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The Relationship Between Inhibition and Social Skills in Children with High Functioning Autism Spectrum Disorders

Matchullis, Ryan

UNIVERSITY OF CALGARY

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by

Ryan L. Matchullis B.A.

The University of Calgary

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Abstract

The purpose of the current study is to enhance understanding of the neuropsychological basis of the social skill deficits in children with high-functioning autism spectrum disorders (HFASD) through an investigation of inhibition, a sub-domain of executive functioning. A total of 16 children with HFASD and 16 age- and gender-matched typically-developing (TD) comparison children were administered task-based measures of inhibition and were rated by parents on inhibition and social skills. Non-parametric statistical comparisons revealed that children with HFASD were rated as having poorer social skills and increased inhibitory dysfunction than their TD peers. Furthermore, this increased inhibitory dysfunction was negatively correlated with poorer social skills in the HFASD group only. The implications of these results are discussed in light of potential interventions and further understanding of the unique neuropsychological profile in children with HFASD. Finally, study limitations and suggestions for future research are highlighted.

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List of Abbreviations

AD……………...Autistic Disorder
ADHD…………Attention Deficit / Hyperactivity Disorder.
ADI-R…….……Autism Diagnostic Interview-Revised
ADOS……...….Autism Diagnostic Observation Schedule
AS……...…….Asperger syndrome
ASD……....….Autism spectrum disorder
BRIEF……….…Behaviour Rating Inventory of Executive Function
CF………..……Cognitive flexibility
CW3………..….Color Word 3 (inhibition task)
DKEFS………...Delis Kaplan Executive Function System
DSM-IV-TR……Diagnostic and Statistical Manual of Mental Disorders, 4th Ed., Text Revised
DSM-5……...….Diagnostic and Statistical Manual of Mental Disorders, 5th Ed.
EF……………...Executive function
fMRI…………...Functional Magnetic Resonance Imaging
FSIQ…………...Full Scale Intelligence Quotient
HFA……………High functioning autism
HFASD………...High Functioning Autism Spectrum Disorder
ICD-10…………International Classification of Diseases and Health Related Problems, 10th Ed.
IN………………Inhibition
IQ……………...Intelligence Quotient
LED……….....…Light Emitting Diode
NEPSY………...A Developmental Neuropsychological Assessment
PFC…………….Prefrontal Cortex
PDD-NOS…...…Pervasive Developmental Disorder – Not Otherwise Specified
PIQ……………..Performance Intelligence Quotient
SSIS……………Social Skills Improvement System Rating Scales
TD……………...Typically developing (i.e., individual with no developmental delay / disorder)
ToM…………....Theory of Mind
VIQ…………....Verbal Intelligence Quotient
WASI…………..Wechsler Abbreviated Scale of Intelligence
WCC…………...Weak Central Coherence
WCST…………Wisconsin Card Sorting Task
WM……………Working Memory

Chapter 1: Literature Review

Autism Spectrum Disorders

Autism Spectrum Disorder (ASD) is a term encompassing five disorders described in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revised* (DSM-IV-TR; American Psychiatric Association, 2000). Autistic Disorder (autism; AD), Rett's Disorder, Childhood Disintegrative Disorder, Asperger's Disorder (Asperger syndrome; AS), and Pervasive Developmental Disorder - Not Otherwise Specified (PDD-NOS) are all categorized by varying qualitative degree of deficit in three distinct areas of abnormal development in relation to expected developmental or mental age: (1) communication abilities, (2) reciprocal social interaction abilities, and (3) the presence of restrictive and repetitive patterns of behaviours and interests. These three symptoms are often referred to as the "autistic triad of impairments" (APA, 2000; Cashin, Sci, & Barker, 2009) and differential diagnosis is based upon language and cognitive development, the age of symptom onset, physical and motor characteristics, and the individual's developmental trajectory (APA, 2000). ASD is more commonly diagnosed in males, at an overall ratio of approximately 4:1 (Fombonne, 2005). Data from the Centers for Disease Control and Prevention (2012) in the United States indicated a prevalence of 6.4 per 1000 children aged 8 years in 2002, with a 23% increase to 11.3 per 1000 (or 1 in 88) children aged 8 years when analyzing the most recent 2008 data.

History and Diagnostic Classification. The term "autism" was first used by Eugene Bleuler in 1911 as a description of individuals with schizophrenia who had appeared to have lost contact with reality (Bleuler, 1911/1950). The term was then applied clinically by Leo Kanner (1943) when describing 11 children who appeared to exhibit an "extreme autistic aloneness" (p. 242). These children were lacking in social response and interest from infancy onward, and were also described as having impaired communication and rigid behaviours. Less than one year later, Hans Asperger (1944) provided parallel descriptions of young males with a similar behavioural profile in the presence of intact verbal abilities.

Despite receiving little empirical support, Kanner's and Asperger's initial descriptions linking autism symptomology to schizophrenia were reflected in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM; APA, 1952) and DSM-II (APA, 1968) as diagnoses of Schizophrenic reaction, childhood type and Schizophrenia, childhood type. However, the empirical distinction between autism and schizophrenia was made through early research by Rutter (1970; 1972) and Kolvin (1971) and in 1980, the DSM-III added "infantile autism" as a diagnosis under the newly created Pervasive Developmental Disorders category (APA, 1980). The current DSM-IV-TR classifies the five disorders within the category of Pervasive Developmental Disorders and closely corresponds to the *International Statistical Classification of Diseases and Related Health Problems, Tenth Edition* (World Health Organization, 1994). The similar descriptions have a strong, positive impact on the ability to merge datasets and compare research findings on these disorders (Gotham, Bishop, & Lord, 2011).

In response to research since the publication of the DSM-IV-TR, proposed changes to the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5; APA, 2010) includes the introduction of an inclusive ASD category in place of separate diagnoses. Diagnostic criteria will be modified such that the "autistic triad" of impairments will become two major categories; (1) social and communication deficits, (2) and fixated interests and repetitive behaviours. Clinically, this modification will require the identification of specific behaviours that must be identified in both of these categories. Level of impairment in individuals meeting criteria for ASD will then be identified with a severity rating of 1, 2, or 3 ("Requiring support", "Requiring substantial support", and "Requiring very substantial support" respectively). These changes are proposed to improve the validity and reliability of ASD diagnosis, as well as represent a disorder better characterized as a single spectrum with varying presentations as opposed to distinct disorders with similar characteristics. In the present study, clinical participants were collapsed into a high-functioning autism spectrum disorders group, which is described in further detail in the following sections. These individuals would most likely be considered as Level 1 in the upcoming DSM-5.

Core Symptoms

Social Interaction. Social challenges for individuals with ASD result from qualitative impairment in understanding and responding to social information (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). Diagnostically, individuals with ASD must demonstrate two of the following in this domain: (1) impairment in nonverbal behaviours such as eye-to-eye gaze, use of facial expressions, body postures, and gestures; (2) a failure to develop normal peer relationships appropriate to developmental level; (3) a lack of self-initiated seeking of shared enjoyment with others; and (4) lack of emotional or social reciprocity. Parents of infants with ASD may notice an inappropriate or lack of reaction to their parents' voice or physical touch. As children age, they may show difficulty sharing the emotions of others (e.g., empathy when a parent is sick or hurt). Mundy (2011) postulates that based on the literature, the central social pathology of ASD can be described best by the third symptom, the lack of spontaneous seeking to share enjoyment, interests, achievements, or general experiences with other individuals.

Behaviours observed in ASD can be compared to individuals with no identified developmental disorder and apparently normal development, often described to be "typically-developing". Between 6 and 18 months of age, typically developing (TD) children display what is termed "joint attention", in which they follow the gaze of a social partner, an action which can also be initiated or sustained by the child (Scaife & Bruner, 1975, Bruner, 1975). This behaviour is the earliest way in which children spontaneously share information with other people and begin to participate in social learning (Mundy, 2011). Individuals with ASD demonstrate impairments in their capacity to initiate and respond to joint attention opportunities beginning early in development (Charman, 2004; Dawson et al., 2004; Loveland & Landry, 1986; Curcio, 1978). This lack of normal joint attention means that children with ASD are not able to be guided by physical and social learning opportunities in the environment by parents and others (Mundy, 2003; Tomasello & Farrar, 1986). Similarly, older children, adolescents, and adults may be impaired in social learning contexts and their capacity for developing relationships because they cannot keep up with the quick exchanges of shared attention present in social situations (Mundy & Sigman, 2006). In essence, this impairment in normal joint attention results in deficits in human information processing that are developmentally involved in creating social-cognitive knowledge and abilities (Mundy, 2011).

Social interaction deficits are also present in areas such as lack of normal early symbolic and imaginative play and social sharing behaviours (Haq & LeCouter, 2004). In this respect, the play of children with ASD is often more isolated and individual, with little pretending or sharing their experience with peers. Instead, play behaviours tend to be repetitive and restricted.

Language and Communication. For individuals with ASD, deficits in communication can present through both verbal and nonverbal means. Diagnostic criteria in the current DSM-IV-TR requires impairment in one of the following areas: (1) a delay in the development of or complete lack of spoken or other forms of language (e.g. sign language); (2) for individuals who acquire speech, deficits in initiating or sustaining conversation with others; (3) stereotyped, repetitive, or idiosyncratic use of language; and (4) lack of spontaneous and variable imaginative or social imitative play as expected of developmental level (APA, 2000).

These deficits may include the presence of abnormal language development, delayed acquisition of verbal language, loss of previously developed abilities, and difficulties with conversational and socially appropriate usage of language (Stephanos & Baron, 2011). Early research by Rutter (1978) indicated that as many as 50% of individuals diagnosed with ASD remain nonverbal through their lifespan. However, more recent research by Lord et al. (2006) found this estimate to be high, as they reported that even for individuals demonstrating more severe symptoms of ASD, up to 40% of school-age children developed speech by 9 years of age, with only 15% remaining nonverbal. For those who do develop verbal abilities, these may be impaired through the presence of echolalia (i.e., repetition of words or phrases spoken by another person), pronoun reversal (e.g., confusing "me" for "I"), and difficulties with the use of pragmatic language (e.g., greeting others, requesting as needed, speaking differently in different social situations, turn taking in conversations, acknowledging personal space, etc.; Cantwell, Baker, Rutter, & Mawhood, 1989; Kanner, 1943, Tager-Flusberg, 1999; 2001). Conversations with an individual with ASD can be characterized by the use of irrelevant information (e.g., the make and year of a car when discussing a specific event, the color of dishes when discussing a social situation), pedantic speaking on preferred topics, and ignorance of attempts to shift conversation to new topics (Tager-Flusberg, 1999; 2001; Eales, 1993). The vocabulary they use may seem odd or age inappropriate (Ghaziuddin & Gerstein, 1996), or they may engage in verbal rituals such as repeating scripts from favourite TV shows or movies (Rydell & Mirenda, 1994). This population also has difficulty processing contextually and socially appropriate comments and non-literal language such as metaphors, sarcasm, and irony (Eales, 1993; Loukusa et al., 2007; Happe, 1995; McKay & Shaw, 2004; Martin and McDonald, 2004). Rapin (1996) described individuals with ASD as having less trouble learning the language structures necessary to produce language than understanding others' use of language; they are often concrete and literal in their language comprehension.

Restrictive and Repetitive Behaviours and Interests. The third area of impairment characteristic of individuals with ASD is the presence of restrictive and repetitive behaviours and interests. Current DSM-IV-TR criteria require these behaviours to manifest themselves in one of the following for consideration of a diagnosis: (1) preoccupation with a stereotyped and restricted pattern of interest that is abnormally focused or intense; (2) inflexible adherence to specific and non-functional routines or rituals; (3) stereotyped and repetitive motor behaviours; and/or (4) preoccupation with parts of objects (APA, 2000).

