RELATIONS AMONG THEORY OF MIND AND EXECUTIVE FUNCTION ABILITIES IN TYPICALLY DEVELOPING ADOLESCENTS AND ADOLESCENTS WITH ASPERGER'S SYNDROME AND HIGH FUNCTIONING AUTISM

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DISSERTATION ABSTRACT

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The aim of the current study was to bring greater clarity to our understanding of the relation between theory of mind (ToM) and executive function (EF), specifically working memory (WM) and inhibitory control (IC), during typical adolescent development and of the specific nature of impairments in ToM and EF in the cognitive profile of individuals with Asperger's Syndrome and High Functioning Autism (AS/HFA). In total, 80 participants, half typically developing (TD) and half with AS/HFA, participated in the study. TD participants were matched to the participants with AS/HFA on chronological age and gender. Participants were tested across two test sessions, approximately one year apart. For Session 1, the TD participants ranged in age from 10.1 to 17.9 years (M = 14.68, SD = 2.05), and the participants with AS/HFA ranged in age from 10.2 to 17.9 years (M = 14.64, SD = 2.19).

I tested the participants on a ToM battery, consisting of an emotional perspective taking measure, the Mind in the Eyes Test, and two cognitive perspective taking measures, the Advanced ToM Vignettes, designed by the researcher, and Happé's Strange Stories. In addition, an EF battery was administered, containing a Reading Span

Task, Change Detection Task, and Flanker Task, which assessed verbal WM, visual WM, and IC, respectively.

Firstly, I found that older children and adolescents with AS/HFA, especially the girls with AS/HFA, performed worse on ToM measures tapping cognitive perspective taking relative to TD peers. Secondly, I observed that ToM and EF continue to develop during later childhood and adolescence as part of both typical and atypical development. Thirdly, I found that verbal WM and IC were more strongly associated with ToM in the AS/HFA group, indicating that individuals with AS/HFA may require more executive resources for ToM reasoning.

Based on my results, I suggest that ToM and EF are still developing during later childhood and adolescence in both TD individuals and individuals with AS/HFA, indicating that the brain regions supporting ToM and EF processing are still plastic and can therefore be targeted for intervention.

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For my parents, who instilled in me from a young age the value of higher education, and my sisters, who paved the way

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CHAPTER I

INTRODUCTION

Overview

The development of a theory of mind (ToM), or the ability to impute mental states to self and other, is considered a landmark achievement in human development. ToM allows us to step away from our own first-person perspective and consider, for instance, the thoughts and feelings of others. This ability allows us to engage in complex yet fluid social interactions. Further, it provides the basis for the greatest of human abilities, such as compassion and forgiveness. Although crucial advances in ToM occur during the preschool years, this multi-faceted, complex ability continues to develop throughout childhood (Carpendale & Chandler, 1996; Flavell, 1999; Perner & Wimmer, 1985; Wimmer & Perner, 1983). Recent research even suggests that the maturation of ToM may extend into adolescence and young adulthood (Apperly, Back, Samson, & France, 2008; Dumontheil, Apperly, & Blakemore 2010).

The development of ToM has been found to depend on domain general abilities, such as language ability and executive function (EF), a set of cognitive abilities that allow us to control and regulate our behavior in the pursuit of goals (Best, Miller, & Jones, 2009; Carlson & Moses, 2001; Carlson, Moses, & Claxton, 2003; Hala, Hug, & Henderson, 2003; Hughes, 1998a). Two domains of EF have been found to play a key role in the emergence and expression of ToM in early childhood; inhibitory control (IC), because of the need to inhibit one's own perspective when considering another's, and working memory (WM), because of the need to hold actively in mind one's own and another's perspective simultaneously.

There is, however, very little research on either the development of ToM or its relation to the development of IC and WM in adolescence (Dumontheil et al., 2010). Adolescence is a developmental stage of particular interest for two reasons. First, social interactions greatly increase in complexity during adolescence. Adolescents must keep track of multiple and often discordant perspectives while discerning ever more subtle social cues, placing greater demands on ToM and EF processing. Second, the adolescent brain undergoes dramatic structural and functional changes in neural systems implicated in ToM and EF processing, suggesting that there may still be development in ToM abilities and the relation between ToM and EF in adolescence (Blakemore, 2008; Giedd, Blumenthal, Jeffries, Castellanos, Liu et al., 1999; Huttenlocher & Dabholkar, 1997; Paus, Zijdenbos, Worsley, Collins, Blumenthal, et al., 1999). Given the limited research on this topic, however, the question still remains whether there is true development in ToM during adolescence or whether ToM is fully developed by adolescence and is simply made more efficient by further developments in EF.

