD children and adolescents. Notably, such findings are indicated in a number of different studies that make use of different methodology, including different tests and reports of attention, executive function, and functional outcomes. It is understood that the skills subsumed under the categories of attention (including orienting, sustaining, shifting, and inhibiting attention) and executive functioning (including higher order processes of planning, cognitive shifting, inhibition, and working memory) are essential to being able to develop functional skills and effectively interact in one's environment.

Attention and Executive Functioning in ASD

Given the importance of attention and executive functioning to functional outcomes in TD populations, it is of great relevance to consider how these abilities might be associated in individuals who experience significant deficits in regards to both these cognitive and functional abilities. Specifically, individuals with ASD have been identified as having lifelong impairment in various attention and executive functioning skills (Corbett & Constantine, 2006; Verte, Geurts, Roeyers, Oosterlan, & Sergeant, 2006). Such cognitive difficulties are thought to be characteristic of ASD, but are separate from the diagnostic criteria, and may explain components of functional impairment experienced by individuals with ASD beyond the effects of the diagnosis itself on functioning.

ASD is a grouping of neurodevelopmental disorders characterized by impairments in social skills and communication, as well as by restricted or stereotyped behaviours and interests

(American Psychiatric Association (APA), 2013). The most current estimates of the prevalence of ASD suggest that it is diagnosed in 1 per 88 people (Centers for Disease Control and Prevention, 2008). In addition to these core behavioural deficits, many functional and cognitive deficits are also associated with ASD. There are many reports indicating that individuals with ASD struggle with a range of functional abilities including socialization, communication, daily living skills, and academics (Kanne, Gerber, Quimbach, Sparrow, Cicchetti, & Saulnier, 2010; Perry, Flanagan, Geier, & Freeman, 2009). Additionally, commonly reported difficulties with orienting, shifting, and sustaining attention (Pierce, Glad, & Schreibman, 1997) suggest an underlying deficit in attention and executive functioning.

Research with baby siblings of individuals with ASD has indicated that attention impairments may be one of the earliest identifiers of risk for developing ASD. Zwaigenbaum et al. (2005) assessed multiple facets of attention in 6- to12-month-old siblings of children with ASD and found that compared to low-risk baby siblings (i.e., those without an older sibling with ASD), the siblings who later developed ASD were more atypical with regards to eye contact, visual tracking, and attentional disengagement. Extending these findings, Elsabbagh et al. (2009) demonstrated that baby siblings of children with autism experience more difficulty in disengaging attention and engaging in facilitated attentional responses than siblings of children not diagnosed with autism. It is quite possible that early in development these attentional difficulties interfere with typical social learning that might contribute to the development of the disorder.

Beyond infancy, individuals with ASD appear to continue to show delays in attentional abilities as compared to their TD counterparts, which may contribute to the development of ASD symptomatology (Keehn et al., 2013). Specifically, although by 8 years of age individuals with ASD show similar abilities in the basic alerting of attention as compared to TD children (Keehn et al., 2010), they continue to struggle with exogenous orienting (Ristic et al., 2005). More specifically, Renner, Grofer Klinger, and Klinger (2006) compared orienting responses of children with ASD as well as age-matched controls for both endogenous, or internally generated, volitional attentional orienting, and exogenous, or externally generated, reflexive orienting of attention. Results showed that, although there were no group differences in endogenous orienting, children with ASD had reduced exogenous orienting ability, indicating decreased reflexive responsiveness to relevant external stimuli. It appears that these deficits continue to exist to some extent through adolescence (Godberg, Maurer, & Lewis, 2001), although results regarding these deficits are mixed. While there is no gold standard of measuring attentional abilities in ASD, and while most studies make use of attention tasks that have been shown to be effective in TD populations, there is a lot of variability in the types of tasks used which may account for variable results.

There also have been a number of reports of impaired components of executive functioning in ASD; however, findings regarding which elements of executive functioning are most impaired in individuals with ASD have been variable. Most common is the finding that children with ASD under-perform on a number of cognitive shifting tasks (Hughes, Russell, & Robins, 1994; Liss et al., 2001; Ozonoff, Strayer, McMahon, & Filloux, 1994). However, one study found that, when controlling for language ability and IQ, inhibition and planning were significantly impaired in individuals with ASD who were 8 to 17 years of age, while cognitive shifting no longer differed from TD controls (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009). Likewise, Montgomery, Stoesz and McCrimmon (2013) found that adolescents and young adults with Asperger Syndrome only show deficits on inhibition tasks when using a subset of tasks from the Delis-Kaplan Executive Function System (DKEFS) (Delis, Kaplan, & Kramer, 2001) as a measure of executive functioning.

It is quite possible that variable results on executive functioning deficits are a result of variation within the measures used between samples. A recent review examining the association between performance-based and parent- or self-rating measures of executive functioning has revealed that these measures appear to assess different constructs of executive functioning, with the former channeling efficiency of cognitive abilities in controlled and optimal settings, and the latter targeting successful goal pursuit and organization in real-world settings (Toplak, West, & Stanovich, 2013). In addition to differences that may be derived from variation in methods of measurement, executive functioning results may also vary with respect to the sample demographics, including age, gender, IQ, and diagnostic classification. For example, given that different components of executive functioning develop extensively through childhood and adolescence at different rates, it would not be surprising to find changes in the components of impaired executive functioning with age. Furthermore, findings relating to executive functioning in ASD are likely to be complicated by comorbid diagnosis, such as the diagnosis of ADHD, due to executive functioning deficits that may be characteristic of ADHD and not of ASD (Corbett, Constantine, Hendren, Rocke & Ozonoff, 2009).

Despite inconsistency in executive functioning results as they pertain to ASD populations, some consistency has been derived from research on saccadic eye movements. Luna et al. (2007) compared performance on Prosaccade, Antisaccade, and Delayed-Memory eye-tracking tasks between individuals with ASD and TD controls who were 8 to 33 years of age. As expected, no difference in basic attention alerting as assessed by the Prosaccade task were identified; however, the ASD group showed impaired performance on both the Antisaccade and Delayed-Memory tasks. Performance on these tasks is reflective of difficulties with inhibition, planning and working memory. Findings of this nature have been shown to have fairly consistent replication (Sweeney, Takarae, Macmillan, Luna, & Minshew, 2004). Such evidence is in line with reports that executive functioning may be a core deficit in ASD (Pennington & Ozonoff, 1996).

Functional Outcomes in ASD

In addition to cognitive impairment, adolescents with ASD experience difficulties across many domains of functioning including academic achievement, adaptive behaviour and social skills. Each of these areas of impairment has important implications for quality of life (Billstedt, Gillberg & Gillberg, 2005). With regards to academics, specific skill development can be critical to becoming a competitive candidate for further education beyond high school and for the job market. Furthermore, developing academic competency can often be a source of self-efficacy for individuals with ASD who experience greater struggles in other areas of life (Camarena & Sargiani, 2009). A recent review of the literature indicates that individuals with ASD have significant deficits in numerous areas of academic functioning, but that for many individuals with ASD, deficits may not become very apparent until the level of skill required increases (Whtiby & Mancil, 2009). More specifically, it is clear that individuals with ASD perform more poorly than their TD counterparts in key areas of academic achievement including reading comprehension (Griswold et al., 2002), written expression (Mayes & Calhoun, 2008), and mathematical problem solving (Mayes & Clahoun, 2008).

Difficulties with adaptive behaviour have also been extensively studied and reported in ASD populations. Most commonly, the Vineland Adaptive Behaviour Scale (Sparrow, Balla, & Cicchetti, 1984; Sparrow, Cicchetti, & Balla, 2005) has been used to assess adaptive behaviour in individuals with autism, and has consistently shown that, although individuals with ASD experience age-related improvements in adaptive behaviour, they continue to score below TD controls on all domains (Baghdadli et al., 2011; McGovern & Sigman, 2005). More specifically, at all stages of life, individuals show the greatest impairment in socialization, but also experience difficulties in communication and daily living skills (Carter et al., 1998; Kanne et al., 2010).

It comes as no surprise that socialization is one of the most impaired domains of adaptive behaviour when we consider the fact that social communication deficits are a primary feature of ASD. Social skills have been repeatedly demonstrated as a primary area of difficulty for individuals with ASD across age groups and regardless of diagnostic severity (Macintosh & Dissanayake, 2006; Ozonoff, South, & Miller, 2000). Furthermore, social skills intervention is a consistent focus of treatment research for ASD given the extensive impairments experienced in this area (Cappadocia & Weiss, 2011). Critical to developing more effective methods of intervention for deficits in social skills, as well as academic achievement and adaptive behaviour, is the need to better understand the underlying mechanisms that contribute to these functional impairments.

Attention and Executive Functioning Relate to Functional Outcomes in ASD

Much of what we know about attention in ASD comes from studies on social attention. An attentional preference for non-social over social information is a well-documented observation in ASD (Volkmar, 2011). For example, Klin et al. (2002) showed video clips of complex social situations to adolescents with ASD and TD age-matched controls and measured their visual fixations. Results showed that adolescents with ASD spent less time looking at eyes, and more time looking at objects and mouths. Klin et al. found that visual preference for non-social stimuli correlated with social impairment.

Such a preference for non-social stimuli may reflect a misallocation of attentional resources that contributes to social impairments (Mazer, 2011). This connection is supported by findings of Pierce, Glad and Schreibman (1997) that the social comprehension of children with ASD breaks down when more than one attentional cue is presented in a context. In this study, children with ASD and TD children were asked questions about social stories they had listened to with one to four social cues that would help lead them to the correct answer (Pierce et al.).

Findings indicated that, while children with autism were able to attend as well as TD controls when only one cue was included in the story, their attentional ability decreased when more cues were included. It is possible that individuals with ASD do not possess the attentional capacity or control required for the complexity of social interactions; thus, impaired attention may help to explain the deficits in social skills that are common in ASD.

Furthermore, a study by May, Rinehart Wilding, and Cornish (2013) assessing the attentional abilities of children with ASD on a visual search task, attentional switching task and sustained attention task, found that attentional switching ability was predictive of deficits in mathematics. These results indicate that, in school-aged children with ASD, a lack of ability to effectively orient attention to relevant stimuli may also interfere with academic achievement. Such trends suggest that, as with TD children, simply understanding and using theoretical concepts is not enough for academic success; it is also important to be able to attend to relevant information pertaining to a task and ignore distraction.

While the studies noted above indicate a potential relationship between attention and functional outcomes, it is important to recognize some of the limitations present in these studies. First and foremost, as with research investigating attention differences between ASD and TD groups, these studies make use of a wide range of measures for assessing attention and functional outcomes. It is very possible that the types of measures used may influence the relationships that are found between variables. Additionally, very few studies have investigated predictive relationships between variables, but rather rely on correlational data. In part this may be the result of smaller sample sizes used in many of the studies. In light of these observations, it is important to note that there is still much to be learned about the relationship between attention and functional outcomes in ASD.

As with attention, there is yet to be much investigation regarding the relationship between executive functioning and functional outcomes in individuals with ASD. Nonetheless, executive functioning has also been linked to some functional impairment in ASD. For example, in a study with preschool-aged children (i.e., approximately 3 to 6 years of age) with autism, McEvoy, Rogers and Pennington (1993) assessed social behaviours and had participants perform a set of behavioural tasks of executive functioning. Both correlation and regression analyses revealed a relationship between executive functioning and social behaviours, including joint attention and social interaction (McEvoy, Rogers, & Pennington, 1993).

A similar association has been observed in adults. In a study investigating the effectiveness of a residential treatment program on cognition and social functioning, a group of adults with high-functioning autism was assessed on central coherence, cognitive shifting, and social competence using a number of measures (Berger, Aerts, van Spaendock, Cools, & Teunise, 2003). Results showed that adults who had poorer cognitive shifting, but not central coherence, before entering the treatment program showed significantly less improvement in social skills over time. Such findings suggest the importance of executive functioning, and especially cognitive shifting, in being able to gain the skills necessary for social interaction. It is possible that deficits in executive functioning interfere with the ability to effectively switch between and organize socially relevant information.

Executive functioning has also been linked to adaptive behaviour in ASD. A comparison of parent-reported executive functioning ability and adaptive behaviour has revealed a correlation between the two broad abilities in both children and adolescents (Gilotty, Kenwirthy, Sirian, Black, & Wagner, 2002). These associations were especially true of working memory and initiation of behaviour components of executive functioning. Such findings are suggestive that, in ASD, difficulties with self-starting and holding information in one's mind may contribute to problems in day-to-day functioning.