It has been suggested, through a review of the literature by Turner (1999), that behavioural impairment in ASD can be viewed as comprising both lower-level behaviours consisting of motor movements, and higher-level behaviours and cognitions that are more complex and involve the need for routine and circumscribed interests. Lower-level behaviours observed in this population can include body rocking, walking on tip toes, whole body spinning or jumping, and hand flapping or waving (Volkmar, Cohen, & Paul, 1986). In addition, and most unfortunately, self-injurious behaviours such as head banging or arm biting are common in individuals with ASD, although this behaviour is most likely attributable to lower cognitive functioning in some individuals and is not necessarily unique to ASD (Freeman et al., 1981; Turner, 1999). Self-injurious behaviours in ASD are observed in considerably greater rates than the general population (Dominich, Davis, Lainhart, Tager-Flusberg, & Folstein, 1997), and have specifically been observed in one sample of 222 seven-year-old children with ASD at a rate of

50% (Baghdadli, Pascal, Grisi, & Aussilioux, 2003). Regardless of level of cognitive ability, it appears that when compared to ability and age-matched comparisons, individuals with ASD are unique in the greater frequency, severity, and duration of their stereotyped and repetitive movements (Freeman et al., 1981; Bodfish, 2011; Szatmari, Bartolucci, & Bremner, 1989).

More common in individuals with higher functioning ASD, higher-level behaviours include an insistence on sameness in areas such as self-care routines, daily schedules, eating routines, and driving or traveling routines (Turner, 1999). The adherence to ritual and routines is not unique to ASD, but is more prevalent in this population and is marked by more severe reactions and distress than in age- and ability-matched comparisons (Bartek & Rutter, 1976, Lord & Pickles, 1996). Individuals with ASD often have intense and circumscribed interests in which they may be preoccupied with unusual objects or physical parts of the environment (e.g., clock faces, fan blades, toilet seats) that serve little or no functional purpose. They may become completely absorbed in hobbies such as trains or video games, becoming abnormally invested through the memorization of facts and complete immersion in the subject (Bodfish, 2011; Campbell et al., 1990). In addition, some individuals may have strong adverse reactions to, or participate in the seeking of, specific sensory sensations such as crying and placing hands over ears when they hear a quiet vacuum, purposely rubbing their face on carpet floors repeatedly (Steyn & LeCouteur, 2003).

Diagnostic Classification. The current paper will focus on AD, AS, and PDD-NOS. A diagnosis of AD may be given when the child or individual meets at least six criteria from among the three areas of impairment with at least two symptoms in the social interaction domain, and one each from the language and communication, and repetitive behaviour and interests domains. At least one area of impairment must be present before the age of 3, with the possibility of Childhood Disintegrative Disorder or Rett's Disorder ruled out (APA, 2000). The prevalence of AD is estimated to be approximately 20.6/10,000, or 1 in 486 (Fombonne, 2009).

Named after Hans Asperger (1991), AS similarly involves the identification of impairment in social interaction and restrictive and stereotyped behaviours. However, individuals with AS do not present with significant delay in language development in the first 3 years of life, or difficulties with self-help and adaptive skills (APA, 2000). In a review of the literature, Fombonne (2009) estimates the prevalence of AS to be 6/10,000, or 1 in 1,667. While a diagnosis of AD must be first ruled out, this rule is not always followed. This lack of diagnostic clarity may lead to higher prevalence of AS diagnoses, when a better fit would be a diagnosis of high functioning autism (HFA), a term often given to individuals who meet the criteria for AD and who do not demonstrate intellectual disability (Szatmari, 2000; Gotham, Bishop, & Lord, 2011).

A diagnosis of PDD-NOS is traditionally reserved for individuals who do not meet full criteria for AD, or fall short of meeting all needed criteria in one of the three domains of impairment. These individuals may have a later onset of symptoms, have sub-threshold symptomology, or strong symptoms in two of the domains but none in the third (APA, 2000). Estimates of PDD-NOS are higher than for AD or AS, at approximately 37.1/10,000, or 1 in 270 individuals (Fombonne, 2009). It is possible that PDD-NOS may be viewed by some as a "catch all" category for individuals who have an ASD that is difficult to specify, or are being diagnosed by clinicians who are uncomfortable in specifying an AD diagnosis (Walker et al., 2004; Lord et al., 2006).

It can be a useful distinction to recognize individuals with ASD by their categorical placement (e.g., AD, AS, PDD-NOS) as well as through the level of severity. This severity can be and is traditionally based on cognitive measures of intelligence, as well as taking into account verbal abilities (Szatmari, 2000). Formal measures of intelligence generate Intelligence Quotient (IQ) scores, composed of both nonverbal and verbal intelligence. Though it was believed that most individuals with ASD had intellectual disability, findings suggest that between 29-60% of children with ASD have at least average levels of nonverbal or full-scale intelligence (Charman et al., 2011; Fombonne, 2005; Tidmarsh and Volkmar, 2003). Gotham, Bishop, and Lord (2011) point out that the social, academic, and adaptive expectations for individuals with ASD who have average intellectual abilities are different than those with lower abilities. In this sense, their social and language deficits will present differently and be utilized in the unique environments they find themselves in.

High Functioning Autism Spectrum Disorders. In general, the high-functioning autism spectrum disorder (HFASD) distinction is made for individuals with ASD with intellectual abilities falling minimally in the average range. As standard measures of intelligence typically have mean scores of 100 with standard deviations of 15, this distinction would require a minimum intelligence score (IQ) of 85.

Although strictly defined criteria for determining high vs. low functioning distinctions have not been unanimously agreed upon, researchers have demonstrated the utility and validity of the differentiation of these two categories (Szatmari, 2000). Studies have established that lower functioning individuals demonstrate more autism symptoms than their higher functioning counterparts (Freeman, Ritvo, Schroth, Ronick, Guthrie, & Wake, 1981; Bartek & Rutter, 1976), and individuals from each category differ in terms of brain-based etiology. Specifically, the functionality and brain volumes found to be abnormal in ASD appear to be different in individuals in these two categories (Goldberg, Szatmari, & Nahmias, 1999). These lower functioning indiviuduals also differ on their natural history and prognosis (Lotter, 1974), as well as their response to interventions. Rapin (1996) conducted a large study with preschool children with ASD and statistically demonstrated that the existence of higher- and lower-functioning subgroups clearly explained the children's patterns of behaviour and symptoms. This low versus high functioning differentiation, which has been used in the research literature for some time, will most likely be reflected in similar form in the upcoming DSM-5 (APA, 2010).

Social Problems. For children with HFASD, deficits in social skills can be a source of many significant problems with peers, family members, and adults (Krasny, Williams, Provencal, & Ozonoff, 2003). Because most children with HFASD are able to participate in regular education classrooms and social activities, they are consistently exposed to social demands and pressures that their lower functioning counterparts are not exposed to (Rao, Beidel, & Murray, 2008). By the time they reach elementary school, many children with HFASD present with significant relational problems, including in the making and maintaining of friendships. For a large number of HFASD individuals, this difficulty can lead to rejection and ridicule by peer groups in early adolescence (Church, Alisanski, & Amanullah, 2000). Despite the frequent desire for relationship, difficulties with developing their social competences can increase the risk of co-morbid mental health issues such as anxiety, depression, and even suicidal ideation (Green, Gilchrist, Burton, & Cox., 2000; Kim, Szatmari, Bryson, Streiner, & Wilson, 2000; Tonge, Brereton, Gray, & Einfeld, 1999; Wing, 1981).

Theoretical understanding of the social difficulties seen in HFASD has been the focus of much research. One explanation surrounds Theory of Mind (ToM), which is defined as an individual's ability to understand another person's mental states; their knowledge, wants, beliefs, and emotions (Premack & Woodruff, 1978). It has been proposed that a deficit in ToM ability underlies many of the social problems experienced by individuals with ASD (Baron-Cohen, 1995); however, this connection has not been firmly supported (Klin, 2000). A second explanation by Frith (1989) proposed that individuals with ASD have "weak central coherence" (WCC), defined as an inability to integrate diverse information to form a higher-level meaning. This has been thought to underlie their potential difficulties integrating information such as complex facial features, expressions, and language during social situations (Lopez, Donnely, Hadwin, & Leekam, 2004). However, recent research has led to the understanding that WCC may occur alongside deficits in social skills, but not directly cause them (see review by Happe & Frith, 2006).

Due to the differences in cognitive abilities, language skills, and behavioural outcomes among individuals in this broad spectrum, these explanations do not address the unique experience of individuals with HFASD, nor do they provide a comprehensive account of their social deficits. Taking this heterogeneity into account, researchers have begun to evaluate the role of various cognitive factors involved in the unique social communication deficits evident in individuals with HFASD. One such focus of empirical investigation is executive functions.

Executive Functions

Baddeley and Hitch (1974) were the first to describe executive functions (EF) as a "central executive", further defined by Lezak (1983) to include a central process that controls how human behaviour is expressed. Specifically, EF was thought to be necessary for the control of appropriate, socially responsible behaviour in a self-serving framework. While concrete definitions have varied over time (see Jurado & Rosselli, 2007), most current researchers agree that EF are higher order neuropsychological processes required to coordinate and control performance on complex problem solving tasks and goal-directed behaviour (Sokol, Muller, Carpendale, Young, & Iarocci, 2010). The three core skills encompassed by EF include working memory, inhibition, and cognitive flexibility (Pennington & Ozonoff, 1996; Bennetto & Pennington, 2003; Best & Miller, 2010). Working memory (WM) involves the ability to hold and manipulate information for short periods of time in one's mental space, without external cues or aids (Alloway, Gathercole, & Pickering, 2006). For example, WM would be utilized when performing mental calculations or remembering a phone number. Inhibition (IN) can be thought of as both simple (e.g., holding back the prepotent response to scratch an itch or cross the street when the "walk" sign turns on when one last car speeds through the intersection) or complex (e.g., inhibiting the desire to make a merchandise purchase to instead review one's finances and consult with a significant other before doing so). In essence, IN is self-control (Best & Miller, 2010). Cognitive flexibility (CF), also termed "shifting", is the ability to move flexibly between different mental states, tasks, or sets of rules (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). For example, different sets of social rules apply to one's behavior in a shopping mall as opposed to a church service, and switching appropriately between these sets is optimal to participating in each situation. CF is also used during conversation, or any situation in which topics or ideas may switch rapidly and one must be flexible to follow along. Other proposed EF abilities include organization, planning, fluency, and emotional regulation.

Conceptualizations of EF have commonly associated their function with pre-frontal and frontal cortex activity in the brain (Luria, 1973; Stuss et al., 2002; Olson & Luciana, 2008), primarily due to the observation of executive dysfunction in individuals with prefrontal brain damage (Stuss & Benson, 1986). However, the specificity of this conclusion has been challenged. In a review of the frontal lobe and EF literature by Alvarez and Emory (2006), they propose that frontal lobe function and EF do appear related, but that non-frontal lobe functioning is also associated with EF. This observation is likely due to a combination effect in which various EF components work together across brain regions to solve complex problems and execute behaviour. Regardless of specificity of location, there has nonetheless been continued evidence for a strong primary connection between the frontal lobes and EF ability (Stuss, 2011; Roca et al., 2010).

Typical Development of Executive Functions. Neuroimaging studies have shown that the frontal lobes begin activation around 6 months of age, despite previous thought that they were relatively inactive during childhood (Chugani, Phelps, & Mazziota, 1987; Jurado & Rosselli, 2007). Through myelination, synaptic pruning, and synaptic growth, the frontal lobes and prefrontal cortex (PFC) continue to mature into late adolescence and even early adulthood, unlike other brain regions that are relatively stable earlier in childhood (Casey, Amso, & Davidson, 2006; O'Hare & Sowell, 2008; Fuster, 1993). It follows then that the trajectory of development of EF coincides with the development of the PFC. In fact, researchers theorize that during typical development, many of the stages associated with childhood growth (e.g., an infant's stimulus-based reactions, preschoolers' ability to think of past and plan for future and begin making complex decisions) are related to the maturity of EF (Denckla, 1996). In general, EF ability appears to develop sequentially as the PFC continues to mature, with growth periods identified between birth to 2 years, 7 to 9 years, and 16 to 19 years, with variation for every child expected (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Anderson, Northram, Hendy, & Wrenall, 2001; Anderson, 2002). Importantly, different EF abilities appear to have different developmental patterns, with some acting as the basis for others, and certain components not reaching full levels of competency until late adolescence (Best & Miller, 2010;

Passler, Issac, & Hynd, 1985). The following description outlines the typical developmental course of these three core EF abilities.