My dissertation work takes a two-pronged approach to the study of the development of ToM and the role that EF plays in ToM development. The first approach examines facets of EF and ToM in typically developing adolescents. This foundational work will provide a fuller account of the developmental trajectory of ToM and the relations between maturing ToM and specific facets of EF in adolescence.

In order to shed further light on our understanding of the critical role that specific facets of EF play in ToM development, the second approach will investigate atypical development of these abilities. Individuals with Autism Spectrum Disorders (ASD), including those with higher functioning autism, may not achieve a fully developed ToM at any point in their lifespan (Baron-Cohen, Leslie, & Frith, 1985; Happé, 1994; Leslie & Frith, 1988; Pellicano, 2007a). The Executive Dysfunction hypothesis posits that early disruptions in the development of EF may underlie the ToM impairments characteristic of ASD (Russell, 1997). However, the Executive Dysfunction hypothesis is vague in that it does not describe the specific impairments in EF that lead to ToM deficits. My proposed study is among the first to explore relations among specific facets of IC and WM on the one hand and ToM on the other in the same sample of individuals with ASD. These data will help refine the Executive Dysfunction hypothesis by highlighting the specific EF deficits that may lead to impaired ToM in individuals with ASD. Further, this line of research on atypical development will complement my research on typically developing adolescents by providing a more complete picture of the developmental relationship between ToM and EF.

In what follows, I will first review the typically developing literature on ToM and the ToM-EF relationship. Next, I will provide a literature review of the impairments in ToM and EF that have been found in ASD. Lastly, I will provide a summary of my research questions.

Typical Development

Theoretical Background on Theory of Mind

ToM research has been a primary focus of the field of developmental psychology for the last three decades (Flavell, 1988; Gopnik & Astington; 1988; Perner, Leekam, & Wimmer, 1987; Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983). This corpus of research has largely concentrated on the first five years of life. The dominant theoretical view on ToM development maintains that *nonrepresentational* ToM emerges by the second year of life, wherein children demonstrate a mentalistic understanding that others experience inner, subjective mental states such as intentions, emotions and desires (Bartsch & Wellman, 1995; Repacholi and Gopnik; 1997; Wellman, Harris, Banerjee, & Sinclair, 1995).

Unlike intentions, emotions, and desires, however, beliefs and knowledge are supposed to accurately represent the world. It is more difficult for young children to grasp the concept that others may represent the world inaccurately. Based on the dominant theoretical view, between the fourth and fifth years of life a conceptual change takes place in children's ToM (Wimmer & Perner, 1983; Flavell, Green, & Flavell, 1986; Gopnik & Astington; 1988). During this developmental period, children come to appreciate that others may hold false beliefs about the world. This new conceptual understanding about other minds is termed *representational* ToM and has been argued to be constrained by the development of certain EF abilities, specifically IC and WM. In this view, EF is not only necessary for the emergence of representational ToM, but the expression of it (Carlson, Mandell, & Williams, 2004; Carlson & Moses, 2001; Carlson, Moses, & Hix, 1998; Flynn, 2007; Hala & Russell, 2001; Hughes & Ensor, 2007; Moses, 2001).

Many developmental psychologists argue that there are no further *conceptual* developments that take place in ToM after the preschool years (Perner, 1988; Perner and Wimmer, 1985). Rather, they suggest that ToM may develop in terms of the recursive ability to stack mental states upon one another, such as thinking about one person's belief about another’s belief (Wimmer & Perner, 1983; Perner & Wimmer, 1985; Sullivan, Zaitchik, & Tager-Flusberg, 1994). Others assert, however, that in middle childhood, children undergo a conceptual change in their understanding of the interpretive nature of the mind (Carpendale, 1995; Carpendale & Chandler, 1996; Chandler & Birch, 2010; Lalonde & Chandler, 2002). Based on this account, by this age children begin to understand that people can interpret the same information differently; that is to say that ambiguous situations may elicit different interpretations among people.

The development of ToM past middle childhood has been understudied. Many developmentalists believe that there are no major conceptual changes that take place after middle childhood. A small number of studies have examined ToM abilities in older children and adolescents. Based on their own research, Epley and colleagues (2004) propose a dual-process account of perspective taking involving both automatic and controlled (i.e., EF) processes. They argue that adults and children do not differ in the automatic tendency to process information from their own egocentric perspective, but do differ in the controlled processes they utilize to adjust to a different perspective. Specifically, adults are more efficient at recruiting the necessary controlled processes, such as IC, to correct an initial egocentric interpretation. Based on this view, ToM itself is not developing further during later childhood and adolescence. Instead, development of domain general abilities, such as IC and WM, in older children and adolescents is leading to processing efficiency in ToM.