Given the importance of executive functioning for academics in typical development (e.g., Latzman et al., 2010; Steele et al., 2012), it was expected that executive functioning would also be critical to academic achievement in individuals with ASD. While the relationship between executive functioning and academic achievement has been a focus in research for other childhood disorders such as ADHD (Diamantopoulou, Rydell, Thorell, & Bohlin, 2007; Riccio, Homack, Jarratt, & Wolfe, 2006), the investigation of the relationship between these abilities in individuals with ASD is negligible. Perhaps the lack of emphasis on understanding academic deficits is related to the previously-noted finding that academic difficulties for individuals with ASD may not arise until the conceptual demands of academic material increase (Whitby & Mancil, 2009). Nevertheless, it may be hypothesized that, as with TD individuals, different components of executive functioning are likely to be important to the organization and conceptualization of academic material.

Studies investigating the relationship between executive functioning and functional outcomes also have a number of limitations. As with research in attention, there is a high degree of variability among the measurements used to assess executive functioning and functional outcomes. Differences in measurement tools have the potential to influence results regarding relationships between cognitive and functional domains. Additionally, studies regarding the relationship between executive functioning and functional outcomes have had variable sample sizes and often only report correlational data rather than investigating predictive relationships.

The Current Study

Much of the literature discussed above provides important insights for beginning to understand the relationship of executive functioning and attention with functional outcomes; however, there are still many gaps within the literature. Perhaps one of the most glaring holes is the lack of information regarding these processes in adolescents. There is a tendency in the ASD literature to focus on the study of younger populations in order to allow for early intervention. However, adolescents with ASD experience a number of difficulties as they age that are not well understood. Additionally, many studies do not control for IQ in statistical analyses. Given that executive functioning and attention are highly related to intelligence (Roca et al., 2010; Steinmayr, Ziegler, & Trauble, 2010), this is not only surprising, but also concerning. Even though many studies only include participants who have a Full Scale IQ (FSIQ) that is within two standard deviations of the mean, this still leaves room for a large degree of variability in IQ scores that might result in spurious findings when not controlled. Thirdly, many studies have relied on parent-report measures as an estimate of both cognitive and functional abilities. While parent-report measures can be very informative, and have been demonstrated to be useful in assessing executive functioning, attention, and functional outcomes in individuals with ASD, drawing comparison between parent-report measures can often include a large degree of bias based on the parent's response style. A mixed-methods approach using both performance tasks and parent-report measures allows one to control for some of the effects of possible parent bias. Finally, while many studies have investigated the general relationship of cognition with functional outcomes at a correlational level in ASD populations, there has been much less effort to investigate whether attention and executive functioning actually work to predict functional abilities in this group.

The current study aims to extend prior research by investigating the predictive relationship of attention and executive functioning on functional outcomes in high-functioning adolescents with ASD, as well as in TD controls. Such research is particularly relevant in light of the fact that executive functions and attention continue to develop through adolescence in TD populations (Best & Miller, 2010; Dye & Bavelier, 2010). There is also evidence of this continuing development in ASD (O'Hearn, Asato, Ordaz, & Luna, 2008). Individuals with ASD do appear to experience improvements in executive functioning throughout adolescence, but this improvement does not reach the level of TD adolescents of the same age (Crone, 2009; Luna et al., 2007; Robinson, Goddard, Dritschel, Wisley & Howlin, 2009). More so, this gap in executive functioning ability between individuals with ASD and TD controls appears to grow with age (Rosenthal et al., 2013).

The current study also endeavors to resolve some previous methodological downfalls. Measures have been carefully selected based on a consensus in the literature and effort has been made to use objective behavioural assessments in addition to parent-report, rather than relying solely on report measures. Furthermore, this study will make use of a sample of individuals who have IQs within the normal range, and will also control for the effects of IQ in data analyses to determine if significant trends continue to exist above and beyond the effects of intelligence.

Through this study, I first intend to further clarify the nature of attention and executive functioning deficits in adolescents with ASD. Second, I intend to shed light on the relationship between cognition and functional outcomes by investigating whether attention and executive functioning are predictors of social skills, academic achievement, and adaptive behaviour in adolescents with ASD and TD controls. Although the current study will be addressing these issues in adolescent populations, I expect the findings to be similar to what has been reported in child populations. As discussed above, preliminary findings with TD adolescent samples have identified clear correlations between cognition and functional impairments, and in some cases have identified predictive relationships. In light of evidence that both executive functioning and attention continue to be impairments for individuals with ASD as they age from childhood to adolescence, it is expected that these cognitive abilities should continue to predict functional impairments in adolescents, as they do in children with ASD. As such, the hypotheses for the current study are as follows:

1. As compared to the TD controls, the ASD groups will show lower scores in attention, executive functioning, and functional outcomes.
2. Attention will be a significant predictor of academic achievement, adaptive behaviour, and social skills in both groups.

3. Executive functioning will be a significant predictor of academic achievement, adaptive behaviour, and social skills in both groups.

It is important to note that, while it is predicted that adolescents with ASD will have lower scores in cognitive and functional abilities than their TD counterparts, it is still expected that a predictive relationship between cognition and functioning will be present in both groups. Although general abilities on these skills may vary between the two groups, previous research indicating a relationship between cognition and functional outcomes suggests that the processes underlying the development of functional abilities in individuals with ASD and TD controls could be similar. More specifically, it is expected that, while executive functioning and attention deficits are associated with a diagnosis of ASD, the influence of these abilities on functional outcomes is at least somewhat separate from the effects of factors related specifically to diagnosis. Fein, Dixon, Paul and Levin (2005) provide evidence in support of such processes in their report of case studies of children who experienced loss of their ASD diagnosis. In each case, children who originally had a clear ASD diagnosis went on to lose their diagnosis and later became diagnosed with ADHD. Despite loss of an ASD diagnosis, these individuals continued to experience difficulties with cognition and functional abilities, suggesting the existence of core impairments that operate beyond the effects of the ASD diagnosis.

By studying these phenomena in adolescents with ASD, this study endeavors to provide important insight into impairments in these populations. Adolescence is an important time of transition for TD individuals as well as clinical populations. Generally speaking, for TD individuals, adolescence is a time of increased responsibility, independence and social complexity. Unfortunately, it is also a period of development that is not well-studied or understood in individuals with ASD. The transition into adulthood can be particularly stressful for individuals with ASD, as well as their families. Primarily, the transition to adulthood is a time during which individuals with ASD are in need of support and guidance as they face obstacles related to independence and increased demands on self-efficacy; however, resources are often not readily accessible at best, and in many instances are non-existent (Hendricks & Wehman, 2009). This is true across the board with regards to supports required for further education, work, home living and community independence. For example, many adolescents with ASD hoping to move on to higher-education are faced not only with the struggles of greater educational demands, but are also faced with increased demands on self-care, organization, and socialization for which supports are not provided (Camarena & Sarigiani, 2009). By obtaining a more accurate understanding of the functional difficulties faced at this time in development, and the cognitive processes that influence these difficulties, it will become possible to consider new theoretical frameworks that can direct future research and clarify our conceptualization of the deficits experienced by adolescents with ASD. Such knowledge will likely make it possible to better target intervention and support for these individuals, and serve to increase knowledge on how to help adolescents prepare for life after high school.

Chapter 2

Methods

Participants

For this study, I recruited 52 participants (23 participants with ASD and 29 TD participants) for data collection. All participants were between 11 and 18 years of age. Adolescents with ASD were primarily recruited from a database of participants in the ASD lab at Queen's University. This database is comprised of families who have been contacted through recruitment events and have expressed interest in participating in studies conducted by the lab. Additional participants with ASD were recruited through newspaper advertisements, advertisement postings online on Kijiji, and flyers posted in doctor's offices around Kingston. TD participants were recruited using the Queen's Developmental Psychology participant database. Similar to the ASD database, this database is comprised of families who have been contacted through recruitment events and have agreed to be contacted for studies at Queen's.

TD participants were group-matched with participants with ASD on gender and mental age. While the designated chronological age requirement for inclusion in this study was 11 to 18 years of age, the mental age requirement was extended to range from 10 to 21 years of age. Three adolescents with ASD were excluded from data analysis because they did not fully complete participation in the study (n = 1) or because their mental age was beyond the designated mental-age range for inclusion (n = 2). Nine additional TD adolescents were excluded from data analyses because they did not fully complete participation in the study (n = 1) or because they did not appropriately match with the ASD group on gender and/or mental age (n = 8). There were no participants who did not speak English as their first language, nor did any of the TD participants have a family history of ASD. Furthermore, participants with ASD in the present study were high-functioning and any individual with a comorbid diagnosis of mental retardation was excluded from data collection. Although five participants with ASD had a comorbid diagnosis of ADHD, they were not excluded from data analyses. The decision to retain these individuals in the final sample was based on the high rate of comorbidity between these diagnoses in the general population (Simonoff et al., 2008; Skokauskas & Gallagher, 2012), which causes difficulties for the recruitment of ASD participants without comorbid ADHD. Additionally, it remains meaningful to understand the deficits experienced by individuals with ASD who have a secondary diagnosis of ADHD since such a diagnosis is so prevalent. Because there are important differences in executive functioning and attention ability between individuals with ASD and ADHD, rather than excluding these participants we controlled for ADHD symptomatology in our statistical analyses. Twenty TD adolescents and 20 adolescents with a diagnosis of ASD were thus included in the final data analyses. All participants were from a few small cities in southeastern Ontario and spoke English as their primary language. Of the participants diagnosed with ASD, four were currently taking medication. In light of the longitudinal nature of the larger associated study, participants were not asked to discontinue medication during their participation in this study. The families of our participants varied in socioeconomic status, with about a third of annual household incomes above $95,000, a third between $55,000 and $95,000, and a third below $55,000.

Materials

Participant sample information.

Demographics questionnaire. The demographics questionnaire was a brief survey that collected general demographic information (ie. age, gender, siblings, primary language, socioeconomic status), as well as background information on the participant's family history, and their physical and mental health history. Information from the demographics questionnaire was used to determine the exclusion of any participants.

Wechsler Abbreviated Scales of Intelligence (WASI). The WASI (Wechsler, 1999) is a standardized assessment of intelligence, composed of 4 subtests, that yields scores for verbal IQ (VIQ), performance IQ (PIQ), and FSIQ. The test is appropriate for use on 8 to 89 year olds, and takes approximately 40 minutes to administer. The WASI was preferred for this study over other measures of IQ due to the brevity of its administration. Internal consistency is high for all composite scores (VIQ = .93, PIQ = .94, FSIQ = .96), as is test-retest reliability. The current study used FSIQ as an estimate of IQ, which was used to determine mental age and was also used as a control in the statistical analyses.

Autism Diagnostic Observation Schedule (ADOS). The ADOS (Lord, Rutter, DiLavore, & Risi, 2002) is a standardized assessment used for the diagnosis of ASD. Through a semi-structured assessment, the administrator is able to observe the participant's behaviour across a number of situations and gather information about the participant's communication and social skills. Administration requires about 45 minutes and yields scores for communication, social interaction, and repetitive or stereotyped behaviours. Given the age and verbal ability of participants in this study, module 4 of the ADOS was used for all participants. Module 4 has been found to have good inter-rater reliability (.82-.89), and test-retest reliability (.74-.98). Furthermore, it has high sensitivity (90%) and specificity (93%) for the discrimination of autism and ASD from non-ASD disorders. Administration of the ADOS was completed by graduate students supervised and trained by a developmental psychologist who had received the necessary training and achieved reliability for use of the measure. This instrument was used to confirm the previously-reported diagnosis of the participants with an ASD.

Conners 3^rd^ Edition ADHD Index Form (Conners). The Conners (Conners, 2009) is a 10-item scale derived from the full-length version used to screen for symptoms of ADHD and related disorders. The 10 items have been selected for being the items that best differentiate individuals with ADHD from the general population. The present study made use of the Parent form, which has moderate cross-informant correlation (.61). Administration took approximately 5 minutes and was completed by the participant's primary caregiver. The ADHD index has high internal consistency (parent = .90), test-retest reliability (parent = .93), and inter-rater reliability (parent = .84). Additionally, discriminant validity is high for the parent form (86% correct classification). The *t*-scores derived from this measure were used to confirm previously-reported diagnoses of ADHD in any participant with ASD who had a comorbid diagnosis of ADHD, as well as a measure of ADHD symptoms in the ASD and TD participants.

Predictor variables.

Delis-Kaplan Executive Function System (DKEFS). The DKEFS (Delis, Kaplan, & Kramer, 2001) is a standardized assessment designed to measure executive functioning ability in individuals 8 to 89 years of age. The DKEFS is composed of nine tests that can be used together in a battery or individually. The current study makes use of five of these tests: the Trail Making Test, Verbal Fluency, Color-Word Interference, the Sorting Test, and the Tower Test. The selection of the five subtests was made based on their repeated use throughout literature as robust measurements of cognitive shifting, planning and inhibition. Together, administration of these five tests required approximately 40 minutes. Internal consistency reported for individuals 12 to 19 years of age for each test ranges from moderate to high (Trail Making Test, .68-.79; Verbal Fluency, .44-.80; Color-Word Interference, .62-.77; Card Sort, .55-.82; Tower Test, .43-.61). Likewise, the test-retest reliabilities for individuals 8 to18 years of age are mostly moderate (Trail Making Test, .50-70; Verbal Fluency, .53-.70; Color-Word Interference, 77-.90; Card Sort, .49-.67; Tower Test, .51). Lower correlations are in-line with what is common of most measures of executive functioning (Barkley, Murphy & Fischer, 2008). The DKEFS has been shown to be appropriate for use with individuals with ASD (Delis, Kramer, Kaplan, & Holdnack, 2004).