Inhibition. Infants can display some simple IN ability, such as delaying eating a treat, with rapid gains observed through early childhood (Garon, Bryson, & Smith, 2008). By 1 year of age, children can inhibit an over learned response, with the largest gains in inhibitory ability seen between 6-9 years (Passler et al., 1985; Brocki & Bohlin, 2004; Klenberg, Korkman, & Lahti-Nuutila, 2001). Most research seems to indicate adult-level mastery of IN between 10-12 years (Welsch, Pennington, & Groissier, 1991; Passler et al., 1985). However, this inhibitory ability continues to be refined through adolescence and adulthood as its application relies on relevant cognitive skills and life experience (Best & Miller, 2010).

Working Memory. Working memory (WM) involves more complex use of EF through the maintenance and manipulation of information, and thus its development relies on more PFC activity (D'Esposito & Postle, 1999). Simple WM, such as keeping information in the phonological loop is present during preschool years. The phonological loop refers to the mental repetition of information using ones internal voice, such as when remembering a phone number for a short period of time. More complex WM ability, such as being able to recite given digits in reverse order, appears to begin to develop around 6 years of age (Garon et al., 2008; Gathercole, Pickering, Ambridge, & Wearing, 2004). Luciana, Conklin, Hooper, and Yarger (2005) observed that both simple and complex WM abilities improved linearly between the ages of 4 to 14/15. In general, WM ability improves into adolescence and adulthood, especially as task demands increase.

Cognitive Flexibility. Miyake et al. (2000) point out that IN is essential to shifting between mental sets, as a new set must be concentrated on and a previous one inhibited.

Additionally, WM abilities are required to some degree to switch between sets of mental rules (Best & Miller, 2010). As with other EF abilities, CF improves with age, starting with the ability to shift between two simple response sets around 3-4 years (Anderson, 2002; Hughes, 1998). As children reach 7-9 years, they begin to show ability to maintain multiple mental sets to shift between, with the ability potentially levelling off around 15 years (Huizinga, Dolan, & Van der Molen, 2006), and continuing to mature into adolescence (Anderson, 2002; Zelazo & Frye, 1998; Davidson et al., 2006).

In summary, EF abilities develop through infancy and childhood, with maturation continuing into adolescence and sometimes adulthood. IN is the first EF observed in children's behaviour, with CF significantly improving later in childhood and WM continuing to strengthen into adolescence. Best and Miler (2010) suggest that these similar, yet differing trajectories of development are in support of the diversity of EF components.

Validity of Executive Function Components. It is important to note that despite some inconsistent results, strong evidence exists for the validity of EF being composed of separate control processes (e.g., WM, CF, IN, etc.) as opposed to a single EF ability. Support includes studies that have shown low intercorrelations between different executive tasks, around $r = 0.40$ or less (Salthouse, Atkinson, & Berish, 2003; Miyake et al., 2000; Lehto, 1996). The low correlations do suggest some underlying commonality among EF, or more likely the possibility of a mechanism that ties their function together. Inhibitory ability has been postulated as being foundational to both the development and function of EF. This component of EF underlies the regulation of emotion, cognition, and behaviour (Miyake et al., 2000; Nigg, 2000). Barkley (1997) strongly defines accurate performance among all areas of EF as relying upon a basis on behavioural IN ability. Pennington, Bennetto, McAleer, and Roberts (1996) put forward that IN, in combination with WM, is a basic mechanism influencing EF performance as a whole. Thus, due to the importance of inhibitory development and ability and its underlying importance to EF development, it remains an important focus for study in TD and ASD populations.

Executive Dysfunction. There are multiple purposes of EF in the daily life of children, particularly as they find themselves entering school and participating in academics and increasingly complex and demanding social situations. The processes encompassed by EF have been linked to academic achievement and learning abilities. Mathematics is one domain in which both WM and IN have been shown to be required for optimal learning and performance, such that deficits in these EF are related to poorer mathematics performance (Blair & Razza, 2007; Bull & Scerif, 2001). In academics in general, St. Clair-Thompson and Gathercole (2006) found that IN dysfunction was significantly related to lower achievement in English, Mathematics, and Science for children ages 11-12. It is clear that EF play a large part in academics and learning, where children and adolescents must remember and follow instructions, organize their activities, and pay attention to relevant information while ignoring irrelevant information (e.g., reading a sentence requires ignoring other lines and words surrounding the text, math requires WM to complete mental arithmetic).

EF also appears to be related to both emotional and social regulation, required as children participate in school and their ever-expanding social experience. Research by Rothbart, Ahadi, Hershey, and Fisher (2001) using the Children's Behaviour Questionnaire found that EF abilities are employed during self-regulation, or the effortful control of oneself in daily activities. Further evidence has shown that a deficit in effortful control in children predicts EF ability later in adolescence. Specifically, control problems such as inattention and hyperactivity were predictive of WM and IN ability in adolescence, leading to poorer self-regulation (Friedman et al., 2007).

Not surprisingly, IN deficits in childhood have been shown to contribute to risk taking behaviours in adolescence (Steinberg, 2007). Finally, EF deficits have been linked to age-related development of an increase in prejudice, inappropriate social behaviour, depression, and gambling behaviours (von Hippel, 2007).

Executive Functions and Social Development

A significant purpose of EF is to assist with self-regulation during social and emotional interactions, and research has indicated that EF is particularly important in a variety of interpersonal and social tasks (McDonald, 2007). This relationship has been partially supported through research documenting the link between EF and ToM. The ability to understand the mental states of others (their emotions, ideas, perspectives), as encompassed in ToM, is believed to be central to developing social and emotional self-regulation (Bachevalier & Loveland, 2006). Evidence of this linkage can be observed in individuals with lesions to frontal lobe regions, mirroring areas involved in EF, who have difficulty with ToM judgements (Channon & Crawford, 2000). In TD children as well as children with ASD, deficits in EF from preschool age to adolescence have been linked to poorer performance on measures of ToM, an ability frequently required in their social interactions (Pellicano, 2007; Carlson, Mandell, & Williams, 2004; Dumontheil, Apperly, & Blakemore, 2010). This relationship has also been found in longitudinal studies showing that early EF abilities predict later ToM ability, allowing for the argument to be made that EF thus allows children to actively use their understanding of others' minds in a social context (see Hughes, 2011). Researchers have shown that preceding ToM ability, children develop a false belief understanding, such that they develop the awareness that others may hold and act on beliefs that are false (e.g., someone taking safety precautions for an attack by bigfoot), or different than theirs (e.g., religious, cultural, etc.). The EF most implicated in the development of false belief understanding is IN, and many studies have shown that this false belief understanding in children is preceded and then mediated by the development of normal inhibitory control (Hughes, 1998; Flynn, O'Malley, & Wood, 2004; Carlson & Moses, 2001). Children with better-developed false-belief understanding have been shown to have higher levels of behavioural regulation, as well as ToM ability (Hughes, Dunn, & White, 1998; Blair & Razza, 2007).

In addition to involvement in ToM abilities, deficits in EF processes have been directly related to problems in normal participation in social and emotional interactions. Examples may be seen in problems with impulsivity and delay of gratification (IN), lack of concentration or distractibility (CF and WM), and understanding the consequences of one's actions (planning and organization) (Hughes, 2002; Morgan & Lilienfeld, 2000; Pennington, 2002). These behaviours are necessary for a child, or an individual of any age for that matter, to self-regulate when participating in reciprocal conversation, play behaviours, collaboration, and almost any other social interaction. In TD preschool children, Cole, Usher, and Cargo (1993) found that deficiencies in EF performance were significantly predictive of an inability to control disruptive behaviour, or for children to regulate themselves in the presence of others. Lower measured EF ability in preschool children has also been shown to be related to poorer regulation of emotions (i.e., negative emotional outburst and dysfunctional coping strategies) and less ability to control impulsive behaviours (Jahromi & Stifter, 2008).

In summary, the development of EF partially proceeds, and is involved in the development of social and emotional competence and regulation. Inhibitory ability has been shown to be related to behavioural and emotional regulation as well as ToM abilities, all of which are required and important for social interactions. Given that children with ASD diagnostically present with a myriad of social interaction deficits, and frontal lobe deficits are widely observed in this population, there is the potential for a unique EF profile as part of this presentation.

Executive Functions in HFASD

Investigation of the characteristic social and non-social impairments experienced by individuals with ASD point to potential deficits in EF (Hill, 2004). These individuals are often inflexible in their thinking and have difficulties adapting to change in their environment or routine (Haq and Le Couter, 2006; Turner, 1999). They also perseverate, focusing on a narrow idea or activity with little practical application, they do not appear future oriented, and do not always plan for the long-term consequences of current actions. Moreover, they present as impulsive, possibly lacking the ability to inhibit responses (Ozonoff, Pennington, & Rogers, 1991). In addition to these behavioural observations, research using brain imaging has linked ASD with deficits in frontal lobe functioning (Schmitz et al., 2006; Girgis et al., 2007). As EF have been shown to be localized primarily in the same area of the cortex, researchers have focused on the unique nature of EF in ASD, and have documented unique deficits in the areas of WM, CF, and IN, albeit with some conflicting results.

WM impairment has been demonstrated throughout childhood, adolescence, and adulthood in individuals with ASD, although they make similar developmental gains when compared to typical development during the period of childhood to adolescence (Luna, Doll, Hegedus, Minshew, & Sweeney, 2007; Goldberg et al., 2002).

CF has been extensively researched in ASD, and is thought to be exemplified by stereotyped and repetitive behaviour, as well as rigidity of thinking and poor regulation of motor acts (Hill, 2004). This deficit has been widely documented on the Wisconsin Card Sorting Task

(WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993). In the WCST, individuals are required to sort cards based on one of three possible categories (number, color, or shape of items) based on an unspoken rule, and then switch to a new sorting rule. These rules are determined simply through an examiner or computer program informing the participant whether they have made a correct or incorrect sort. Individuals with ASD have been shown to consistently demonstrate deficits in CF on this task as indicated by significantly greater perseverative errors (continuing to provide the same incorrect response once the sorting rule has changed) as compared to both TD and some clinical groups such as children with language impairments and ADHD (Ozonoff & Jensen, 1999; Guerts, Verte, Oosterlaan, Roeyers, & Sargeant, 2004). In a review of the literature surrounding EF in ASD, Hill (2004) highlights that perseverative errors on measures of CF may currently be seen as the most well documented EF deficit in ASD.

Finally, mixed evidence for an impairment in IN in the HFASD population exists in the research literature. Inhibitory ability can be measured through a variety of methods, reflecting a multitude of IN functions. Simple response IN may be observed in go/no-go tasks. In these tasks, children are presented with a “go” cue in which they are told to respond as quickly as possible (e.g., touch a button at the sound of a tone). This activity creates a prepotent response to respond by pressing the button. Then, children are presented with a “no-go” cue (e.g., an obviously different tone), to which they are required not to respond, requiring them to inhibit their prepotent response to press the button (Shulz et al., 2007). Many more “go” cues are presented to ensure the buildup of this prepotent response. Complex response IN can be measured with tasks that ask a child to inhibit a prepotent verbal response. The day-night task has children say “day” when they see a picture of a moon, and “night” when they see a picture of a sun (Gerstadt, Hong, & Diamond, 1994). Another classic task used for the measurement of response IN is the Stroop task, where children are required to name the color of printed words in which the meaning of the word in incongruent to the color of the ink it is printed in (e.g., the word "green" is printed in red ink; Stroop, 1935). Both of these tasks require natural responses (e.g., associating the sun with day, automatically reading the letters of a word) to be inhibited, and an alternate response produced. Nigg (2000) provides some clarification, reminding us that tasks measure different types of IN, including interference control where one must inhibit a response to an interfering stimulus, IN of a motor response, and cognitive IN observed in tasks explained above. While Stroop-based, go/no-go, and other tasks used to measure inhibitory ability may be adapted in some way for different studies (e.g., stimulus changes, language used, timing delivered), they continue to be referred to based on the task type they are modelled after.