The Trail Making subtest is a set of five separate timed tasks in which participants were required to search for numbers, connect numbers and letters in order, and connect circles along a path as quickly as they could. Specifically, one of the tasks included in this subtest, the Trail Making Switching Task, required participants to switch between numbers and letters while connecting them in numerical and alphabetical order. This task is largely a measure of cognitive shifting and working memory. Completion time for this task was recorded and converted to a scaled score. This score was used in data analysis as one measure of executive functioning.

The Verbal Fluency subtest includes three separate tasks that required participants to list as many words as quickly as they could under different categories. Specifically, the Verbal Fluency Switching task required participants to name as many objects as they could in two different categories while switching back and forth between categories. This task yielded a switching accuracy scaled score, which reflected the number of times the participant correctly switched between categories when naming words. This is also a measure of cognitive shifting and was used as a measure of executive functioning in this study.

The Colour-Word Interference subtest includes four separate timed tasks that required participants to say colour names and read words as quickly as they could without making mistakes. The Colour-Word Interference Inhibition task is likened to the traditional Stroop task, and is primarily a measure of inhibition ability. In this task, colour names were written out in a colour of ink that was incongruent with the colour name. Participants were required to say aloud the colour of ink and ignore the written name of the colour. Completion time for this task was recorded and converted to a scaled score. The scaled score from this task was used as another measure of executive functioning.

The Card Sort Free Sorting task required participants to sort six cards into two different groups in as many ways as possible, and to explain how they sorted the two groups. This measure is similar to the traditional Wisconsin Card Sorting Task. The Card Sorting task is generally a measure of planning or monitoring, but also includes components of cognitive shifting and inhibition. This task yielded a Free Sorting Correct Card Sorts score, which reflects the number of times the participant correctly sorted the cards into two groups. This score was converted to a scaled score and was used as a measure of executive functioning in this study.

Finally, the Tower subtest, similar to the Tower of Hanoi or Tower of London tests, required participants to build various towers using a set of five blocks. Participants were directed to build the towers in the fewest number of moves possible and were required to do so within a time limit. A Total Achievement score was calculated from the number of moves required to build each tower and converted into a scaled score. The Total Achievement scaled score reflects elements of cognitive shifting, planning and inhibition, and has been used in data analysis as a measure of executive functioning for this study.

Eye tracking measures. Eye tracking measures, which assess saccadic movements, or quick movement of the eyes towards visual stimuli, can be helpful in assessing attention and executive functioning. The current study made use of three eye-tracking measures administered on the computer. The first was a Prosaccade task (Paolozza, Titman, Brien, Munoz, & Reynolds, 2013), which required participants to follow a red dot as it disappeared from the middle of a black screen and reappeared either to the left or right across the horizontal plane. This task was made up of 60 trials. The percent of saccadic errors on the Prosaccade task was used as a simple measure of attentional alerting.

An Antisaccade task (Paolozza et al., 2013) was administered second. This task required the participant to look in the opposite direction of a red dot on a black screen as it disappeared from the middle and reappeared either to the left or right across the horizontal plane. That is, if the dot reappeared on the right, the participant was supposed to look to the left. Again, this task was made up of 60 trials. Third, a Delayed-Memory sequential task (Paolozza et al., 2013) was administered. In this task the participant had to sustain attention on a red dot in the middle of a black screen while two additional dots appeared, one after the other, in two different locations on the screen. Once the middle dot disappeared, the participant had to look to the location where the two dots appeared in the order they appeared. This task was made up of 73 trials. The percent of saccadic errors for the Antisaccade task and the percent of saccadic sequence errors on the Delayed-Memory task were used as additional measures of executive functioning. These tasks are typically viewed as measures of executive functioning due to the sequence of responses that are required in a response-response contingency, rather than simply one response to an environmental event. Specifically, they tend to reflect inhibition, planning and working memory abilities.

Eye position in these tasks was recorded using the Eyelink 1,000 eye tracking system. Participants were seated comfortably in a stable chair, approximately 55 to 60 cm from the eye-tracker. Administration of the complete eye-tracking battery required approximately 30 minutes. A more technical description of the eye-tracking measures can be found in Appendix A.

Attention measures. Four computerized tasks were designed for the further assessment of attention in this study. These tasks were derived from traditional attention measures and included the Flanker task, Multiple Object Tracking task, Useful Field of View task, and Attentional Blink task. Administration of these tasks required approximately 45 minutes. For each attention task, the number of trials included was a result of balancing the ability to achieve a reliable sample of attentional ability from each participant with keeping the tests as short as possible. These tasks were administered to pilot participants to assess where an appropriate balance between these factors would be achieved. The following is a general description of each of these tasks; however, a more technical description can be found in Appendix B.

In the Flanker task (Eriksen & Schultz, 1979) a letter appeared surrounded by an outer ring in the middle of a grey screen. A second letter, either an N or X, appeared on the outer ring. The letter in the centre of the ring was either congruent with the letter on the ring (i.e. both letters were N or both letters were X), incongruent with the letter on the ring (i.e. one letter was N and the other was X), or neutral in relation to the letter on the ring (i.e. the letter in the centre was a letter other than N or X). This image flashed on the screen, then the participant had to indicate which letter appeared on the outer ring. The participant completed 75 trials, with 25 trials per congruency condition. Overall accuracy scores for making a correct response were used in the data analyses.

In the Multiple Object Tracking task (Cavanagh & Alvarez, 2005), eight small dots appeared scattered in stationary positions on a black screen. Either two or four of the dots were coloured green, while the remaining dots were white. After two seconds the dots all turned white and moved semi-randomly around the screen for 8 seconds. When the dots stopped moving, one dot turned blue. The participant had to indicate whether this dot had been white or green at the beginning of the trial. This task was repeated for 40 trials, with two green dots for 50% of the trials and four green dots for the other 50%. Accuracy scores for correctly identifying a dot as green or white when tracking four moving dots were used for data analyses. Although both the two-object and four-object trials were completed to assess trends in attention ability for a larger study related to this thesis, only the four-object tracking task was used as a measure of attention for the present study to provide a better sense of the variability in attention ability.

In the Useful Field of View task (Ball, Beardm Roenker, Miller & Griggs, 1988), an eight-spoke wheel flashed on a white screen with a black triangle on one spoke. The position of the black triangle changed from trial to trial in both its position in the periphery (e.g., 4, 8 and 11 degrees from the central fixation), and spoke location. After 64 ms a distracting image of randomly sized black and white rectangles appeared for 1 second. The distracter screen was followed by another eight-spoke wheel that had each spoke numbered. The participant was required to indicate on which spoke the triangle appeared. This task was completed for 192 trials with the rectangle appearing in the three different periphery locations for approximately one-third of the trials each. Accuracy scores for correctly identifying the location of the triangle when it appeared in the most peripheral location (e.g., 11 degrees) were used in the data analyses. As with the Multiple Object Tracking task, the Useful Field of View task included trials at three different periphery locations to assess attention trends for a larger study; however, only the 11-degree trials were used for the present study to provide a sense of the variability in attention.

Finally, in the Attentional Blink task (Shapiro, Schmitz, Martens, Hommel & Schnitzler, 2005), a stream of 20 black letters appeared in the middle of a grey screen. One letter was white, and appeared within the 3rd to 14th position in the stream of letters. Each letter appeared for 75 ms with a 25 ms blank screen in between. At the end of the task, the participant had to indicate which letter appeared in white, and whether or not the letter X appeared in the stream. Participants were required to complete 160 trials. In 50% of the trials no X was present, and in the other 50% of trials the X appeared within one to eight letters after the white target letter. The data for this task did not follow the typical trends previously reported in literature, and as such this measure was excluded from group comparison and regression analysis.

Outcome variables.

Woodcock-Johnson III Tests of Achievement (WJ-III). The WJ-III (McGrew, Shrank, & Woodcock, 2007) is a standardized assessment used to measure academic achievement across a number of domains. Altogether the WJ-III is composed of 12 standard tasks and an additional 10 supplementary tasks that can be used together in a battery or individually. The current study makes use of five subtests from the WJ-III to assess academic skills across a broad range. These subtests include two tasks assessing oral language (Story Recall and Understanding Directions), one task assessing written language (Writing Fluency), and two tasks assessing mathematics (Math Calculations and Math Fluency).

More specifically, the WJ Stories task required participants to listen to an audio recording of two to four short stories. After each story, the participants were asked to repeat the story as best as they could remember. Participants were scored according to how much of each story they were able to recall and raw scores were converted to standard scores. This task is reflective of each participant's ability to attend to and remember oral information.

In the WJ Directions task, participants listened to an audio recording that directed them to point to different groups of items in a picture. Each new set of directions becomes increasingly difficult as pointing directions add caveats on what to point to in different situations. Participants are required to distinguish between relevant pointing instructions and irrelevant information. Participants were scored according to how many groups of items they were able to correctly point to and raw scores were converted to standard scores. This task is reflective of each participant's ability to attend to, conceptualize and organize oral information.

In the WJ Writing Fluency task participants were given a set of pictures, each with three descriptor words. The participants were required to create short sentences for as many pictures as possible in seven minutes using all three words. Participants were scored according to the number of correct sentences they completed and raw scores were converted to standard scores. This task is somewhat reflective of each participant's ability to organize verbal information, but more so of their ability to focus on a task and work efficiently for a sustained length of time.

The WJ Calculations task required participants to complete as many math problems as they were able without any time limit. The math problems increased in difficulty, beginning with simple addition and subtraction and increasing to more complex arithmetic, as well as questions pertaining to fractions and algebra. Participants were scored according to how many questions they answered correct and raw scores were converted to standard scores. This task is somewhat reflective of participant's general arithmetic ability without time constraints, as well as more complex mathematical problem solving.

In the WJ Math Fluency task, participants were required to complete as many simple arithmetic problems as they could in three minutes. Arithmetic problems included addition, subtraction and multiplication. Participants were scored according to how many math problems they correctly answered and raw scores were converted to standard scores. This task is both an assessment of general arithmetic ability, as well as ability to focus on a task and work efficiently.

Each of these subtests has moderate to high test-retest reliability for individuals aged 11 to 18 (Story Recall, .86-.89; Understanding Directions, .62-.85; Calculations, .83-.87; Math Fluency, .97-.98; Writing Fluency, .79-.84). The subtests were selected based on their relevance to executive functioning and attention skills, as well as for their broad representation of a number of academic abilities. The five subtest scaled scores have been used as separate measurements of different aspects of academic ability, and subsequently act as outcome variables in five separate multiple linear regressions. The WJ-III is designed for use with individuals 2 to 90 years of age and administration of these five tests required approximately 30 minutes.

Vineland Adaptive Behaviour Scales, 2nd Edition (VABS-II). The VABS-II (Sparrow, Cicchetti, & Balla, 2005) is a standardized, semi-structured interview designed to assess day-to-day functioning in individuals from birth to 89 years of age. The current study uses the Adaptive Behaviour Composite score, which is derived from the Communication, Daily Living Skills and Socialization domains on the VABS-II. The Communication domain includes items pertaining to receptive, expressive and written language. The Daily Living Skills domain includes items pertaining to personal care such as hygiene and health, domestic care such as household chores and cooking, and community skills such as financial responsibility and time awareness. The Socialization domain includes items pertaining to interpersonal relationship skills, play and leisure activities, and coping skills. This measure was used to assess adaptive functioning, an outcome variable used in one of the multiple linear regressions. The internal consistency for each subdomain ranges from .71 to .90, while the test-retest reliability ranges from .74 to .78.

Interviews were completed either over the phone or in person with the participant's primary caregiver, and required approximately 45 minutes for administration.

Social Skills Rating System (SSRS). The SSRS (Gresham & Elliot, 1990) is a survey designed to assess social skills and problem behaviours in the general population from parent, teacher and self-report. This survey has been used frequently with both TD and ASD populations. The current study used scores from the parent report forms as a measure of social functioning. The participant's primary caregiver completed the parent forms, which are appropriate for use with children in grades 7 to 12. Teacher report data was also collected; however, the data collection for the teacher report was not complete enough to include scores in data analyses[1]. Completion of this questionnaire required approximately 10 minutes. Internal consistency is high for the social skills domain score (parent = .90), as is the test-retest reliability (parent = .87). The SSRS yields results for two domains: the Social Skills Domain and the Problem Behaviours Domain. This study made use of the Social Skills Domain score as a measurement of social functioning, which was another outcome variable used in one of the multiple linear regressions. The Social Skills Domain was selected over the Problem Behaviours Domain for analysis because it assesses a broader spectrum of factors related to social development and functioning.

A summary of the predictor and outcome measures included in this study has been provided in Figure 1. In this model, executive functioning and attention, as indicated by a number of different measures, are expected to predict functional outcomes across the three domains of academic ability, adaptive behaviour, and social skills. Such a model may prove useful as a potential theoretical framework for studying the relationships between cognition and functional outcomes. This model is based on the relationships that are suggested to exist between cognition

[1] During the time period of data collection teachers from the school board in our district were on work-to-rule. As a result, many teachers were unwilling to contribute to the study. Additionally, due to time constraints we had to conduct a fair amount of data collection during the summer when our participants were out of school, which limited access to teacher data.

and functional abilities as reported in the literature discussed above. While the basis of such a model is investigated in the present study, it is not tested against other models.

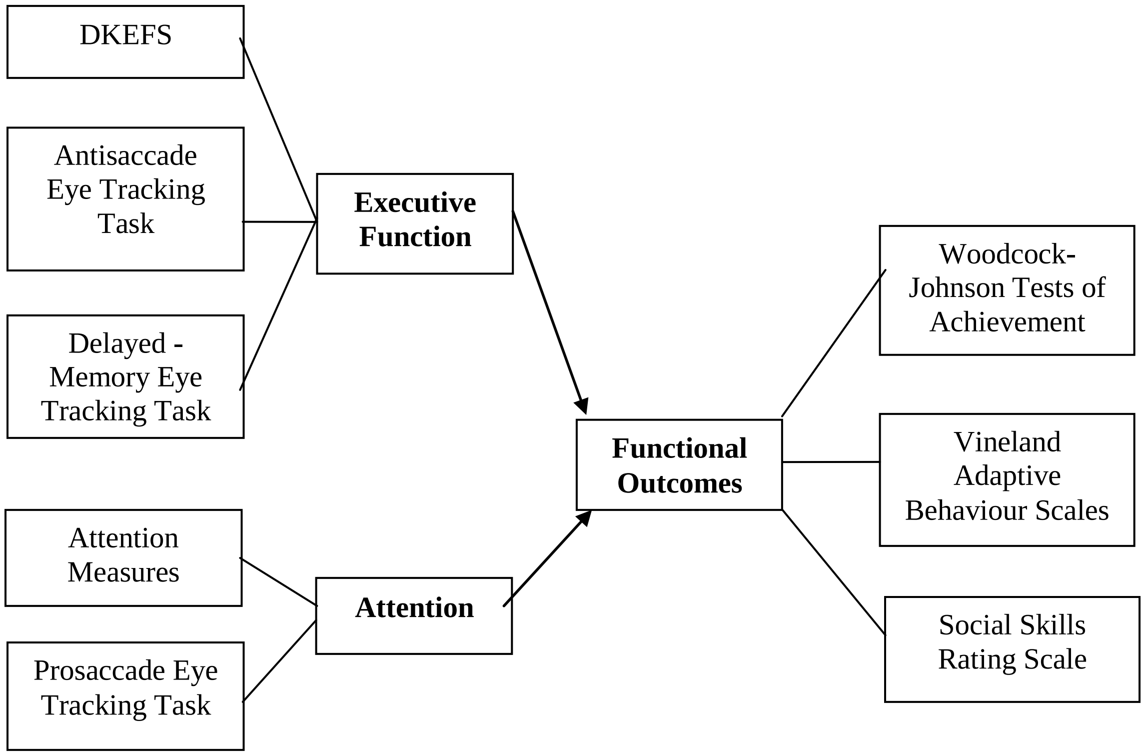

Figure 1. Summary of predictor and outcome measures.

Procedure

Testing was conducted over two different two- to three-hour sessions, and was completed in conjunction with a larger project investigating the effects of videogame training on attention and executive functioning, conducted by Dr. Elizabeth Kelley and Dr. Daryl Wilson. This larger project required participants and their families to commit to a total of 12 hours of testing over the period of three months, as well as approximately 20 hours of videogame training. Such an extensive commitment caused some difficulty with recruitment and participant attrition.

When the participant came into the lab with their caregiver for the first testing session, the caregiver was given a letter of information and asked to sign a consent form. Additionally, the participant was asked to sign an assent form. Once consent and assent were obtained, the participant began testing. While testing was in progress, the caregiver completed the Demographics Questionnaire and SSRS. In most cases, the VABS-II interview would have been conducted with the caregiver prior to coming into the lab for testing, however in some cases the VABS-II was also completed by either a graduate student or trained lab volunteer while the participant was being tested. Generally, parent reports were completed during the first session, but in cases where the VABS-II had to be administered these measures were completed over the two sessions.

The first testing session included the WASI, DKEFS and eye-tracking measures, administered in a counterbalanced order. The WASI and DKEFS were completed in an adjoining room to where the caregiver waited with the door closed. Both assessments were administered in accordance with standard protocol outlined in the manuals. Video cameras, which the participant was made aware of, were set up to record the administration of both tests for later scoring. The eye-tracking measures were completed in a separate room, down the hall from the main lab. Eye tracking calibration and data collection were completed with the lights off to enhance accuracy of the eye tracker. The eye tracker was calibrated before each of the three tasks, and instructions were provided verbally before each task was administered.

The second testing session included the WJ-III and attention measures. These measures were administered in a counterbalanced order. The ADOS was also administered at the end of session two with participants diagnosed with an ASD. As in session one, the WJ-III and ADOS were completed in an adjoining room to where the caregiver waited with the door closed. Both assessments were administered in accordance with standard protocol outlined in the manuals. Video cameras, which were pointed out to the participant, were set up to record the administration of both tests for later scoring. The attention measures were completed in a separate room, down the hall from the main lab. Participants were asked to complete a trial run of each attention task, and then completed the full test battery. Instructions for each task were provided before each task began during both the trial run and during completion of the full test battery. A script was developed to standardize the instructions provided. A list outlining test administration order and time requirements is presented in Table 1.

Table 1. ***Administration Order and Time Requirements for Completion of Testing***

Visit 1		Visit 2	
Measure	Time	Measure	Time
WASI	45 minutes	WJ-III	30 minutes
DKEFS	40 minutes	Attention Measure Battery	45 minutes
Eye-Tracking Measures	30 minutes	ADOS	45 minutes

During testing, participants were provided scheduled breaks between each measure; however, participants were also free to take breaks as they pleased at any point during testing. The test administrator monitored engagement and prompted for extra breaks where necessary. Given the large number of tasks to be completed over both sessions, an interactive visual schedule was designed to help participants track progress and maintain engagement. The schedule outlined each task to be completed, as well as break times. Participants were given checkmarks to place next to each task on the schedule in order to remind them of their progress and how many tasks had to be completed before the session ended.

Data Analysis

Each variable was tested for skew and kurtosis. Results did not reveal any serious violation in the distribution of data. Results from these tests are listed in Appendix C.

In order to evaluate the first hypothesis that individuals with ASD would have lower scores than TD controls on measures of cognition and functional outcomes, one-way multivariate analysis of covariance (MANCOVA) was used to evaluate differences between groups while controlling for FSIQ and ADHD symptomatology. In total, three MANCOVAs were conducted: one with executive functioning scores as the dependent variable, one with attention measure scores as the dependent variable, and one with functional outcome sores as the dependent variable. Missing data were dropped on a case-by-case basis for each MANCOVA.

Multiple regressions were conducted in order to assess the remaining two hypotheses regarding the ability of executive functioning and attention to predict functional outcomes. Prior to completing regression analyses, bivariate Pearson correlations were conducted to determine correlations between the predictor and outcome variables. The Multiple Object Tracking scores did not significantly correlate with most outcome variables, and as a result were excluded from subsequent regression analyses. Given the large number of predictor variables in comparison to sample size, correlational data were also used to explore the possibility of creating composite predictor variables. While many predictors had strong to moderate correlations with each other, and could be grouped in meaningful ways, composite predictors failed to correlate with outcome variables. As such, multiple regressions were conducted with the full set of individual predictors and results were interpreted understanding that there is a lack of power in these analyses.

Hierarchical multiple regression analyses were conducted to assess the predictive ability of attention and executive functioning on functional outcomes when controlling for FSIQ, diagnostic group, and ADHD symptomatology. Diagnostic group was dummy-coded to reflect membership in the ASD group. In each hierarchical multiple regression, the first step included FSIQ, ASD diagnosis, and Conners *t*-score as a set of predictors. These predictors were included as controls. The second step added in the attention measures and executive functioning measures as a subsequent set of predictors. The attention measures included the Flanker task (attentional control), Useful Field of View task (attentional breadth), and the Prosaccade percent errors (attentional orienting and sustained attention). The executive functioning measures included scores from the DKEFS Trail Making (shifting), Verbal Fluency (shifting and fluency), Colour-Word Inhibition (inhibition), Sorting (shifting and concept formation), and Tower tests (planning), as well as error scores from the Antisaccade (inhibition) and Delayed-Memory (inhibition and working memory) eye tracking tasks. The attention and executive functioning measures were entered together in the second step in order to allow them to compete for variance given that there was no specific hypothesis regarding one set of measures being more important than the other. A multiple regression was completed for each of the seven outcome variables: WJ Stories, WJ Directions, WJ Writing Fluency, WJ Calculations, WJ Math Fluency, the Vineland (adaptive behaviour), and the SSRS (social skills).

Chapter 3

Results

Comparison between Groups on Participant Sample Information

I performed *t*-tests in order to evaluate any significant differences between the TD and ASD groups on chronological age, mental age, verbal IQ (VIQ), performance IQ (PIQ), FSIQ, and Conners *t*-score. Additionally I conducted a Pearson chi-square analysis to evaluate if the observed gender counts between the TD and ASD groups differed from expected values. Results from *t*-test and chi-square analyses are shown in Table 2.

As intended by group-matching, the groups were very well matched on mental age. There were also no significant differences between the groups on chronological age or VIQ; however, the groups did significantly differ on PIQ and FSIQ such that the ASD group had lower scores on both variables. This finding is not surprising given that matching on mental age is bound to cause differences between the groups on some of the other variables due to the wider range of IQ scores found in an ASD sample. Specifically, mean scores for FSIQ, VIQ and PIQ were in the Average range for both ASD and TD groups. The range of FSIQ scores fell within 2 standard deviations from the mean for both the ASD and TD groups, with FSIQ for the ASD group ranging from the Borderline to Superior classifications and FSIQ for the TD group ranging from the Low Average to High Average classifications. The VIQ scores for the ASD group ranged from the Extremely Low to Superior classifications, while VIQ scores for the TD group ranged from the Borderline to Superior classifications. The PIQ scores for the ASD group ranged from the Extremely Low to Superior classifications, while the PIQ scores for the TD group ranged from the Average to Superior classifications.

There was a significant difference between groups for the Conners *t*-score such that the ASD group had higher scores than the TD group. Although scores for both groups ranged from within 1 standard deviation below the population mean to beyond 3 standard deviations above the population mean, the ASD group had an average score beyond 2 standard deviations above the population mean and the TD group had an average score within 1 standard deviation above the population mean.

A comparison of gender distribution between groups revealed that the observed distribution of males and females between the TD and ASD group did not significantly differ from the expected values.