Although some studies have indicated no significant differences between ASD and TD individuals on traditional Stroop-based (Hill & Bird, 2006; Russell, Jarrold, & Hood, 1999; Ozonoff & Jensen, 1999) as well as on some go/no-go (Ozonoff & Strayer, 1997) tasks, behavioural difficulties with EF in general have been reported in the ASD population (Biro & Russell, 2001; Russell, Hala, & Hill, 2004). For example, children with ASD struggle with delay of gratification tasks and some evidence indicates an IN deficit on some go/no-go tasks where they are observed to inhibit a prepotent response much more slowly, and have difficulty with inhibiting an ongoing response (Guerts, Verte, Oosterlaan, Roeyers, & Sargeant, 2004; Verte, Guerts, Roeyers, Oosterlaan, & Sargeant, 2006). Thus, researchers have provided evidence for a range of unique EF difficulties in ASD, including IN, with other studies documenting intact abilities (Boucher, 1988; Hughes, Russell, & Robbins, 1994; Ozonoff & Jensen, 1999; Russell & Hill, 2001). Conclusions regarding the cause of these inconsistencies may be the result of methodological differences, and Hill (2004) proposes this confound primarily results from the inclusion of participants with cognitive impairments in studies, as well as observed differences in task selection and participant matching. While the majority of these studies used participants with IQ $\geq$ 70, there is no consistent inclusion or matching criteria. Hill (2004) concludes that future studies carefully select ASD individuals with IQ's in the normal range with matched to TD comparisons to address these issues. Despite these inconsistencies, EF impairments unique to ASD do appear to exist. However, inconsistent evidence seems greatest for the nature of inhibitory deficits specifically in this population, which for the purposes of this study will be discussed in further detail below.

Inhibition in HFASD

As stated earlier in this paper, IN as measured by the Stroop task appears to be intact in individuals with HFASD across a multitude of studies, even after statistically controlling for the level of reading abilities of participants (Eskes et al., 1990; Ozonoff & Jensen, 1999). The lack of difference observed when using Stroop-based tasks has been suggested to possibly be the result of their traditional construction using a single page of multiple stimuli instead of single presentation (Christ, Holt, White, & Green, 2007).

A similar task known as the flanker task requires participants to look at specific visual information while ignoring competing information (interference IN: Eriksen & Eriksen, 1974). For example, participants are required to press a left button when they see a circle, and a right button when they see a square, presented in the center of their visual field. During this task, a random distracting stimulus that is either neutral or competing is presented, and participants must inhibit their attendance to that material and only respond to the target stimuli. This form of IN ability measurement has rarely been used in ASD research, with mixed results when used. Christ et al. (2007) found that children with HFASD responded significantly slower than comparison children on the task, but did not differ in error rates. This is in contrast to a previous study by Iaroccia and Burack (2004) in which they concluded that children with ASD demonstrate no difference in ability on this task.

Evidence from go/no-go tasks have been mixed, but appear to provide some support for a performance difference. An early study by Ozonoff, Strayer, McMahon, and Fillioux (1994) showed a deficit in children with HFASD, specifically in a slower time to inhibit responses than TD children. These results have been replicated by Raymaekers, van der Meere, and Roeyers (2004) who increased the ratio of go to no-go presentations from Ozonoff et al. (1994) study, finding that children with HFASD performed more poorly when presentation was fast (1 or 2 seconds in between), but not when it was slower (approx. 6 seconds). Johnson et al. (2007) also demonstrated that children with HFASD committed more response IN errors through "commissions", or the addition of responses when none was required. However, there have also been results indicating no significant differences between individuals with HFASD and those who are TD on the go/no-go type task (Ozonoff & Strayer, 1997; Christ et al., 2007).

One area in which a consistent IN deficit appears is in the IN of a prepotent or automatic/reflexive response (Hill, 2004). This deficit has been demonstrated through two task types: the Window's Task, and the antisaccade task. In the Windows Task, children are presented with two boxes they can see into, one with chocolate (or some treat) and one without. Without being told so, they only receive the chocolate by pointing to the empty box, as demonstrated when the researcher takes the chocolate away when they point to the box with chocolate inside. Multiple studies have indicated that children with HFASD and lower functioning ASD demonstrate significant difficulty inhibiting their automatic response to point to the box with chocolate inside, despite repetitive negative feedback from the experimenter

(Russell, Mauthner, Sharpe, & Tidswell, 1991; Hughes & Russell, 1993; Russell et al., 2003) This deficit has also been demonstrated in a modified version of the task without a social component involving the experimenter (Hughes & Russell, 1993). The antisaccade task also looks at the IN of an automatic response without a social or verbal component. Participants are required to suppress an automatic eye movement to track a moving peripheral target, and instead create a planned eye movement in the other direction. This task is less supported by cognitive strategizing, and in general has low task demands but requires a high amount of IN because a reflexive response (as opposed to a learned behaviour) must be inhibited. Errors are observed when the individual begins to look at the stimulus and then quickly corrects to the correct strategy, which is interpreted to indicate that the instructions were understood and a true failure in EF (IN) was demonstrated (O'Hearn, Asato, Ordaz, & Luna, 2008). A deficit in basic IN through the antisaccade task has been reliably demonstrated in HFASD (Minshew, Luna, & Sweeney, 1999; Goldberg et al., 2002; Luna, Doll, Hegedus, Minshew, & Sweeney, 2007). These antisaccade results are important for studying basic IN in individuals with HFASD, who may otherwise have the ability compensate in tasks such as those Stroop based with their greater verbal and cognitive abilities.

In addition to experimental tasks, several studies have examined brain activation during IN tasks using functional magnetic resonance imaging (fMRI) techniques in individuals with HFASD. In one study using go/no-go and Stroop-based tasks, Schmitz et al. (2006) observed no performance differences between adults with HFASD and a TD comparison group. However, they observed greater activation in associated PFC brain areas in the HFASD group, which they posit indicates greater effort needed for them to inhibit responses and possible inefficient brain function in this area. In a similar study with versions of the go/no-go task, an HFASD group once again demonstrated no performance difference from a comparison group. However, fMRI data showed decreased activation in associated frontostriatial brain areas when compared to TD individuals, which the authors propose indicate poor functional connectivity in brain regions associated with IN (Kana, Keller, Minshew, & Just, 2007). Finally, data by O'Hearn et al. (2008) using an antisaccade task indicate individuals with HFASD performed more poorly on the task and also showed decreased brain activity in frontoparietal regions as compared to the comparison group. They also observed increased usage of these frontoparietal regions as individuals with HFASD developed through adolescence and adulthood, although it was delayed through the trajectory when compared to TD individuals. It is possible that the differences in level of activation of PFC brain areas between these studies were the result of the HFASD groups consisting of different diagnoses (e.g., differing numbers of individuals with AS). Regardless, it can be seen that brain activity is significantly different in individuals with HFASD during IN tasks and that increased effort is required for normal response rates (O'Hearn et al., 2008).

A unique study by Lemon, Gargaro, Enticott, and Rinehart (2011) sought to search for gender differences in inhibitory ability in the HFASD population. Their study examined 10 males and 13 females with HFASD in comparison to TD comparisons on measures of IN. Participants were given a stop task in which they pressed a button in response to random presentations of green and red LED lights. The green light was presented approximately 1/3 of the time, and when this stimulus was presented, participants were required to stop their normal pressing of the button, requiring the IN of learned response. Results indicated that while all groups had similar ability to inhibit responses as necessary, females with HFASD were significantly slower in doing so over their male counterparts. Lemon et al. (2011) suggest these findings are significant because most HFASD participants in EF research are male, which may provide a partial explanation for inconsistent results for response IN in this population (Christ, Holt, White, & Green, 2007). As an example, research by Ozonoff and Strayer (1997) regarding IN response time concluded there was no impairment in HFASD, however, all participants in the study were male.

It is possible that some of the contradictory results of inhibitory performance in HFASD may be the result of mixed participant groups consisting of individuals with AS, PDD-NOS, and HFA with average cognitive profiles. However, researchers investigating the EF profiles of these subtypes of HFASD have suggested that they are relatively equivalent (Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995; Miller & Ozonoff, 2000), with individuals diagnosed with PDD-NOS potentially performing slightly better on EF measures then those with HFA or AS. Recent work by Verte, Guerts, Roeyers, Oosterlaan, and Sergeant (2006) compared the EF profiles of 50 children with HFA, 37 children with AS, and 25 children with PDD-NOS to a group of 47 comparison children and also concluded that the overall EF profiles of the clinical samples were more similar than different. On IN response time, the three HFASD groups performed worse than comparisons but could not be differentiated from each other. Results such as these suggest that grouping these three clinical categories into an HFASD group with similar intellectual functioning can be useful and valid for EF research in comparison to TD individuals.

The Role of Inhibition in Social Skills in HFASD

Despite the fact that EF have been shown to be linked to social interactions and EF have been shown to be impaired in HFASD, there has been little research done attempting to link specific EF with particular impairments in HFASD, including their lower social interaction skills (Happe, Booth, Charlton, & Hughes, 2006). This connection has been researched extensively in other disorders, and particularly in ADHD. It is well known that a deficit in IN for this population underlies many of their social and behavioural problems such as blurting out answers in class despite knowing the rules, and acting impulsively with little thought to consequences (Barkley, 1997). Individuals with HFASD display similar behaviour, frequently acting impulsively, seemingly unable to inhibit or delay responses as needed for a goal (Ozonoff, Pennington, and Rogers, 1991). As previously mentioned, EF has been linked to ToM, thought to be a necessary part of social interaction ability. However, there has been little support for a direct link between IN ability and the social interaction deficits seen in individuals with HFASD.

In general, the research focusing on the linking EF deficits with the autistic triad of impairments has been met with little success. In a study by Bishop and Norbury (2005), no relationship between IN and any of these three impairments was found, although sample size was small (14 children with HFASD). Other research found significant correlations between IN (in combination with WM) and social abilities; however, these relationships become insignificant when the level of verbal ability of HFASD children was partialled out (Joseph & Tager-Flusberg, 2004). These results were replicated by Kentworthy, Black, Harrison, della Rosa, and Wallace (2009) who failed to find relationships between IN deficits and HFASD symptoms severity using both task-based neuropsychological measures and behaviour rating measures of IN. The results of these studies may reflect the measures chosen. Two of the studies (Bishop & Norbury, 2005; Kent worthy et al., 2009) used IN tasks from the Test of Everyday Attention for Children (TEA-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1999), while another (Joseph & Tager-Flusberg, 2004) employed tasks from the NEPSY (Korkman, Kirk, & Kemp, 1998). Directly administered neuropsychological measures have been criticised for potentially lacking ecological validity (Hill & Bird, 2006; Bernstein & Waber, 1990), and as social interaction ability is completely involved in "real-life" realistic situations, relationships found through these measures may be a problem. Task-based measures have children completing tasks in a lab or clinic setting under standardized timing and instructions, with performance compared to norm groups gathered by the measures. In contrast, behaviour-based measures target behaviours that have been observed in the child over time, by a teacher or parent, in multiple settings such as school, home, and play situations. In response to this problem of potential ecological validity, Kentworthy et al. (2009) used the Behaviour Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kentworthy, 2000), a rating scale designed to capture real life behaviours associated with EF impairment. These three studies also focused on social abilities as indicated by measures specifically designed to capture severity of ASD symptomology. The primary measure used was the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999), from which the studies gathered a measure of the three characteristic HFASD impairments including in social interaction. The ADOS is a structured interview conducted with individuals suspected of having ASD in which conversation and play are used to determine symptom severity. Thus, all three studies focused on symptoms as measured by behaviour observed in a clinic or experimental setting. However, social interaction symptoms may be better measured by the interactions and behaviours they influence in real life, day to day interactions that children find themselves in. These observations lead to a more useable comparison of the social skills of children with HFASD in comparison to TD children in place of simply ASD symptom severity. Thus, the three primary studies focusing on EF, and IN particularly, in relation to social interaction in HFASD have failed to employ measures that observe both IN ability and social interaction skills in a day-to-day context.