Table 2. ***Participant Sample Information***

	ASD		TD		
	Mean (SD)	Range	Mean (SD)	Range	Significance, Effect Size
Gender	19 male, 1 female		17 male, 3 female		*p = .29*
Chronological Age	15.22 (1.79)	12.00 – 18.00	14.12 (1.86)	11.83 – 17.58	*p* = .07, Cohen's *d* = .60
Mental Age	14.82 (3.41)	10.05 – 20.58	15.10 (2.39)	10.56 – 19.69	*p* = .77, Cohen's *d* = .10
FSIQ	97.10 (17.11)	70 – 130	106.80 (7.64)	88 – 120	*p* = .03, Cohen's *d* = .73
Verbal IQ	93.35 (19.92)	55 – 129	103.25 (11.59)	78 – 125	*p* = .06, Cohen's *d* = .61
Performance IQ	101.15 (14.91)	69 – 125	109.30 (8.61)	95 – 126	*p* = .04, Cohen's *d* = .67
Conners Score	77.40 (16.51)	44 – 90	59.15 (17.76)	44 – 90	*p* = .002, Cohen's *d* = 1.06
ADOS	11.56 (3.29)	7 – 17	N/A		

Note. Age scores are in years; IQ scores are standard scores; Conners scores are *t*-scores with an average of 50 and standard deviation of 10; For the ADOS module 4, Autism cut-off minimum score is 10 and autism spectrum cut-off minimum score is 7

Comparison between Groups on Cognitive and Functional Outcome Measures

Executive Functioning Measures

A one-way MANCOVA was conducted to evaluate the differences between the ASD group (n = 19) and TD group (n = 20) on the seven executive functioning measures: the DKEFS Trail-Making task, DKEFS Verbal Fluency task, DKEFS Colour-Word Interference task, DKEFS Card Sorting task, DKEFS Towers task, the eye-tracking Antisaccade task, and the eye-tracking Delayed Memory task. The covariates were FSIQ and ADHD symptomatology. There was no violation to homogeneity of covariance as tested using Box's Test of Equality; however, Levene's test for equality of variances was violated for the DKEFS Trail Making and Colour-Word task. Given differences between ASD and TD populations, it is not uncommon for this test to be violated within ASD literature[1]. Additionally, minor violations of homogeneity of variance do not tend to cause significant issues in statistical analyses when sample sizes are equal (Owen & Froman, 1998). A significant multivariate effect for group was found on the executive functioning dependent variables ($F(7,29) = 4.82$, $p = .001$, Pillai's Trace = .54, $\eta_p^2 = .54$). Group means and univariate results for group differences on the executive functioning measures are shown in Table 3. The mean scores on all DKEFS measures fell within 1 standard deviation from the population means for both the ASD and TD groups. The ASD group scored significantly lower than the TD group on the DKEFS Verbal Fluency test and the DKEFS Tower test, but there were no significant differences between groups for the remaining measures of executive functioning.

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[1] ASD populations are generally very heterogeneous and it is common for data to have high variability for ASD populations. As a result of the increased heterogeneity in this population the variance between ASD and TD populations is often significantly different. This is generally recognized as acceptable in the ASD literature.

Table 3. ***Comparison of Scores on Executive Functioning Measures Between ASD and TD Groups***

	ASD	TD		
	Mean (SD)	Mean (SD)	*F*-value	η_p^2
Trail Making	8.42 (4.46)	9.65 (1.95)	.003	.00
Verbal Fluency	8.63 (3.32)	12.10 (2.83)	6.82*	.16
Colour-Word	8.63 (3.96)	10.80 (1.85)	.71	.02
Sorting	9.63 (3.13)	10.20 (1.94)	.42	.01
Towers	8.74 (3.36)	11.90 (2.15)	10.42**	.23
Antisaccade Percent Error	32.90 (27.29)	32.12 (19.94)	.01	.00
Delayed Memory Percent Error	9.80 (9.03)	6.78 (8.69)	.13	.00

Note. DKEFS subtest means are all scaled scores with a mean of 10 and standard deviation of 3.

*p < .05, **p < .01

Attention Measures

A one-way MANCOVA was conducted to evaluate the differences between the ASD group ($n = 19$) and TD group ($n = 19$) on three attention measures: the Flanker task, the Multiple Object Tracking task, and the Useful Field of View task. The Attentional Blink task was not included as a dependent variable because the results for this measure from the current sample deviated from the trends typically reported. It is unclear why this deviation has occurred. Additionally, the Prosaccade eye-tracking task was not included as a dependent variable because its inclusion resulted in significant violations of Box's M due to large differences in variance between groups. The covariates included in the MANCOVA were FSIQ and ADHD symptomatology. Homogeneity of covariance was violated as indicated by Box's Test of Equality ($F(6,9390) = 8.25$, $p < .001$, Box's M = 54.44); however, the MANCOVA is robust to violations of this test. Additionally, Levene's test for equality of variances was violated for the Flanker task. There was no significant multivariate effect for group found on the attention measures dependent variables ($F(3,32) = 1.94$, $p > .05$, Pillai's Trace = .15, $\eta_p^2 = .15$). Due to a nonsignificant multivariate result for group the univariate results are not reported or interpreted. Group means for scores on the attention measures are shown in Table 4.

Table 4. ***ASD and TD Group Means for the Measures of Attention***

	ASD	TD
	Mean (SD)	Mean (SD)
Flanker	.77 (.33)	.94 (.04)
Multiple Object Tracking	.74 (.18)	.70 (.14)
Useful Field of View	.70 (.23)	.70 (.25)

Note. All means are proportion correct.

*$p < .05$, **$p < .01$

Functional Outcomes

A one-way MANCOVA was conducted to evaluate the differences between the ASD group (n = 18) and TD group (n = 18) on the seven measures of functional outcomes: the WJ Stories task, WJ Understanding Directions Task, WJ Writing Fluency task, WJ Calculations task, WJ Math Fluency task, the Vineland, and the SSRS. The covariates included were FSIQ and ADHD symptomatology. Homogeneity of covariance was violated as indicated by Box's Test of Equality ($F(28,4028) = 1.61$, $p = .02$, Box's M = 57.97); however, the MANCOVA is robust to violations of this test. Levene's test for equality of variances was not violated for any of the functional outcome measures. A significant multivariate effect for group was found on the functional outcome dependent variables ($F(7,26) = 8.25$, $p < .001$, Pillai's Trace = .69, $\eta_p^2 = .69$). Group means and univariate results for group differences on the functional outcome measures are shown in Table 5. The mean scores on the WJ Stories task, the WJ Directions task, and the WJ Writing Fluency task were within 1 standard deviation of the population mean for both the ASD group and TD group. For all three tasks, the ASD group scored below the population mean while the TD group scored above the population mean. The mean scores on the WJ Calculations task and the WJ Math Fluency task were just below 2 standard deviations from the population mean for the ASD group, and were within 1 standard deviation of the population mean for the TD group. Likewise, the mean scores on the Vineland and the SSRS were within 2 standard deviations below the population mean for the ASD group, and were within 1 standard deviation of the population mean for the TD group. The ASD group scored significantly lower than the TD group on the WJ Stories task, the WJ Directions task, the Vineland, and the SSRS, but there were no significant differences between groups for the WJ Writing Fluency task, the WJ Calculations task, nor the WJ Math Fluency task.

Table 5. ***Comparison of Scores on Functional Outcome Measures Between ASD and TD Groups***

	ASD	TD		
	Mean (SD)	Mean (SD)	*F*-value	η_p^2
WJ Stories	94.17 (17.16)	110.94 (12.52)	5.20*	.14
WJ Directions	88.89(20.48)	103.44 (10.59)	4.19*	.12
WJ Writing Fluency	88.28 (18.22)	103.11 (12.63)	3.17	.09
WJ Calculations	79.50 (20.93)	93.44 (16.96)	.49	.02
WJ Math Fluency	78.22 (14.87)	88.56 (9.28)	1.48	.04
VABS	75.83 (8.56)	102.61 (9.72)	53.20**	.62
SSRS	81.44 (14.75)	101.22 (8.54)	12.05**	.27

Note. All means are standard scores

*$p < .05$, **$p < .01$

Multiple Regression Analyses

Bivariate Pearson correlations were conducted to evaluate correlations among executive functioning and attention measures, as well as to evaluate correlations between cognitive measures and measures of functional impairment (Table 6). Correlations were used to identify variables to be included in multiple regression analyses.

Table 6. ***Pearson Correlations for Predictor and Outcome Variables***

	Trail Making	Verbal Fluency	Colour-Word
Trail Making	1.00		
Verbal Fluency	.17	1.00	
Colour-Word	.48**	.31	1.00
Sorting	.27	.58**	.28
Tower	.21	.35*	.17
Flanker	.18	.29	.44*
Multiple Object Tracking	.14	.25	.35*
Useful Field of View	.42**	.04	.46**
Prosaccade Percent Errors	-.50**	-.17	-.46**
Antisaccade Percent Errors	-.21	-.46**	-.32*
Delayed Memory Percent Errors	-.42**	-.34*	-.56**
WJ Stories	.44**	-.46**	.46**
WJ Directions	.36*	.36*	.45**
WJ Writing	.50**	.43**	.57**
WJ Calculations	.54**	.23	.62**
WJ Math Fluency	.50**	.27	.65**
VABS	.12	.42**	.37*
SSRS	-.03	.23	.25

* $p < .05$, ** $p < .01$

Table 6. ***Pearson Correlations for Predictor and Outcome Variables (continued)***

	Sorting	Tower	Flanker
Sorting	1.00		
Tower	.42**	1.00	
Flanker	.42**	.50**	1.00
Multiple Object Tracking	.52**	.27	.34*
Useful Field of View	.32*	.22	.47**
Prosaccade Percent Errors	-.17	-.22	-.33*
Antisaccade Percent Errors	-.50**	-.25	-.33*
Delayed Memory Percent Errors	-.57**	-.23	-.41**
WJ Stories	.33*	.37*	.52**
WJ Directions	.47**	.68**	.73**
WJ Writing	.48**	.44**	.53**
WJ Calculations	.43**	.39*	.56**
WJ Math Fluency	.30	.19	.42**
VABS	.20	.49**	.40*
SSRS	.04	.30	.25

* $p < .05$, ** $p < .01$

Table 6. ***Pearson Correlations for Predictor and Outcome Variables (continued)***

	Multiple Object Tracking	Useful Field of View	Prosaccade Percent Errors
Multiple Object Tracking	1.00		
Useful Field of View	.38*	1.00	
Prosaccade Percent Errors	.05	-.25	1.00
Antisaccade Percent Errors	-.39*	-.50**	.27
Delayed Memory Percent Errors	-.42**	-.40*	.34*
WJ Stories	-.05	.15	-.56**
WJ Directions	.30	.48**	-.37*
WJ Writing	.27	.52**	-.48**
WJ Calculations	.39	.49**	-.34*
WJ Math Fluency	.19	.49**	-.43**
VABS	-.08	.01	-.21
SSRS	-.21	.03	-.15

* $p < .05$, ** $p < .01$

Table 6. ***Pearson Correlations for Predictor and Outcome Variables (continued)***

	Antisaccade Percent Errors	Delayed Memory Percent Errors	WJ Stories
Antisaccade Percent Errors	1.00		
Delayed Memory Percent Errors	.47**	1.00	
WJ Stories	-.16	-.39*	1.00
WJ Directions	-.43**	-.44**	.55**
WJ Writing	-.36*	-.57**	.48**
WJ Calculations	-.22	-.63**	.43**
WJ Math Fluency	-.31*	-.56**	.35*
VABS	.01	-.13	.53**
SSRS	.09	-.04	.47**

* *p* < .05, ***p* < .01

Table 6. ***Pearson Correlations for Predictor and Outcome Variables (continued)***

	WJ Directions	WJ Writing	WJ Calculations
WJ Directions	1.00		
WJ Writing	.69**	1.00	
WJ Calculations	.66**	.73**	1.00
WJ Math Fluency	.46**	.77**	.73**
VABS	.35*	.37*	.46*
SSRS	.31	.32	.31

* *p* < .05, ***p* < .01

Table 6. ***Pearson Correlations for Predictor and Outcome Variables (continued)***

	WJ Math Fluency	VABS	SSRS
WJ Math Fluency	1.00		
VABS	.30	1.00	
SSRS	.28	.75**	1.00

* *p* < .05, ***p* < .01

Academic Achievement

The WJ Stories task is a measure of a participant's ability to attend to and remember oral information. A hierarchical multiple regression was performed to determine if attention and executive functioning predicted scores on this task beyond the predictive ability of FSIQ, ASD diagnosis, and ADHD symptomatology (Table 7). The first step of the model, which included FSIQ, diagnosis, and Conners *t*-score as predictors, was significant and explained 32% of the variability in WJ Stories scores. The addition of the set of attention and executive functioning measures in the second step explained an additional 5% of the variance. The second step was not significant. The overall model was significant and explained 37% of the variance in WJ Stories scores. FSIQ was positively significantly associated with WJ Stories scores, while ASD diagnosis was negatively significantly associated with the WJ Stories scores. None of the attention or executive functioning measures was significantly associated with the WJ Stories scores.

Table 7. ***Hierarchical Multiple Regression for the Prediction of WJ Stories Scores with FSIQ, Diagnosis and Conners Score Entered First, Followed by Attention Measures and Executive Functioning Measures***

	Variable	β	$AdjR^2$	F	ΔR^2	ΔF
Step 1	FSIQ	.37*	.32	6.60**	.32	6.60**
	ASD Diagnosis	-.41*				
	Conners *t*-score	.02				
Step 2	FSIQ	.14	.37	2.62*	.05	1.27
	ASD Diagnosis	-.19				
	Conners *t*-score	.07				
	Flanker	.23				
	Useful Field of View	-.10				
	Prosaccade Percent Error	-.31				
	Trail Making	.21				
	Verbal Fluency	.21				
	Colour-Word	.08				
	Sorting	-.02				
	Towers	-.06				
	Antisaccade Percent Errors	.15				
	Delayed Memory Percent Errors	.04				

*$p < .05$, **$p < .001$

The WJ Directions task is a measure of each participant's ability to attend to, conceptualize and organize oral information. A hierarchical multiple regression was performed to determine if attention and executive functioning predicted scores on this task beyond the predictive ability of IQ, ASD diagnosis, and ADHD symptomatology (Table 8). The first step of the model, which included FSIQ, diagnosis, and Conners *t*-score as predictors, was significant and explained 47% of the variability in WJ Directions scores. The addition of the set of attention and executive functioning measures in the second step of the model explained a further 12% of the variance. The second step was not significant. The overall model was significant and explained 59% of the variance in WJ Directions scores. FSIQ was positively significantly associated with WJ Directions scores, while ASD diagnosis was negatively significantly associated with the WJ Directions scores. None of the attention or executive functioning measures was significantly associated with the WJ Directions scores.

Table 8. ***Hierarchical Multiple Regression for the Prediction of WJ Directions Scores with FSIQ, Diagnosis and Conners Score Entered First, Followed by Attention Measures and Executive Functioning Measures***

	Variable	β	$AdjR^2$	F	ΔR^2	ΔF
Step 1	FSIQ	.62**	.47	11.50**	.47	11.50**
	ASD Diagnosis	-.30*				
	Conners *t*-score	.11				
Step 2	FSIQ	.42*	.59	5.04**	.12	2.03
	ASD Diagnosis	-.23				
	Conners *t*-score	.02				
	Flanker	.21				
	Useful Field of View	.02				
	Prosaccade Percent Error	-.05				
	Trail Making	.11				
	Verbal Fluency	-.24				
	Colour-Word	.09				
	Sorting	.03				
	Towers	.21				
	Antisaccade Percent Errors	-.29				
	Delayed Memory Percent Errors	.18				

*$p < .05$, **$p < .001$

The WJ Writing Fluency task is a measure of each participant's ability to organize verbal information, as well as their ability to focus on a task and work efficiently for a sustained length of time. A hierarchical multiple regression was performed to determine if attention and executive functioning predicted scores on this task beyond the predictive ability of IQ, ASD diagnosis and ADHD symptomatology (Table 8). The first step of the model, which included FSIQ, diagnosis, and Conners *t*-score as predictors, was significant and explained 39% of the variability in WJ Writing Fluency scores. The addition of the set of attention and executive functioning measures in the second step of the model explained a further 8% of the variance. The second step was not significant. The overall model was significant and explained 47% of the variance in WJ Writing Fluency scores. FSIQ was positively significantly associated with WJ Writing Fluency scores, while ASD diagnosis was negatively significantly associated with the WJ Writing Fluency scores. None of the attention or executive functioning measures was significantly associated with the WJ Writing Fluency scores.

Table 9. ***Hierarchical Multiple Regression for the Prediction of WJ Writing Fluency Scores with FSIQ, Diagnosis and Conners Score Entered First, Followed by Attention Measures and Executive Functioning Measures***

	Variable	β	$AdjR^2$	F	ΔR^2	ΔF
Step 1	FSIQ	.49**	.39	8.63**	.39	8.63**
	ASD Diagnosis	-.32*				
	Conners *t*-score	-.02				
Step 2	FSIQ	.14	.47	3.44**	.08	1.49
	ASD Diagnosis	-.14				
	Conners *t*-score	-.06				
	Flanker	.09				
	Useful Field of View	.31				
	Prosaccade Percent Error	-.17				
	Trail Making	.01				
	Verbal Fluency	.11				
	Colour-Word	.09				
	Sorting	.03				
	Towers	.13				
	Antisaccade Percent Errors	.11				
	Delayed Memory Percent Errors	-.12				

*$p < .05$, **$p < .001$

The WJ Calculations task is reflective of participant's general arithmetic ability without time constraints, as well as more complex mathematical problem solving. A hierarchical multiple regression was performed to determine if attention and executive functioning predicted scores on this task beyond the predictive ability of IQ, ASD diagnosis, and ADHD symptomatology (Table 8). The first step of the model, which included FSIQ, diagnosis, and Conners *t*-score as predictors, was significant and explained 55% of the variability in WJ Calculations scores. The addition of the set of attention and executive functioning measures in the second step of the model explained a further 13% of the variance. The second step was significant, but none of the attention or executive functioning predictors was significantly associated with the WJ Calculations scores. FSIQ was positively significantly associated with WJ Calculations scores. The overall model was significant and explained 68% of the variance in WJ Calculations scores.

Table 10. ***Hierarchical Multiple Regression for the Prediction of WJ Calculations Scores with FSIQ, Diagnosis and Conners Score Entered First, Followed by Attention Measures and Executive Functioning Measures***

	Variable	β	$AdjR^2$	F	ΔR^2	ΔF
Step 1	FSIQ	.65**	.55	15.57**	.55	15.57**
	ASD Diagnosis	-.06				
	Conners *t*-score	-.20				
Step 2	FSIQ	.50*	.68	7.00**	.13	2.42*
	ASD Diagnosis	-.07				
	Conners *t*-score	-.15				
	Flanker	.04				
	Useful Field of View	.17				
	Prosaccade Percent Error	.09				
	Trail Making	.15				
	Verbal Fluency	-.18				
	Colour-Word	.21				
	Sorting	-.11				
	Towers	.06				
	Antisaccade Percent Errors	.08				
	Delayed Memory Percent Errors	-.17				

*p < .05, **p < .001

The WJ Math Fluency task is a measure of general arithmetic ability, as well as ability to focus on a task and work efficiently. A hierarchical multiple regression was performed to determine if attention and executive functioning predicted scores on this task beyond the predictive ability of IQ, ASD diagnosis, and ADHD symptomatology (Table 8). The first step of the model, which included FSIQ, diagnosis, and Conners *t*-score as predictors, was significant and explained 35% of the variability in WJ Math Fluency scores. The addition of the set of attention and executive functioning measures in the second step of the model explained a further 17% of the variance. The second step was significant, but none of the attention or executive functioning predictors was significantly associated with the WJ Math Fluency scores. FSIQ was positively significantly associated with WJ Math Fluency scores. The overall model was significant and explained 52% of the variance in WJ Math Fluency scores.

Table 11. ***Hierarchical Multiple Regression for the Prediction of WJ Math Fluency Scores with FSIQ, Diagnosis and Conners Score Entered First, Followed by Attention Measures and Executive Functioning Measures***

	Variable	β	$AdjR^2$	F	ΔR^2	ΔF
Step 1	FSIQ	.36*	.35	7.32**	.35	7.32**
	ASD Diagnosis	-.19				
	Conners *t*-score	-.28				
Step 2	FSIQ	.08	.52	4.05*	.17	2.25*
	ASD Diagnosis	-.05				
	Conners *t*-score	-.31				
	Flanker	.24				
	Useful Field of View	.15				
	Prosaccade Percent Error	.02				
	Trail Making	.03				
	Verbal Fluency	-.04				
	Colour-Word	.28				
	Sorting	-.22				
	Towers	.11				
	Antisaccade Percent Errors	-.10				
	Delayed Memory Percent Errors	-.13				

*$p < .05$, **$p < .001$

Adaptive Behaviour

The Vineland Scales measure adaptive behaviour, including communication, daily living skills and socialization. A hierarchical multiple regression was performed to determine if attention and executive functioning predicted scores on this measure beyond the predictive ability of IQ, ASD diagnosis, and ADHD symptomatology (Table 8). The first step of the model, which included FSIQ, diagnosis, and Conners *t*-score as predictors, was significant and explained 69% of the variability in Vineland scores. The addition of the set of attention and executive functioning measures in the second step of the model reduced the explained variance by 10%. The second step was not significant. The overall model was significant and explained 59% of the variance in Vineland scores. ASD diagnosis was negatively significantly associated with the Vineland scores. None of the attention or executive functioning measures was significantly associated with the Vineland scores.

Table 12. ***Hierarchical Multiple Regression for the Prediction of Vineland Scores with FSIQ, Diagnosis and Conners Score Entered First, Followed by Attention Measures and Executive Functioning Measures***

	Variable	β	$AdjR^2$	F	ΔR^2	ΔF
Step 1	FSIQ	.04	.69	27.19**	.69	27.19**
	ASD Diagnosis	-.79**				
	Conners *t*-score	-.09				
Step 2	FSIQ	.11	.59	5.02**	-.10	.24
	ASD Diagnosis	-.76**				
	Conners *t*-score	.05				
	Flanker	-.06				
	Useful Field of View	.11				
	Prosaccade Percent Error	-.14				
	Trail Making	-.12				
	Verbal Fluency	.06				
	Colour-Word	.07				
	Sorting	.02				
	Towers	-.02				
	Antisaccade Percent Errors	.17				
	Delayed Memory Percent Errors	.05				

*$p < .05$, **$p < .001$

Social Skills

The SSRS is a broad measure of social skills as indicated by parent report. A hierarchical multiple regression was performed to determine if attention and executive functioning predicted scores on this measure beyond the predictive ability of IQ, ASD diagnosis, and ADHD symptomatology (Table 8). The first step of the model, which included FSIQ, diagnosis, and Conners *t*-score as predictors, was significant and explained 45% of the variability in SSRS scores. The addition of the set of attention and executive functioning measures in the second step of the model reduced the explained variance by 1%. The second step was not significant. The overall model was significant and explained 44% of the variance in SSRS scores. Both ASD diagnosis and Conners score were negatively significantly associated with the SSRS scores. None of the attention or executive functioning measures was significantly associated with the SSRS scores.

Table 13. ***Hierarchical Multiple Regression for the Prediction of SSRS Scores with FSIQ, Diagnosis and Conners Score Entered First, Followed by Attention Measures and Executive Functioning Measures***

	Variable	β	$AdjR^2$	F	ΔR^2	ΔF
Step 1	FSIQ	-.02	.45	9.74	.45	9.74**
	ASD Diagnosis	-.50*				
	Conners *t*-score	-.33*				
Step 2	FSIQ	.09	.44	2.91*	-.01	.93
	ASD Diagnosis	-.52*				
	Conners *t*-score	-.43*				
	Flanker	-.14				
	Useful Field of View	.38				
	Prosaccade Percent Error	-.30				
	Trail Making	-.44				
	Verbal Fluency	.13				
	Colour-Word	-.35				
	Sorting	-.15				
	Towers	-.04				
	Antisaccade Percent Errors	.06				
	Delayed Memory Percent Errors	-.27				

*$p < .05$, **$p < .001$

Chapter 4

Discussion

The first aim of the present study was to attempt to clarify the nature of executive functioning and attentional abilities in adolescents with ASD. Although the literature suggests that these abilities are impaired in individuals with ASD as compared to TD controls, findings regarding the components of executive functioning and attention that are impaired have been variable, and are especially understudied in adolescent populations. Furthermore, this study aimed to investigate the predictive relationship of attention and executive functioning with functional outcomes in ASD and TD adolescents. Such predictive relationships have already been suggested for TD adolescent populations, as well as for younger ASD populations; however, much of this evidence is correlational in nature. Identification of predictive relationships could be helpful in the development of theoretical models that can be used to explain underlying mechanisms responsible for the development of functional abilities in individuals with ASD and may help to guide future research regarding these abilities and intervention.

Based on the previous literature, it was expected that adolescents with ASD would not perform as well as TD adolescents on measures of cognition and functional outcomes. Results from this study are not entirely consistent with the original hypotheses. Adolescents with ASD did not differ from the TD group on most measures of attention and executive functioning. The only area in which individuals with ASD performed lower than the TD group was on two measures of executive functioning that are reflective of cognitive shifting and planning. Nonetheless, the current sample of ASD adolescents showed significant impairments as compared to TD adolescents with oral language-based academic achievement, adaptive behaviour and social skills.

It was also expected that both attention and executive functioning would predict performance on measures of academic achievement, as well as adaptive behaviour and social skills. The results of this study do not provide evidence in support of these hypotheses. The current results do not indicate that either the attention or executive functioning measures were significantly associated with language-based academic ability. With regards to math-based academic ability, although there was some evidence indicating that the addition of attention and executive functioning to these regression models resulted in a significant increase in the variance explained above and beyond the effects of IQ, ASD diagnosis, and ADHD symptomatology in the first step of the model, none of the attention nor executive functioning measures were uniquely significantly associated with math-based academic ability scores. As such, it is unclear if the increase in explained variance was due to a redistribution of variance, an increase in error explained, or if it was truly due to unique predictive ability of the attention and executive functioning measures that was not made apparent due to lack of power. Additionally, neither attention nor executive functioning was shown to be a predictor of adaptive behaviour or social skills.