Summary

Although researchers have investigated the development and importance of IN to social interaction in TD children, this aspect of functioning has not been sufficiently investigated in children with HFASD, a population described primarily by a qualitative deficit in social communication and interaction (American Psychiatric Association, 2000). Moreover, researchers have yet to concretely link IN dysfunction with social interaction skill deficits in this population. Given the foundational aspect of IN in the development of other EF and the demonstrated relationship between IN and social interaction in TD children, it is of great importance to better understand the nature of IN functioning in children with HFASD. By doing so, the opportunity exists to develop novel ways of understanding this population, and new arenas in which to potentially direct intervention for gains in social interaction skills.

Chapter 2: The Present Study

Beginning in childhood, children with HFASD begin along a trajectory of social difficulties including potential bullying and ridicule, isolation, and the development of comorbid mood disorders that can negatively impact their course of development. Due to the significant impact of social skill deficits for children with HFASD, this project aims to focus on these social skills and potential explanations for their deficits. For many reasons, the study of EF and how they may contribute to behavioural symptoms and deficits in developmental disorders is of great utility (Frith, 2001; Pennington, 2002). Understanding the unique cognitive presentations, or phenotypes, in HFASD can provide important information for genetic etiologies as well as direct intervention by understanding the cause or antecedents of some behaviour problems (Gottesman & Gould, 2003; Fisher & Happe, 2005; Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006). The execution of these factors in a well-designed study such as the present one can therefore provide valuable information in the further understanding of the neuropsychological and behavioural profile of children with HFASD.

The present study is designed to answer the following research questions:

1. Do children with HFASD demonstrate poorer social skills than their TD peers?
2. Do children with HFASD demonstrate a deficit in IN when compared to TD children?
3. Do children with HFASD demonstrate a difference in performance on task- versus behaviourally-based measures of IN?
4. Is there a relationship between IN and social skills in children with HFASD?

Hypotheses

As IN is thought to be implicated in social skill development in the HFASD population, the following hypotheses were generated for this study:

1. Children with HFASD will demonstrate significant deficits in social skills when compared to TD children on behaviourally-based measures.
2. Children with HFASD will demonstrate significant deficits in inhibitory ability, as measured on both task-based and behaviourally-based measures, when compared to TD children.
3. IN and social skills will be significantly correlated in children with HFASD such that poorer IN performance will be related to lower social skill ratings. No significant relationship will be observed in the TD sample due to theorized normal development of IN ability in this population.

Method

Participants

For the purpose of this study, individuals classified as meeting clinical criteria for a high-functioning autism spectrum disorder (HFASD) were used. Specifically, clinical participants were required to demonstrate average to above average IQ, no more than one standard deviation below the mean. The study consisted of 16 children aged 8-12 with HFASD (M = 10.09, SD = 1.28, 15 males) and 16 age- and gender-matched TD comparison children (M = 10.13, SD = 1.24, 15 males). Initial diagnoses of the clinical sample were provided by a psychiatrist or psychologist professionally licensed in their appropriate jurisdiction and trained on proper diagnostic techniques. Diagnosis of the clinical sample was confirmed using the Autism Diagnostic Interview – Revised (ADI-R; Rutter, Le Couter, & Lord, 2003). In order to ensure that the clinical sample met the cognitive requirement to be classified as HFASD, participants were required to demonstrate verbal intelligence (VIQ) and nonverbal (performance) intelligence (PIQ) of 85 or higher on the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). All participants were required to have no documented impairing mental health concerns as gathered through parent report. Typically-developing comparison participants did not participate in the ADI-R, but were required to have no diagnosed or reported significant mental, developmental, or physical health disorders on the participant information questionnaire. Detailed demographic information of the sample can be found in Table 1.

Parents completed additional measures in regards to their child (Participant Information Questionnaire, Social Skills Improvement System, and Behaviour Rating Inventory of Executive Function).

Families were recruited for participation through mental health settings, the University of Calgary Applied Psychological and Education Services clinic, various University of Calgary public postings, medical clinics and hospitals, family and friend connections, professional networking-based connections, and various service organizations for individuals with ASD in Alberta. Prior to any contact with families, approval was obtained through appropriate and authorised representatives or governing bodies of these organizations as necessary.

Measures

Autism Diagnostic Interview – Revised. The Autism Diagnostic Interview – Revised (ADI-R; Rutter, Le Couter, & Lord, 2003) is a semi-structured interview conducted with parents or caregivers consisting of 93 items, and is considered a "gold-standard" measure in the assessment and diagnosis of ASD. The ADI-R assesses four key content areas including impairments in social interaction, impairments in communication, the presence of restricted and repetitive behaviours and interests, and the age of onset with specific cut-offs designated as diagnostically valid for each category. Test developers report the test-retest and interrater reliabilities for both clinical and nonclinical participants to be excellent, with most coefficients greater than 0.90. Validity of the measure was determined using a sample of 226 children with ASD. They report that concurrent validly with independent clinician formulation was very good (mean kappa = 0.74), and criterion validity with the previous version of the ADI-R (ADI) was excellent. Finally, the ADI-R is reported to have excellent discrimination between ASD and non-ASD individuals, with sensitivity of 1.0, and specificity greater than 0.97 (Rutter, Le Couter, & Lord, 2003). Recent research has demonstrated that the ADI-R can be reliably administered over the phone when used by trained researchers, with no difference in results in the diagnostic algorithm or final diagnosis reached in comparison to face-to-face administration (Ward-King, Cohen, Penning, and Holden, 2010). As such, parents were offered the option of completing the ADI-R via telephone or in person, although most were conducted in person by graduate students trained to research reliability standards.

Wechsler Abbreviated Scale of Intelligence. All participants were required to demonstrate VIQ, PIQ, and Full Scale IQ (FSIQ) of 85 or higher on the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) to qualify for inclusion. The WASI is considered a short administration tool for measuring intellectual functioning that has been shown to be especially useful for research purposes, as administration varies from 30-60 minutes. The VIQ is based on verbal reasoning and verbally based knowledge and linking abilities. The PIQ is based on information of visual spatial ability, visual based reasoning, and logical thinking ability. The Full Scale Intelligence Quotient (FSIQ) is then comprised of both PIQ and VIQ measured abilities, with all scores presented in standard scores (M = 100, SD = 15).

For children ages 6 to 16, internal reliability coefficients have been reported as .93 for VIQ, .94 for PIQ, and .96 for full FSIQ scores (Wechsler, 1999). Adult FSIQ scores have shown concurrent validity through correlations to those generated by the more comprehensive Wechsler

Adult Intelligence Scale, Fourth Edition at .92 (Axelrod, 2002). Research by Saklofske, Caravan, and Schwartz (2000) resulted in confirmation of the concurrent validity of the WASI in a small sample of Canadian children (n = 64, mean age = 9.5 years), with correlations yielding similar patterns to those reported in the manual.

Delis-Kaplan Executive Function System. One of two methods in which IN ability was measured was in a direct fashion with all participants using the task-based Delis-Kaplan Executive Function System (DKEFS: Delis, Kaplan, and Kramer, 2001). The DKEFS contains a set of nine standardized tests that can be used as standalone measures, or together to gather comprehensive information on EF in individuals between the ages of 8 to 89 (Swanson, 2005). For information on IN ability specifically, the Color-Word Interference Test (CW) from the DKEFS was used. In CW, children's ability to read the names of colors is first established, as well as their ability to correctly visually distinguish the colors red, blue, and green. The third subtask (CW3), from which data was specifically used for this study, has the administrator present children with a grid of color names that are presented in different colors of ink – red, blue, and green – in contrast to the standard black ink. Children are required to name the color of the ink the words are printed in, but to not read the word, as quickly and accurately as they can. This is considered a Stroop-based task, as children must inhibit their prepotent response to read the words in order to instead name the color of ink. Scaled scores for the CW3 task are available for both completion time as well as errors committed ($M = 10$, $SD = 3$). Two scaled scores generated for CW3 were used: one indicative of children's ability to complete the page in the expected number of seconds (CW3 Scaled Score), and another indicative of their total inhibitory errors committed while identifying the ink color (CW3 Errors Scaled Score). While the CW3 Errors Scales Score is optional, it can provide additional information regarding differences in the number of inhibitory errors committed between groups regardless of page completion time. Information from the DKEFS Technical Manual places the test-retest reliability of the CW3 task (completion time) at .90, considered to be high. No test-retest coefficients were reported for the CW3 errors committed scores. Validity for the task was determined through intercorrelations between other CW components, with correlations reported to be moderate as expected for the relationship between the abilities the task is measuring (Delis, Kaplan, & Kramer, 2001).

Behaviour Rating Inventory of Executive Function. Inhibitory ability was also assessed through the Behaviour Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, and Kentworthy, 2000), gathering information on observed behaviours in day-to-day interactions and activities that are related to the expression of EF ability. The BRIEF is normed on children between the ages of 5 to 18 years of age, with valid forms for parents, teachers, and children. For the purposes of this study, the BRIEF-parent form was used. Parents answered questions on a three-point scale (never, sometimes, often), completing the questionnaire in approximately 10-15 minutes. This measure gathers information on 8 domains of EF, including IN, CF, emotional control, initiation, WM, planning, organization, and monitoring. For the purposes of this study, the Inhibit sub-domain T-score (M = 50, SD = 10) was used in data analyses.

Test developers report that the Inhibit sub domain, composed of 10 questions, is representative of the ability of a child to resist, inhibit, or purposely not act on an impulse in behaviour at the appropriate time. Questions tap areas such as acting out or being silly when not appropriate, interrupting or blurting things out, and other varying behaviours related to IN. Internal consistency coefficients for the Inhibit sub-domain on the parent-form are reported as

.94 in a clinical sample of children referred for neuropsychological assessments, and .91 in the normative sample. Test-retest reliabilities range from .76 to .84 on the Inhibit sub domain, with mean T-score differences between 0.6 to 4.4. Gioia et al. (2000) report that the content validity of the measure was ensured through careful development with paediatric neuropsychologists, retaining only items with high interrater agreement in the measure. Previous studies using the BRIEF have indicated that children with HFASD demonstrate higher executive dysfunction, including on the inhibit sub domain scale specifically, when compared to matched comparisons (Landa & Goldberg, 2000; Kentworthy, Guy, & Wallace, 2000).

Social Skills Improvement System. To gather information on children's social skills, parents and children were given the Social Skills Improvement System (SSIS: Gresham, Elliot, Cook, Vance, and Kettler, 2010) rating scales. The SSIS provides parent-, teacher-, and student-report forms to be filled out in regards to the child's social behaviour. The use of the SSIS allows for multiple perspectives on the child participants' social skill ability demonstrated in real life environments such as school, play, and home settings with other children and adults. It assesses the domains of Social Skills and Problem Behaviour, providing composite scores and percentile ranks for each of these two categories based on normative data. For the purposes of this study, the Social Skills domain from the parent- and student-report forms was used in statistical analyses. This domain gathers information on communication, cooperation, assertion, responsibility, self-control, engagement, and empathy (Gresham & Elliot, 2008). Children answer 46 questions on the student-form (normed for children 8-18 years) that gather information on their social skills through selecting whether they feel the statement is not true, a little true, a lot true, or very true of them. Parents also complete 46 questions about their child's behaviour, answering whether their child never, seldom, often, or almost always engages in various behaviours. Parents also rate their perceived value of each question by recording how important they believe the behaviour to be for their child's success, with options of not important, important, or critical. For the age group used in this study, Gresham and Elliot (2008) report internal consistency coefficients of .95 for the parent-form, and .94 for the child-form Social Skills scales. Test-retest correlations for the Social Skills scale were reported as .84 and .80 respectively. Content validity of the SSIS was ensured through careful item selection that involved reviewing literature on the previous version of the measure, surveys of research literature into social skill deficits, and research into the relationship between specific social behaviours and their social outcomes as youth develop. In the Social Skills domain, subscales are positively correlated at a moderate to high level, suggesting that for the most part the content measured is related, which is not unexpected. Finally, research has shown that as expected, individuals with ASD typically obtain scores in the Social Skills domain on the SSIS-Parent form approximately 1.5 standard deviations below the normative nonclinical sample. However, on the student form children with ASD do not obtain scores significantly different then their non-clinical peers on the Social Skills domain (Gresham & Elliot, 2008). It is important to note that no cognitive or adaptive level was indicated for this sample of children with ASD.

Participant Information Questionnaire. Parents of child participants completed an information questionnaire which gathered information on any mental, language, or physical based diagnoses that may have been in conflict with correctly meeting ASD criteria or qualifying for participation in the comparison group. The questionnaire also gathered background and demographic information relevant to the study and categorization of participants (i.e., birth date, year diagnosed with HFASD, current grade and school, etc.).

Procedure

This study is part of a larger project investigating EF, emotional intelligence, and resilience in children with HFASD. As such, participants were contacted to participate in the larger study, which included all measures and procedures described above in addition to others. Participant families were recruited through various organizations, school boards, and advertising opportunities for which proper consent and ethical consideration was obtained.

Interested families were sent an initial package that included consent forms and questionnaires for parents (SSIS Parent-form, BRIEF, and Participant Information Questionnaire) to complete. Upon completing these, they were asked to come to the University of Calgary campus for additional direct measures and questionnaires (WASI, DKEFS, ADI-R, SSIS Student-form). The WASI was administered as an initial measure to confirm intellectual functioning, followed by the other direct measures used in the larger study that were administered in randomized order. Testing at the University of Calgary was usually completed over 2 separate sessions to ensure children and families were not overly fatigued. Parking was paid for families, and they received a gift card as a thank you once participation was complete. Children were also given the opportunity to choose a toy as an additional thank you.

Chapter 3: Results

The HFASD and comparison samples were matched according to gender and chronological age within a maximum deviation of 3 months. Nonparametric tests were chosen primarily due to non-normal score distributions observed specifically on BRIEF and SSIS-parent scores. Independent Samples Mann-Whitney U Tests were used to determine possible significant differences between participant groups on age, VIQ, PIQ, FSIQ, CW3 Scaled Scores, CW3 Errors Scaled Scores, BRIEF Inhibit T-scores, and SSIS Parent and student ratings (see Table 1). No significant differences were found between the group's ages, VIQ, or FSIQ. However, a significant difference was found for scores on PIQ, with the HFASD sample scoring higher (M difference = 8.44, $p < .05$).

Table 1.

Descriptive Information and Mean Comparisons on Measures for Comparison and HFASD Sample

	Total Sample *M (SD)*	Control Sample *M (SD)*	HFASD Sample *M (SD)*	Diff.	Significance
Age	10.11 (1.24)	10.13 (1.24)	10.09 (1.28)	0.04	
Gender (# Male)	30	15	15		
Verbal IQ	120.6 (12.32)	118.81 (12.53)	122.38 (12.25)	3.57	
Perf. IQ	117.03 (12.45)	112.81 (12.33)	121.25 (11.41)	8.44	*
Full Scale IQ	120.94 (11.81)	117.37 (11.51)	124.50 (11.34)	7.13	
CW3 Time SS	10.94 (2.24)	11.06 (2.05)	10.81 (2.48)	0.25	
CW3 Errors SS	10.66 (3.27)	11.06 (3.55)	10.25 (3.02)	0.81	
SSIS Parent	92.50 (21.82)	104.31 (15.18)	80.69 (21.35)	23.62	**
SSIS Student	99.44 (15.33)	102.25 (12.25)	96.62 (17.86)	5.63	
BRIEF – Inhibit	55.16 (13.43)	46.94 (6.88)	63.38 (13.46)	16.44	***

note: * $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

The first hypothesis was partially supported in that a significant difference was found between groups on the SSIS Standard Scores. However, this difference was only observed on SSIS Parent ratings and not on SSIS Student ratings. Specifically, parents of children with HFASD rated their children as having poorer social skills than the comparison group, U(30) = 47.5, Z = -3.036, $p < .01$, but children's self-ratings on the SSIS did not differ significantly between groups, U(30) = 104.5, Z = -.886, $p > .05$. Due to the unexpected results on SSIS-student forms for the HFASD group, follow up nonparametric related-samples comparisons using the Wilcoxon Signed Ranks Test were conducted. Results indicated that there was indeed a statistically significant difference between SSIS Parent ratings (*Mdn* = 86.00) and SSIS Student ratings (*Mdn* = 96) of social skills in the HFASD group; $z = -2.303$, $T = 23.50$, $p < .05$. However, when comparing SSIS Parent-ratings (*Mdn* = 104) and SSIS Student-ratings (*Mdn* = 104) in the TD group, this difference was observed to be non-significant; $z = -.441$, $T = 76.50$, $p > .05$.

The second hypothesis regarding the nature of children's inhibitory ability was also partially supported. Analysis revealed no significant difference between groups on the either CW3 completion time (U(30) = 123.5, Z = -.172, $p > .05$) or CW3 errors committed (U(30) = 94.50, Z = -1.27, $p > .05$). However, a significant difference was found on the BRIEF Inhibit subscale, such that parents of children with HFASD indicated that their children demonstrated significantly greater IN dysfunction than the comparison sample (U(30) = 35.5, Z = -3.494, $p < .001$).

Finally, nonparametric correlations utilizing Spearman's rho were used to investigate the relationship between BRIEF Inhibit scores and SSIS Parent-ratings due to the significant differences demonstrated between groups on these measures. The results of the SSIS Student-ratings and CW3 tasks were not included in this correlational analysis because there were no significant differences found between groups. Analysis revealed no significant relationship between BRIEF Inhibit scores and SSIS Parent-ratings in the TD comparison sample (ρ (14) = -.117, p = > .05; Table 2).

Table 2.

Bivariate Correlation Between Ratings of Inhibitory Dysfunction and Social Skills – Comparison Sample

		SSIS Parent Social Skills Standard Score	BRIEF Parent Inhibit T-score
SSIS Parent Social Skills Standard Score	Correlation Coefficient	1.000	
	p. (2 tailed)	.	
BRIEF Parent Inhibit T-score	Correlation Coefficient	-0.117	1.000
	p. (2 tailed)	>.05	.

However, a significant relationship was found between these two measures in the HFASD group (ρ (14) = -.664, p = .005 ; Table 3).

Table 3.

Bivariate Correlation Between Ratings of Inhibitory Dysfunction and Social Skills – Clinical Sample

		SSIS Parent Social Skills Standard Score	BRIEF Parent Inhibit T-score
SSIS Parent Social Skills Standard Score	Correlation Coefficient	1.000	
	p. (2 tailed)	.	
BRIEF Parent Inhibit T-score	Correlation Coefficient	-0.664	1.000
	p. (2 tailed)	0.005	.

These relationships can be observed visually in scatterplots for both groups: in Figure 1 for the comparison sample, and Figure 2 for the HFASD sample.

Chapter 4: Discussion

Consistent with past research findings, children with HFASD were rated by parents as having poorer social skills then their TD peers. This finding is not unexpected, as social interaction and communication deficits are diagnostically characteristic of the population (Landa, 2007; Macintosh & Dissanayake, 2006; APA, 2000). However, an interesting finding is that these rating differences were not true for child self-report ratings, such that children with HFASD did not identify themselves as having the same level of social skill deficits that their parents observed. Follow-up nonparametric comparisons confirmed statistically significant differences between parent- and student-forms on the SSIS in the HFASD group, but not in the TD group. The SSIS test developers report the same findings in their study comparing children with ASD to their TD peers (Gresham & Elliot, 2008). However, they do not report the cognitive or adaptive functioning of these children and it is therefore not possible to determine whether the sample would be considered similar to the one utilized in this study (i.e., HFASD). One possible explanation for the difference in parent versus student ratings may be that although the social skills measure used in this study is normed on an age appropriate population for comparison, it may not be normed or as sensitive for children of this age with HFASD. The difference in self-ratings may also result from the specific developmental stage of the children with HFASD, such that they are not fully self-aware of their social challenges. Children with HFASD have been reported to use their cognitive capabilities to compensate for their social impairments (Kasari, Chamberlain, & Bauminger, 2001; Sigman & Ruskin, 1999); however, limited research has explored their self-perceptions of their social abilities (Vickerstaff, Heriot, Wong, Lopes, & Dossetor, 2007). In contrast to the findings in the current study, past research has found that children with HFASD tend to identify themselves as having lower social skills than their TD peers (Capps, Sigman, & Yirmiya, 1995). The results from the Vickerstaff et al. (2007) study also indicated that children with HFASD tend to rate themselves has having poorer social skills using a sample similar to the current study (*M* age = 11.86, range = 7.92-13.92, *M* IQ = 105.41). Interestingly, these studies have also shown that IQ is negatively correlated with ratings of self-perceived social skill ability in children with HFASD (Capps et al., 1995; Vickerstaff et al., 2007). Given that the sample in the current study had a higher overall IQ than that reported in Vickerstaff et al. (2007), and Vickerstaff et al. (2007) employed the use of the predecessor to the SSIS, the results of the current study would have been expected to be similar: that children with HFASD rate their own social skills as poorer than TD children. Additional research in the future should continue to focus on the nature of self-perceived social skills in this population to determine the nature of the current findings.

Another possible mechanism through which the student ratings of social skills did not differ may be through the influence of protective factors in the HFASD group. As the HFASD sample demonstrated average to above average intellectual abilities, they have the capacity to begin understanding the deficits they possess in social interaction in comparison to others (Wing, 1992). Researchers have suggested that in HFASD, greater intellectual abilities are related to increased awareness of social deficits and therefore may lead to a greater risk for depression (Bauminger, 2002; Bauminger & Kasari, 2000, Vickerstaff et al., 2007), which has been a confirmed relationship in TD children (Blechman, McEnroe, Carella, & Audette, 1986; Dalley, Bolocofsky, & Karlin, 1994). Due to this knowledge of personal weakness, it is possible that the children with HFASD may choose to represent themselves in a more positive, less socially challenged fashion. However, there seems to be no conclusive reason as to why the current sample of children with HFASD appears to lack the self-awareness that would accurately identify them as having poorer social skills then their TD peers. Many children completed the forms in the close presence of the examiner, and may have felt the need to compensate and present themselves as having greater ability than they truly do. This process may even have been done subconsciously, as illustrated by the Positive Illusory Bias (PIB). The PIB occurs in the general population, where children and adults tend to see and report themselves as being and performing better than a hypothetical "average". While not comprehensively investigated in individuals with HFASD, PIB has been researched in children with ADHD, and it has been shown that many children with ADHD overestimate their abilities and competence despite their actual competence being observed as poorer than their peers (Owens et al., 2007). It is difficult to theorize why children with HFASD would demonstrate greater effects of PIB, with no additional inflation of scores seen in the TD group. As the SSIS was normed on a large population of TD children it is possible that the means created for this measure then reflect any potential PIB effects in the TD child and adolescent population. Further, as the SSIS was not normed on an HFASD population, no potential effects of PIB have been accounted for in the measure, which may be a potential reason for the higher than expected scores when children with HFASD reported their own social skills on this measure. Moreover, a consistent finding of low to moderate agreement between raters when using rating scales has been reported. A large meta-analysis by Achenbach, McConaughy, and Howell (1987) indicated that the average correlation between children, parents, teachers, and mental health workers ratings was approximately $r = .20$ on a wide variety of social, emotional, and behaviourally targeted rating scales. Researchers have recently concluded that on the SSIS rating scales in particular, parent and TD child ratings on the Social Skills standard score were significantly related; however, this was only a correlation of $r = .21$. The authors of this study conclude that clinical judgement and further assessment methods are among the best ways to understand and potentially resolve discrepant ratings (Gresham, Elliot, Cook, Vance, & Kettler, 2010). Due to the multitude of factors (e.g., potential protective factors, possible effects of PIB, SSIS not being sensitive or normed to HFASD children specifically) surrounding the SSIS-student report scores for the HFASD group, and keeping in mind the average discrepancy between raters, the SSIS-parent ratings in the context of this study may be taken as a more reliable source of information regarding HFASD children's true social skill performance. Parents see children in many contexts, and are able to compare a child to others around them. For the HFASD sample this may include comparisons to TD siblings or others at school, on the playground, at church, the mall, or other naturalistic settings. Therefore, overall, it can be determined that a reliable and accurate reporting by parents indicated significantly poorer social skill abilities and behaviours in the HFASD sample versus the comparison sample.