Performance Differences between TD Adolescents and those with ASD

Although results for executive functioning did not turn out as hypothesized, they are not entirely unexpected given what is reported in the literature. Specifically, there is a lot of variation in the literature regarding which components of executive functioning are most impaired in ASD. One report of executive functioning deficits using an adolescent ASD population indicated that individuals with ASD achieve lower scores in all areas of executive functioning in comparison to TD individuals (Troyb et al., 2013). The most commonly reported deficit in executive functioning for individuals with ASD is that of cognitive shifting (Rosenthal et al., 2013). However, these findings tend to arise in younger populations and when there are no controls on

IQ. There are mixed reports regarding whether cognitive shifting remains a deficit in ASD when controlling for IQ (van der Sluis et al., 2005, Bull et al., 2008). There are also reports that in adolescent populations, individuals with ASD tend to struggle more with inhibition and monitoring (Robinson et al., 2009). Results from the current study are in agreement with findings that in adolescents with ASD, executive functioning impairments tend to be related to cognitive shifting and planning, which in the current study were assessed by the Verbal Fluency Shifting task and the Towers task. Other measures of executive functioning included in this study also incorporated elements of cognitive shifting and planning, namely the Trail Making Shifting task and the Card Sorting task; however, these tasks also strongly channel other elements of executive functioning (e.g., inhibition and working memory), which may explain why they were not significantly different between groups.

Results for group differences on attention measures were particularly surprising. The current study indicated that when controlling for IQ and ADHD sypmtomatology there were no differences in attention ability between adolescents with ASD and TD adolescents. In TD individuals most basic attentional processes are well developed by the time they reach adolescence, although many attentional abilities do continue to develop through to adulthood (Dye & Bavelier, 2010). Individuals with ASD lag behind their TD counterparts when it comes to attentional abilities (Keehn, Muller, & Townsend, 2013). As such it was expected that group differences would be observed between ASD and TD adolescent populations. A lack of difference could indicate that the more basic attentional processes measured in this study are no longer significantly impaired as compared to TD individuals by the time individuals with ASD reach adolescence. It is possible that some higher-order attention abilities more closely related to executive control remain impaired in adolescents with ASD; however, we have not assessed these in the current study. An alternate explanation for the current findings might be that the attentional demands of the extensive protocol for this study caused the TD group to under-perform on measures of attention. More specifically, requiring adolescent participants to partake in testing sessions that lasted between 2 to 3 hours may have depleted attentional resources, causing performance on attention-related tasks to deviate from what they might typically be capable of in a less demanding context. In considering possible explanations for the current findings, it is also important to recognize that the analyses for group differences were underpowered. As such, the null findings may not be a true representation of there being no differences between groups, but rather a representation of issues with power.

Despite unexpected findings for group differences on attention and executive functioning, results for functional outcomes were mostly as hypothesized. Although higher-functioning individuals with ASD have average intelligence, it was expected that symptoms related to the ASD diagnosis might interfere with learning in school. When controlling for FSIQ and ADHD symptomatology, adolescents with ASD were found to be more impaired than TD controls on the academic tasks assessing oral language ability, but there were no group differences on the math-based and writing fluency achievement tasks. Previous studies have also found evidence that computation abilities are generally intact in adolescents with ASD, and that there is no difference from TD adolescents on mathematical tasks that primarily rely on computation (Whitby & Mancil, 2009). Thus, the lack of evidence for difference between groups on math ability when controlling for IQ and ADHD symptoms in this sample could be reflective of the primarily computational nature of these math tasks (although the WJ Calculations task does require some problem solving ability).

More surprising was the finding that the ASD group did not significantly differ from the TD group on the writing fluency task when controlling for IQ and ADHD diagnosis. Previous research has consistently reported deficits in writing fluency within ASD samples, as well as deficits with related skills such as processing speed, visual-motor integration, and written expression tests (Mayes & Calhoun, 2003; Mayes & Calhoun, 2008). Difficulties with writing fluency and related skills have also been consistently reported in ADHD populations (Mayes & Calhoun, 2007). It may be that these commonly reported writing deficits in individuals with ASD are strongly related to diagnostic traits that overlap with individuals with ADHD, such as attentional difficulties. As a result, when those underlying traits are controlled for there is no further significant variance that can be attributed to writing fluency beyond what overlaps with deficits related to ADHD. However, it is still quite possible that lack of evidence for group differences on the writing fluency task, as well as on the math-based academic tasks, could be a result of the small sample size and underpowered analyses for the detection of group differences.

Unlike math and writing achievement, the adolescents with ASD did not perform as well on oral language achievement tasks as did the TD adolescents when controlling for IQ and ADHD symptomatology. Given that communication and language impairments are a core deficit in ASD, it is not surprising that the adolescents with ASD in this sample struggle with verbal tasks of achievement. This trend has been reported repeatedly throughout literature. Namely, although decoding skills may be intact in high-functioning individuals with ASD, reading comprehension, verbal reasoning and written expression are generally areas of difficulty (Whitby & Mancil, 2009).

Adaptive behaviour scores were also significantly lower for adolescents with ASD than for TD adolescents. This difference existed above and beyond the effects of IQ and ADHD symptomatology. As previously discussed, impairments in adaptive behaviour have been consistently reported across many domains of functioning for individuals with ASD (Baghdadli et al., 2011). Parents of children with ASD consistently express concern regarding day-to-day living and what the future holds for their child given difficulties with communication, self-care, community living and coping (Hendricks & Wehman, 2009).

Furthermore, as with adaptive behaviour, social skills scores were also significantly lower for adolescents with ASD as compared to the TD adolescents. Given that social skills impairment is a key feature of the ASD diagnosis, it follows that measures of social skills would show lower scores as compared to TD individuals. Notably, although many individuals with ASD show increased social functioning as they age through adolescence (Seltzer, Shattuck, Abbeduto, & Greenberg, 2004), results of this study indicate that their social abilities remain behind those of their TD peers at least for this sample.

Attention and Executive Functioning as Predictors of Academic Achievement

Results from the current study were not consistent with the hypothesis that attention and executive functioning would be predictive of academic ability. Attention and executive functioning abilities were not shown to be significantly associated with language-based academic achievement and did not provide any further explanation of the variance in language-based achievement scores above and beyond the predictive ability of IQ, ASD diagnosis, and ADHD symptomatology. Only IQ and ASD diagnosis were significantly associated with performance on language-based achievement tasks including the WJ Stories task, the WJ Directions task, and the WJ Writing Fluency task. In a school setting, the Stories and Directions tasks may be likened to the skills necessary for listening to lessons and comprehension of language-based instructions and information. Additionally, writing fluency is likely to require the ability to stay focused and work efficiently on a task. In light of this, it seems surprising that attention and executive functioning would not predict these abilities. In part, these findings may be reflective of the fact that the current study did not have sufficient power to elucidate relationships of attention and executive functioning with language-based academic skills. Perhaps with a larger sample size these predictive relationships would be found to be significant. Alternately, it may be that a relationship does not exist between these factors.

Similar to the language-based academic tasks, attention and executive functioning were also not significantly associated with performance on math-based academic tasks. Although the addition of attention and executive functioning measures to the regression model did result in a significant increase in explained variance beyond what was explained when only FSIQ, ASD diagnosis, and ADHD symptomatology were included in the model, neither the attention nor executive functioning measures were unique predictors of math ability. Only FSIQ was shown to be significantly associated with the WJ Calculations task, as was the case with the WJ Math Fluency task. As such, it is not clear whether the increase in explained variance was the result of a true predictive relationship of attention or executive functioning with math ability, or if instead the explained variance was due to a more complete characterization of error in the model or a redistribution of variance between factors in the model. It is possible that attention and executive functioning may truly be predictive of math ability, but in the present study the clear lack of power has restricted the chances of identifying any such relationship. Conceptually, it makes sense that attention and executive functioning would play a role in the development of math ability. Specifically, in mathematics, one is required to organize information, shift between different mathematical concepts, hold information in their minds and problem solve. Furthermore, there is a requirement for the ability to orient and sustain attention in order to complete these tasks efficiently. In typically developing populations there has been some evidence that attention and executive functioning predict math skills (Latzman et al., 2010; Steele etal., 2012). As such, is surprising that no relationship was identified in the present study. Future research with greater power would help in clarifying whether the current results were due to power issues.

Attention and Executive Functioning as Predictors of Adaptive Behaviour and Social Skills

In the current study, the measures of attention and executive functioning were not found to predict adaptive behaviour; however, as a set of predictors, IQ, ASD diagnosis and ADHD symptomatology were found to predict adaptive behaviour. Specifically, ASD diagnosis was negatively significantly associated with adaptive behaviour scores, indicating that adaptive behaviour difficulties were explained primarily by an ASD diagnosis in this sample. This is not surprising given the high correlations that are typically reported between symptomatology and adaptive behaviour in ASD (Kenworthy, Case, Harms, Martin, & Wallace, 2010). It is possible that in adolescence, factors other than executive functioning and attention that have not been considered in the present study play a primary role in the development of adaptive behaviour skills. For example, a recent investigation of adaptive behaviour outcomes in individuals with ASD found that theory of mind was a mediator of the relationship between early language skills development and adolescent adaptive behaviour (Bennett et al., 2013).

As with adaptive behaviour, attention and executive functioning did not predict social skills above and beyond the influence of IQ, ASD diagnosis, and ADHD symptomatology. Specifically, both ASD diagnosis and ADHD symptomatology were significantly associated with social skills scores, but none of the attention or executive functioning measures were uniquely predictive of social skills scores. This is especially surprising given theories that attentional misallocation due to lack of attentional control interferes with important social learning opportunities for individuals with ASD (Volkmar, 2011). As with adaptive behaviour, it may be possible that factors not considered here play a greater role in the prediction of social skills development. For example, there is evidence that both emotional intelligence and theory of mind may be predictors of social abilities in young adults with ASD (Montgomery, Stoesz, & McCrimmon, 2012)

Although the current study did not find a relationship of attention and executive functioning with adaptive behaviour or social skills, such findings may be primarily the result of methodological issues. As such, it is still possible that executive functioning and attention may be important to the development of adaptive behaviour and social skills. For example, it is possible to imagine how abilities in organization and planning would be critical for day-to-day activities such as making meals, completing chores, and figuring out how to get to different places within one's community. Likewise, it is possible to consider how social functioning might require the ability to sustain attention on relevant stimuli, inhibit responses to non-relevant stimuli, and to hold many pieces of information in one's mind at any given time. The inability to identify such relationships between these abilities and cognition in the current study may reflect the clear issues with power that are present in the current study. It is possible that an increase in sample size or a reduction in the number of predictors might help to elucidate relationships between these factors. Additionally, issues with the suitability of the measures used may have also contributed to null findings. Specifically, two sub-domains of the Vineland assess communication and social functioning, which are both primary deficits in the ASD diagnosis. As such, there is already a lot of overlap between ASD diagnosis and adaptive behaviour built into the measurement of adaptive skills in the present study. Likewise, it is also possible that the lack of any predictive relationship with social skills could be due in part to lower ecological validity or sensitivity of the SSRS as a measure of social functioning in adolescent populations, at least for socials skills that are strongly related to executive functioning and attention.

Limitations and Future Directions

It is important to keep in mind that the present research has been conducted on a relatively small sample. A small sample size becomes problematic on three accounts: problems with statistical analysis, problems with data collection, and problems with generalizability. First, a sample of this size does not allow for enough power to detect significant effects using certain statistical analyses. Specifically, failed attempts to identify moderation effects or predictive relationships between single predictors and outcome variables, could be in part attributed to issues with sample size. Furthermore, it is not advisable to conduct multiple regressions with such a high number of predictors as is used in this study given the sample size. Including a high number of predictors in relation to sample size has the potential to create spurious effects. Concerns regarding small sample size in reference to statistical analyses certainly warrants the necessity to interpret the current results with caution.

Small sample size also raises issues with regards to complete data collection. In the present study, five participants' parents did not provide social skills data. With such a small sample, missing data for five participants becomes a substantial percentage of the data. Pattern analysis during imputation identified that there was no particular pattern to the missing data, or in other words, participants were not specifically avoiding completion of this part of the study for any reason, suggesting that an increased sample size would likely have helped to reduce the percentage of missing data on this measure.

In combination with issues of missing data, a small sample size further creates problems regarding the generalizability of any findings. Given the limited number of participants included in the current sample it is important to be mindful that it is less likely that the sample is a fair representation of the larger population. As such, the findings in the current study must be interpreted with caution.

In addition to sample size, the current study is also limited by sample heterogeneity. Previous literature has suggest that differences in factors such as age, IQ, and comorbid diagnosis may be responsible for some of the differential results in attention and executive functioning data (Best and Miller, 2010; Latzman, Elkovitch, Young, & Clark, 2010). Although the range of FSIQ scores included in this study fell within two standard deviations above and below average FSIQ, the range of FSIQ scores included was very broad. It is possible that there might be important differences relating to executive functioning and attention for individuals who have FSIQ scores that fall closer to the low and high end of this spectrum. Additionally, in light of the difficulties encountered in recruiting a sample for this study, inclusion criteria regarding comorbid diagnosis was lenient. Five individuals with an ASD diagnosis included in the sample had also been diagnosed with Attention-Deficit/ Hyperactivity Disorder (ADHD) at some point in their lives. Furthermore, a few TD individuals included in this study received scores in the clinical range on a screening measure of ADHD, despite having never received a diagnosis. Given the difficulties with attention and executive functioning experienced by individuals with attention problems, this issue may have had an influence on findings. It is important to note that given the high comorbidity of ADHD in individuals with ASD, it is still meaningful to understand cognition and functional outcomes in these individuals; however, differences between individuals with and without a secondary diagnosis of ADHD are likely to complicate results.

In light of issues with sample size and heterogeneity, it will be critical in future research to aim for collection of a larger sample and to apply more stringent inclusion criteria. Obtaining the desired sample size in the present study was made more difficult due to the large time commitment required for participation in the larger study of which this study was a part. The issue of time commitment was especially problematic because the present study was conducted in conjunction with a larger longitudinal project that required a total of 12 hours of testing and 20 hours of training across three months. Finding a way to minimize time commitment would likely help in the recruitment of participants. Additional methods to improve recruitment might include conducting testing in larger city centers where there is a greater pool of individuals diagnosed with ASD to recruit from. Such testing was not feasible for the present study, again because of the longitudinal nature of the larger associated project. Thirdly, future studies would benefit from broadly advertising studies in newspapers and magazines. The present study made use of such methods of recruitment, but only did so near the end of data collection. These methods proved to be very successful, and in the future could be used earlier in the data collection phase to increase sample size. Increases in sample recruitment will allow for the use of more stringent inclusion criteria, which should involve the exclusion of participants with ASD who also have a diagnosis of ADHD and further restriction on IQ.

Another methodological limitation is with regards to the burden of measurement and time commitment required for the present study. Time commitment has already been discussed to present issues with regards to participant recruitment; however, it could also have had an influence on the data collection itself. Participants were in testing for two sessions that ranged in time from 2 to 3 hours. This time commitment becomes particularly concerning when considering the computerized attention measures and eye-tracking measures, which are not very engaging and require a high degree of focus. The attention battery that was used in the current study has been administered extensively to older populations with success, but has not been administered in full to an adolescent population. It is possible that the attentional demands for completing this battery of tests was too great for adolescent populations and interfered with task performance. Similarly, eye-tracking measures have been used with this age group, but rarely in combination with such a demanding protocol of other tests. Future studies would benefit from reducing the burden of measurement in order to enhance the validity of the data.

There is no gold standard for measuring attentional abilities in individuals with ASD, and in general the attention literature makes use of a broad variety of tasks to measure various components of attention. It would likely be beneficial for future studies to investigate optimal methods for assessing attention in individuals with ASD. A specific goal of such endeavors should be to reduce the number of trials that are necessary for obtaining a reliable sample of data from each participant. Additionally, efforts in developing suitable attention measures for an adolescent ASD population might aim to create measures that are more engaging and ecologically valid as compared to some of the standard protocols for assessing attention in TD adults which include pressing keys on a keyboard in response to black and white stimuli on a screen. Such measures might include videos or images with attentional stimuli embedded in them. However, it will be necessary to balance how engaging such measures are with confounds that might complicate interpretation of the data obtained.

With the resolution of the above noted sample and methodological issues, important findings could likely be revealed through the use of factor analysis and structural equation modeling in future studies. Such statistical techniques require larger sample sizes and would benefit from a more homogenous sample. The ability to conduct factor analysis would allow for a better understanding of how different attention and executive functioning variables group together. The advantage of such knowledge would not only provide clarity to interpretation of results, but could also inform appropriate variable groupings for further analyses. Collecting a larger and more homogenous data set and performing such statistical analyses would likely provide insight into the relationships between attention, executive functioning, and functional outcomes, as well as the differences that arise between an ASD and a TD population. More specifically, applying these changes in future research could allow for deeper investigation of a theoretical framework exploring potential core cognitive deficits that are critical for the development of functional outcomes in ASD.

With regards to developing a theoretical model that might help to characterize the cognitive bases of functional deficits, there are many theories that could potentially be investigated with a larger sample size. While the current results failed to identify a predictive relationship of attention and executive functioning with functional outcomes, IQ and ASD diagnosis were shown to be associated with many outcomes. It might be of interest to consider whether executive functioning or attention ability mediate such relationships through testing a multiple mediation model. Alternately, it would also be interesting to consider whether executive functioning or attention interact with the effects of diagnosis on functional outcome. For example, one might hypothesize that when attention or executive functioning abilities are high, there is less difference between groups on functional ability, but when executive functioning abilities are low the typically developing group might have much higher functioning than the group with ASD. Such a hypothesis could be tested using factorial analysis of variance or by using moderation models.

Implications

In light of the many limitations in the present study, the results provide restricted insights to understanding the experience of adolescents with ASD. Despite these limited finding, the present study provides a starting point for developing more targeted questions regarding functional development in adolescents with ASD. A great focus within the literature is in understanding development of younger individuals with ASD so that we might better understand how to intervene in a meaningful way as early as possible. However, individuals with ASD continue to struggle throughout their lives and there is not a strong understanding of the mechanisms that can explain how functional abilities develop and change as individuals with ASD age. This becomes particularly concerning when we consider the transition through adolescence to adulthood, when individuals must learn to become more independent and develop the skills necessary to be successful after high school. The relevance of this issue is heightened when we consider the extensive cost of individuals with ASD who struggle to support themselves during and after this transition (Ganz, 2007). The present study begins to provide some insight into understanding the areas of life in which adolescents with ASD are struggling, and the cognitive mechanisms that may explain these struggles.

Current findings highlight the need for considering a theoretical framework that could be used in future research to better investigate deficits associated with ASD. The previous literature has done a fair job at identifying the existence of deficits across a number of cognitive and functional domains for individuals with ASD; however, efforts to explain why these deficits exist and how they can be remediated have been minimal. It is possible to consider that given impairments in attention and executive functioning, adolescents with ASD may not have the fundamental cognitive abilities to allow them to acquire the functional skills that are acquired naturally and without effort by TD adolescents who do not experience the same cognitive deficits. Further development of a framework to explain the development of these skills is critical to conceptualizing the experience of adolescents with ASD and to eventually developing more effective methods of intervention.

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Appendix A

Eye-Tracking Protocol

Eye movements were recorded using the Eyelink 1,000 eye tracking system. Participants observed eye-tracking tasks on a 17” LCD monitor, and eye movements were tracked by a desktop infrared camera placed approximately 55 to 60 cm from the participant’s left eye. The position of the left pupil was digitized in both the vertical and horizontal axes at a sampling rate of 500 Hz. Before commencing each of the three eye-tracking tasks, the eye movements of each participant were calibrated using 9 targets that appear sequentially at different locations on the screen. After calibration, the process was repeated to validate that the average error between fixation and target was less than 2 degrees.

Prosaccade Task

This task consisted of 60 trials. Each trial began with illumination of a central fixation point. After 800 to 1,200 ms the central fixation point disappeared for 200 ms and then a peripheral target appeared randomly at 10 degrees to the left or right. Participants had 1,000 ms to make a saccade towards the peripheral target. Participants were instructed to look at the target as soon as it appeared. No error feedback was given.

Antisaccade Task

Like the Prosaccade task, this task consisted of 60 trials. Each trial began with illumination of a central fixation point. After 800 to 1,200 ms the central fixation point disappeared for 200 ms and then a peripheral target appeared randomly at 10 degrees to the left or right. Participants had 1,000 ms to make a saccade in the opposite direction of the peripheral target. Participants were instructed to look away from the target as soon as it appeared. No error feedback was given.

Delayed-Memory Task

This task consisted of 73 trials. Each trial began with illumination of a central fixation point. The central fixation remained for 200 to 1,000 ms before two peripheral targets appeared on the screen. The two peripheral targets appeared for 100 ms each. The central fixation point remained illuminated while the peripheral targets flashed on the screen, and remained illuminated for an additional 0, 600, 1,200, or 18,000 ms after the two peripheral targets disappeared. Participants were told to maintain fixation at the central fixation point while the 2 peripheral targets appeared. After the central fixation point disappeared, the participants were to make a saccade to the locations where the periphery targets had appeared in the order that they appeared. In each of the four quadrants of the LCD screen, peripheral targets could appear in 9 potential locations in an invisible 3 by 3 grid centered at a 10 degree visual angle from the central fixation point.

Appendix B
Attention Measure Protocol

Participants observed the computerized attention battery on a 17" LCD monitor, seated approximately 55 to 60 cm from the screen. Multiple blocks of each task were presented, and participants were offered breaks between each block as needed.

Flanker Task

In this task a letter appeared with a ring around it in the middle of the screen. Participants were instructed to watch for either an N or an X on the ring around the central letter. Letter sizes were in 26-point font. The targets on the outer ring could appear in one of 8 positions approximately 6.6 degrees from the central fixation letter. Target letters were X or N. The letter in the centre of the screen could be either N or X, or a neutral letter (P, A, S, B, F, T, or R). A fixation dot appeared in the centre of the screen for 1 sec before each trial began. The letters appeared on the screen for 150 ms. The participant was instructed to type either N or X on the keyboard in correspondence with the target letter that appeared on the outer ring. The next trial started when the participant pressed a key to classify the target letter as being X or N. There were 75 trials in total, with approximately 25 per congruency condition. Congruency conditions included an incongruent condition, in which both the central fixation and periphery target letters were either N or X but were different from each other, a congruent condition, in which both the central fixation and periphery target letters were either N or X and were the same as each other, and a neutral condition, in which the central fixation was a neutral letter and the periphery target letters were either N or X.

Attentional Blink Task

Participants were instructed to look for a white letter and the letter X in a stream of letters in the centre of the screen. The letters were in 18-point font. A central fixation dot appeared for 1 sec before the beginning of each trial. Each trial included the appearance of 20 letters. Each letter appeared for 75 ms with a blank screen appearing between each letter for 25 ms. The white target letter could appear anywhere in the 3rd to 14th letter position, and the following X target could appear within the 1st to 8th positions after the white letter. An X target was present in 50% of trials. When the stream finished, the computer prompted the participant to enter the identity of the white letter, and then to press X if an X appeared and N if no X appeared in the stream. There were 160 trials broken into 4 blocks of 40.

Multiple Object Tracking Task

Participants were instructed to remember and track dots as they moved randomly around the screen. Before each trial began, a central fixation dot appeared for 1 sec. After the 1 sec fixation, there was an initial object display of 8 discs of approximately 0.3 degrees. Either two or four targets were filled in green and the others were white. After 2 sec, the discs all became white and moved around semi-randomly for 8 sec in a 29 degree by 29 degree area. The discs changed directions if they hit either the boundary of the area or another disc. After the 8 sec of motion, the objects stopped and one object was filled in blue. The participant then pressed Z if they believed the object had been a target (green dot), and M if they believed it had been a non-target (white dot). This task had 40 trials broken into 4 blocks of 10.

Useful Field of View Task

Participants were instructed to watch for a black triangle on one of eight spokes and then to indicate on which spoke the triangle appeared. Before each trail began a central fixation dot appeared for 1 sec. Following the fixation period a black triangle of approximately 0.5 degrees appeared on one of 8 spokes in one of three boxes of approximately 0.6 degrees. The triangle and boxes were spaced at 4, 8 or 11 degrees from fixation. After 64 ms, a mask of randomly sized black and white rectangles and ovals was presented that filled the screen for 1 sec. The 8 spokes then reappeared with a number on each spoke. The participant pressed the key on the keyboard number-pad that corresponded with the spoke that they believed the target had appeared on. The next trial began after a response was given. This task had 192 trials broken 4 blocks of 48 trials.

Appendix C

Skew and Kurtosis

Table 14. ***Skewness and Kurtosis for FSIQ, Predictor Variable and Outcome Variables***

	Skew	Kurtosis
FSIQ	-.50	-.05
Trail Making	-1.06	.73
Verbal Fluency	-.53	-.13
Colour-Word	-1.29	2.42
Sorting	-.88	2.55
Tower	-.45	.68
Flanker	-2.11	3.47
Multiple Object Tracking	-.10	-.81
Useful Field of View	-.1.15	.75
Prosaccade Percent Errors	2.78	15.55
Antisaccade Percent Errors	.58	-.68
Delayed Memory Percent Errors	.95	-.32
WJ Stories	-.71	1.38
WJ Directions	-.31	.46
WJ Writing	.07	.38
WJ Calculations	-.13	.79
WJ Math Fluency	..33	.35
VABS	.20	-.55
SSRS	-.44	-.58