Unanticipated results were found when comparing group abilities on measures of IN. Inhibitory deficits on task- and behaviourally-based measures were hypothesized to be present in the HFASD sample; however, this difference was not found for task-based measures. Children with HFASD demonstrated equal ability to their TD peers to complete the CW3 task in sufficient time, and without a significantly greater number of errors. These results are similar to other research into IN in children with various forms of ASD that have shown few performance differences on Stroop-based tasks when compared to TD peers (Eskes, Bryson, & McCormick, 1990; Ozonoff & Jensen, 1999). In contrast, the BRIEF ratings indicate that parents observe behaviours in their children with HFASD that are related to more IN dysfunction than their TD peers. Researchers have shown that task-based neuropsychological measures, including the D-KEFS, may be useful for some level of categorization of individuals but show little ecological validity (Hill & Bird, 2006; Bernstein & Waber, 1990). As posited by Kleinhans, Akshoomoff and Delis (2005), despite some average performance on tests of cognitive IN, task-based measures may not have enough sensitivity to the specific process that leads to the general behavioural disinhibition observed clinically in individuals with HFASD. In addition, there is evidence that children with HFASD demonstrate more accurate and fast reading ability then their TD peers, although they have lower comprehension abilities (Nation, 2006; Frith & Snowling, 1983; Golinkoff 1975, 1976). Adams and Jarrold (2009) postulated that this reading ability difference gives children with HFASD an advantage on Stroop-based tasks, such that they are better able to ignore the semantic interference of the printed word when asked to name the color of the ink. These researchers reported that children with HFASD performed equally to or better than TD children, despite the HFASD group having poorer reading comprehension. As a result, the results observed on the CW3 task in this study may have been influenced by the reading comprehension ability of the HFASD sample. In the future, research may continue to focus on the influence of reading abilities on Stroop-based tasks, and the ecological validity of the task particularly in HFASD populations.

The current study investigated IN in relation to social skills, a combination of abilities rooted primarily in behaviour and choices observed in naturalistic settings as they occur. The SSIS gathered parent ratings of these behaviours, and these may therefore be more relevant to comparison with naturalistic observations of behaviour related to EF function as measures by the BRIEF. In this study, parent ratings of children's behaviour in relation to EF on the BRIEF Inhibit subscale were indeed significantly different. Specifically, parents rated children with HFASD as exhibiting higher levels of inhibitory dysfunction than the comparison group. As previously mentioned, the results on the CW3 task may be influenced by the differences in reading ability between groups. In addition, the relatively simple rules involved in the task may not be sensitive enough to delineate differences when comparing to TD children (Hill, 2004; Christ et al., 2007). While both the CW3 task and BRIEF are measures of IN, the BRIEF gathers observations on behaviours in which children need to employ IN ability when the situation is much more complicated, with multiple rules and potential outcomes associated with behaviour. As a result, the HFASD group did not differ on task-based inhibitory performance, but did demonstrate a unique deficit inhibiting responses and behaviour in this more complex, naturalistic settings as observed by their parents.

Finally, nonparametric correlations were run to test the hypothesized relationship between IN and social skills in children with HFASD. This relationship was explored using the BRIEF Inhibit and SSIS Parent results, but excluded the CW3 and SSIS Student results due to a lack of significant difference between participant groups on these measures. Spearman's rho analysis indicated no significant relationship between parent-rated inhibitory ability and parent-rated social skills in TD children. However, a moderate, negative relationship was found in the clinical group. Importantly, in line with the hypothesis regarding this relationship, increased inhibitory dysfunction in naturalistic settings was correlated to decreased observed social skills in this population. This relationship supports the possibility that an executive dysfunction in IN ability may partially underlie or contribute to many of the social skill deficits experienced by children with HFASD.

These results are in contrast to multiple studies that were unable to link inhibitory ability with social interaction deficits in HFASD (Kentworthy et al., 2009; Joseph & Tager-Flusberg, 2004; Bishop & Norbury, 2005). The difference may be due to both the sample used in these previous studies, and the selection of measures. One study had a large sample size (n = 89), but with age rages between 6-17 and with no TD comparison group (Kentworthy et al., 2009). Bishop and Norbury (2005) did utilize a comparison sample of n = 18, but this was for a clinical sample of 56 children ages 6-10, only 14 of which were considered HFASD. Finally, the sample in Joseph and Tager-Flusberg's (2004) study also had a large age range (5 years 7 months to 14 years 2 months; n = 31), and lower measured cognitive abilities then the current sample (mean VIQ = 83, mean PIQ = 88). IN measures in these three studies were primarily task–based, including the NEPSY and TEA-Ch with only one study utilizing the BRIEF (Kentworthy et al., 2009). However, Kentworthy and colleagues collapsed the BRIEF results into broad indices of EF that included the IN subscale, and statistical analyses did not look specifically at this scale in relationship to social abilities (Kentworthy et al., 2009). In addition, all three studies measured social interaction skills as a function of symptom severity on the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1999) or the ADI-R. These measures are highly sensitive to social interaction skills; however, they are highly specific to social features specifically associated with ASD diagnoses. Thus, the current study is unique in assessing social skills in the sample through a measure designed to be compared to TD children, through behaviours additional to those associated specifically with ASD symptoms. Further, the results from this study are unique in linking EF deficits in IN to social skills, as the currently limited research on the subject has consistently demonstrated no significant connection.

It is possible that, despite carefully considered methodology, additional factors influenced the final data collected from this study. First, it can be seen that the cognitive abilities as measured through IQ were slightly higher in the study sample than the average in the normative population (where $M = 100$, $SD = 15$). While there is no explanation for this finding in the sample, it is important to note the difference between intelligence and executive functions.

Although both concepts represent cognitive abilities, researchers have shown that the relationship between the two is not significantly strong and they may be considered relatively distinct cognitive concepts and abilities (Kolb & Winshaw, 1990; Ardila, Pineda, & Rosselli, 2000). Should intelligence be directly related to EF, a measured deficit in one area would require a deficit in the other. However, children with unique EF deficits, such as those with ADHD, do not demonstrate significantly lower FSIQ scores that could be accounted for by these deficits (Mayes & Calhoun, 2006). Specifically, research by Friedman et al. (2006) has allowed for the conclusion that IN is not significantly related to intelligence, with IN only explaining 2-14% of the variance in IQ scores when combined with CF ability. As a result, the higher IQ scores observed in both groups in this study do not directly influence the measured inhibitory ability of participants. In addition, no significant differences were found in this study between the HFASD and TD samples on VIQ and FSIQ. There were significant differences observed in PIQ scores; however, these were on average greater for the HFASD group, which would have if anything given the HFASD group a slight advantage on visual tasks. Thus, because these groups performed similar on measures of intelligence, and intelligence and EF are distinct abilities, the relationships found in this study to social skills in the HFASD sample can continue to be applied to IN ability alone.

Second, consideration must be made in regards to potential crossover of items on the BRIEF and SSIS. As both measures aim to gather information based on a child's behaviour in real life settings, the potential exists for parents to provide answers on both questionnaires when considering the same behaviour. Measuring the same behaviour twice would cause conflict, as parents may then be rating a behaviour as resulting as a lack of social skill and a lack of inhibitory ability, making it difficult to draw relational conclusions. An examination of items on the BRIEF Inhibit subscale reveals that they gather information on separate behaviours than those on the SSIS Parent-form, with no apparent crossover. Therefore, with no items obviously assessing similar behaviours, it is possible to separate the behaviours representing social skills from the behaviours purely representing problems with IN ability and allowing for the retention of relational conclusions.

Limitations

This study is limited by some factors that would otherwise increase its strength or the generalizability of results. First, the sample size limited the strength of the statistical analyses as well as the ability to conduct more robust statistical procedures. Finding committed families for this duration of participation was challenging, and matching the comparison sample to the clinical sample based upon age and gender further limited the number of participants analyzed in this study. Second, it has already been pointed out that the average IQ of study participants was much higher than the average in the normative and theoretical population. Despite researchers that have attempted to separate EF abilities from intelligence, it is possible that the higher intelligence of this sample may have played a small part in performance on the CW3 tasks. Specifically, the HFASD sample demonstrated significantly higher PIQ, which is a measure of visually based reasoning, categorization, and spatial processing abilities. As the CW3 task employs some visual reasoning abilities, the higher PIQ performance in this study, especially in the HFASD sample, may have led to increased performance on this task. However, the link between PIQ performance and Stroop-based IN tasks has not been investigated, and future research may focus on determining the effects of higher measured intelligence on task-based EF performance. Third, this data was collected at a single time sample and participants were not followed longitudinally. With a larger sample and the addition of data collected at incremental time points, a more concrete, developmental view of both inhibitory ability and social skills could be determined in both populations. A longitudinal study may also lead to conclusions different from those in the current study, as childhood is a time of brain and social development resulting in constantly changing EF and social abilities. The relationship observed in this study may possibly change, getting either stronger or weaker as children age. Fourth, it may have been beneficial to choose different or additional task-based measures of IN. As previously mentioned, Stroop-based IN tasks have resulted in few differences in performance between individuals with ASD and TD individuals. Christ, Holt, White, and Green (2007) note that most research with Stroop-based tasks in ASD has used card versions in which a whole page of stimuli is presented as a trial. Scores are derived from recording the time to complete the entire page. Other researchers highlight that further investigation of IN using Stroop-based tasks may benefit from a more sensitive version in which a single trial version is used where stimuli are presented one at a time, intermixed with neutral stimuli (Perlstein, Carter, Barch, & Baird, 1998). The CW3 task from the DKEFS is essentially one such task, in which an entire page of stimulus is presented. However, the employment of this Stroop-based task in a well-designed study such as this allows for further support of this finding. The use of a task assessing IN ability that is not Stroop-based, such as a flanker or go/no-go task may have provided additional information to this study. Fifth, the significant relationship observed in this study was between two parent ratings of behaviour and not between a task-based and parent rating measure. Although it was shown that the SSIS and BRIEF were gathering ratings on different behaviours, the use of these two measures in correlational analysis necessitates certain assumptions. Specifically, parent ratings are assumed to be related to neuropsychological functioning, and then to deficits in social skills. It is possible that having found relationships involving task-based IN measures may have allowed for conclusions more directly related to true, more distinct IN abilities. Sixth, because the BRIEF and SSIS rely on observations of everyday behaviours, parent ratings may tap abilities in addition to IN and social skills (e.g., motor speed, verbal abilities). Research by Joseph and Tager-Flusberg (2004) found a relationship between IN and social interaction symptoms in HFASD; however, when verbal ability was partialled out, this relationship became insignificant. The results of the current study may be strengthened through the partialling out of verbal ability measured through participants VIQ scores from the relationship between the BRIEF and SSIS results. These partial correlations were not possible in the current study due to limitations surrounding the use of parametric statistics. Future research with larger sample sizes with data meeting parametric assumptions may further probe this relationship with the effects of other abilities, including VIQ, removed from relationships. Finally, there may have been interesting data that was not gathered due to the gender ratio in the current study. Current estimates place the overall ASD prevalence at approximately 4.6 males to one female (CDC, 2012). While this is an estimate of the broader ASD category, the current study had a much higher ratio of 15 males to one female with HFASD. In light of the work by Lemon et al. (2011) that found females with ASD were slower on tasks of IN, the results of the current study may have been different if more females had been included. However, the current study aimed to recruit participants of both genders, and the sample ratio simply reflects the children and families who opted to participate. Despite these limitations, the results of this study continue to point to the possible existence of a link between behavioural IN and observed social skills in children with HFASD.

Implications and Future Directions

In light of the current study, there are multiple directions for future research. Replication of the current study with a larger sample size would allow for more generalizable results. As well, it would be important to follow a large sample of children as they enter adolescence and adulthood. By measuring social skills and inhibitory ability in children with HFASD over a longer time period, developmental trends may be observed. Future research may also focus on measuring inhibitory ability with a variety of non Stroop-based tasks that would allow for further exploration of how neuropsychological tasks of IN may be related to social skills.

The results of this study may be replicated with similar measures, or with other forms of behavioural measures. For instance it may be valuable to directly observe children's daily and social interactions. Moreover, gaining behaviour ratings of both IN and social skill ability through classroom teachers would provide much additional information. Researchers may decide to code social skills in a variety of situations, and simultaneously and separately code behaviours related to inhibitory ability. Analysis of this data would allow for corroboration of these results.

Additional investigation of the self-awareness children with HFASD have in regards to their social interaction skills would be of great value. In the current sample, children with HFASD were apparently not fully aware of their poorer social skill abilities in comparison to their TD peers as seen on the SSIS. While this level self-awareness may be seen as a protective factor guarding HFASD children's self-concept, it can also be a roadblock for success through intervention. As these children develop an accurate self-awareness, they can begin to better understand the specific skills they need to improve, and advocate for themselves, seeking support throughout their development.

Future research should continue to focus on the relationship between EF and the core and secondary deficits experience by individuals with HFASD. In light of the oncoming changes to ASD diagnostic criteria and categorization in the DSM-5, part of this focus may be on the differences between these newly defined groups. The categorization of individuals into one of 3 groups requiring various levels of support necessitates an investigation of the potential EF ability differences for the purposes of intervention. Researchers have shown that a variety of EF, especially WM, can be trained with long term gains in ability for both TD children and those with HFASD (Diamond & Lee, 2011; de Vries, Prins, Schmand, & Guerts, 2012). In addition, children with HFASD can be trained on ToM (Fisher & Happe, 2005). As IN ability has been referred to as a necessary EF for ToM ability, and ToM is an important part of social interaction ability, the training of IN in concert with ToM may be additionally beneficial to gain secondary abilities in social skills.

Traditional intervention for improving social skills in individuals with HFASD include a variety of social skills training programs in a one on one or group setting, with the focus being on allowing the skills to be practiced in real social situations outside of a clinic setting (Schreiber, 2011; Cappadoccia & Weiss, 2011). In light of the current study, the relationship between inhibitory ability and social skills may be seen as an additional avenue for intervention. Future research may be successful in providing effective interventions for training inhibitory ability in a clinic-based and environmentally based setting. Should this training be effective, secondary gains in social skills could be explored. The relationship in the current study suggests that effective and lasting training of inhibitory ability in a day-to-day setting may in fact improve the overall social skills of these children. Moreover, research has shown that the training of EF contributed to documentable improvements in ToM ability, a factor in understanding others for successful social interaction (Fisher & Happe, 2005). Thus, as children with HFASD exhibit unique deficits in IN, and IN as an EF can be trained, these areas may be targeted for intervention in the hope that social skills may improve as well. Furthermore, with the advances in computer and internet technology, this training may be delivered to children with HFASD through virtual environments. This intervention approach would allow for potentially more affordable or accessible training for some families who cannot otherwise make it to places where direct social skills or EF training is conducted. It also allows children to utilize a computer system and possibly game formats that they are comfortable and interested in. Current research and theory into this form of intervention delivery supports the use of virtual reality based training for a variety of needs in children with HFASD (Parsons & Mitchell, 2002; Parsons, Mitchell, & Leonard, 2004). This potential is encouraging; as families of children with HFASD would be well served by additional interventions that may help them experience improved success with friends and family. The existence of an intervention that increases IN ability, provided concurrent to social skills training, may compound their effectiveness and give children and their families a renewed hope for their child's social development and success.

Figures

Figure 1. Bivariate Correlation Scatterplot Showing the Relationship Between Ratings of Inhibitory Dysfunction and of Social Skills – Comparison Group

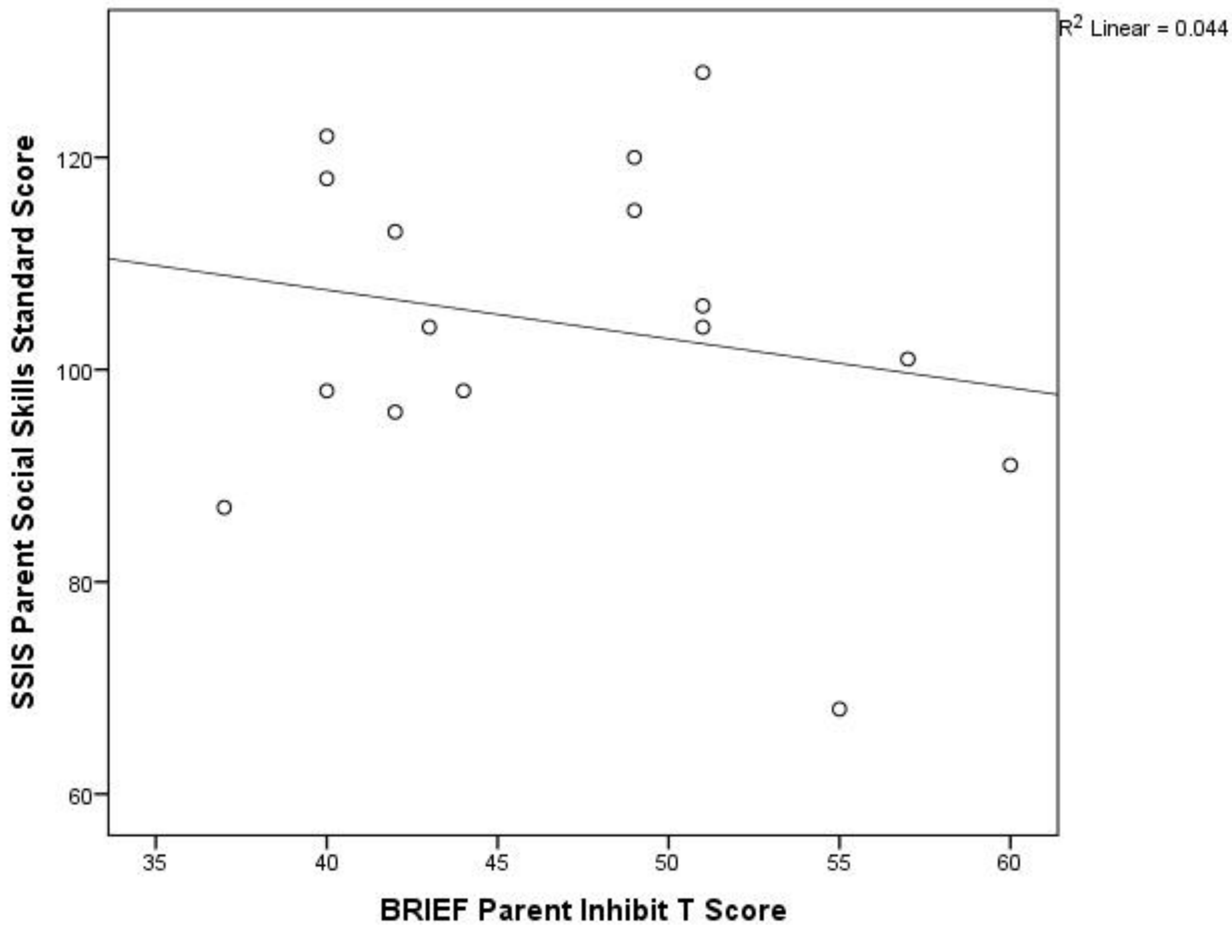
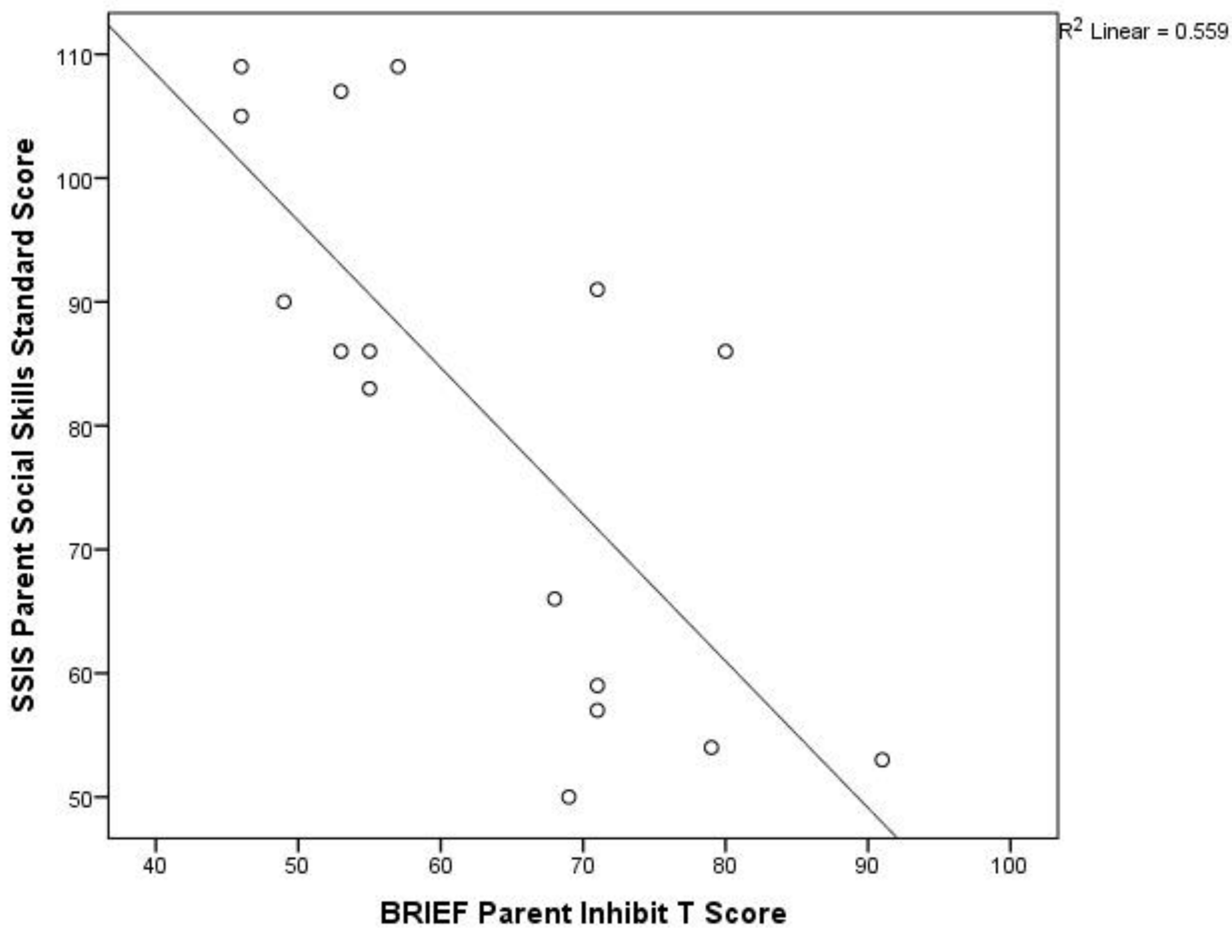


Figure 2. Bivariate Correlation Scatterplot Showing the Relationship Between Ratings of Inhibitory Dysfunction and of Social Skills – Clinical Group



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