Dumontheil et al. (2010) agree that the development of controlled processes influences the efficient use of ToM in adolescence. However, they argue that during adolescence there is continued development in the propensity to take another’s perspective. This increase in the propensity for perspective taking that emerges during adolescence may be the result of an expanding social world. During adolescence, there is a dramatic increase in the amount of time spent with peers rather than with family. Adolescents typically develop a strong desire to maintain positive friendships and romantic relationships, motivating them to better understand others. Thus, the increased propensity to take others' perspectives that arises during adolescence may build on a preexisting tendency for perspective taking rather than being the result of a conceptual change in ToM.

Empirical Research on Theory of Mind

Theory of mind in childhood. By five years of age, most children perform well on false belief measures like the Change-in-location task, suggesting that they have developed a *representational* ToM (Bartsch & Wellman, 1995; Flavell et al., 1986; Gopnik & Astington; 1988; Hogrefe et al., 1986; Perner et al., 1987; Wimmer & Perner, 1983). As an example, Wimmer and Perner's (1983) Change-in-location task involves a story character, Maxi, who does not see his mother move his chocolate to a new location, resulting in Maxi holding a false belief about the location of his chocolate. Child participants are asked where Maxi will look for his chocolate. The child participants cannot rely on the *actual location* of the object to correctly answer the test question. Clearly they need to understand the *belief* of the character in order to succeed on this task. Once false belief understanding has been established, ToM expands into higher-order, recursive mental state reasoning which allows an individual, for instance, to think about one person's belief about another's belief (Liddle & Nettle, 2006; Perner, 1988;

Perner and Wimmer, 1985). Recursive ToM typically develops throughout childhood and adolescence.

Theory of mind in adolescence. Although there is limited research on ToM development in adolescence, this developmental period is of particular interest because it entails important changes in brain functioning and behavior that may reflect further advances in the propensity to use ToM. There are dramatic structural and functional changes that occur during adolescence in frontal, parietal, and temporal cortical regions that support both EF and ToM processing (Blakemore, 2008; Blakemore, den Ouden, Choudhury, & Frith, 2007; Giedd et al., 1999; Huttenlocher & Dabholkar, 1997; Moriguchi, Ohnishi, Mori, Matsuda, & Komaki, 2007; Paus et al., 1999; Wang, Lee, Sigman, & Dapretto, 2006). For example, gray matter volumes of these cortices peak during adolescence, and are followed by synaptic pruning (Giedd et al., 1999). One study that specifically examined neural development of ToM in adolescence found that the vmPFC was recruited in adolescents more than adults during a cartoon vignette task designed to assess emotional perspective taking (Sebastian et al., 2012). This finding supports the view that ToM continues to undergo developmental change during adolescence.

Regarding behavioral changes, Dumontheil et al. (2010) found that the *propensity* to take account of another person's perspective, as measured by Keysar's Director's Task (Keysar, Barr, Balin, & Brauner, 2000), is still improving in late adolescence. In this referential communication task, the director gives participants instructions to move certain objects around a grid. Some of the shelves in the grid are occluded from the director's visual perspective, whereas all of the shelves are visible to the participant. On experimental trials, participants need to use the information about the director's perspective and ignore their own salient perspective in order to interpret ambiguous instructions correctly. After controlling for EF differences, adolescents performed better on this task in comparison to children, but worse compared to adults. These findings indicate adolescence is a period of development in the propensity to take account of another person's perspective (Dumontheil et al., 2010).

Further, research suggests that the strategy used to take another's emotional perspective develops during adolescence (Choudhury, Blakemore, & Charman, 2007). In this study, participants ranging in age from 8-36 years, performed a computerized task in which they read short stories and had to either answer how they would feel about the given situation based on their own first person perspective or a third person perspective. The researchers examined the difference in reaction time between first and third person judgments to determine how efficiently a participant made judgments about others' emotions. RT differences decreased significantly with age. The reaction time difference was close to zero for adult participants, suggesting that adults rated their own and other's emotions equally quickly. On the other hand, children and adolescents showed more of a random pattern of results. They either made rapid judgments about their own emotions and relatively slow judgments about others' emotions, or the reverse pattern. Based on these data, the researchers argue that children and adolescents might use different emotional perspective taking strategies from adults. They suggest that perspective-taking strategies may develop during adolescence.

These studies on adolescent development of ToM indicate that the propensity for perspective taking and strategies used in perspective taking may undergo extensive development during adolescence. Adolescence is a crucial period for social development because adolescents relative to children devote more time and energy to both friendships and romantic relationships (Csikszentmihalyi & Larson, 1984; Furman & Buhrmester, 1992). The strong desire for relationships with peers may motivate adolescents to understand others in order to maintain positive relationships.

Theoretical Background on the ToM-EF Relationship

EF is a multifaceted construct that includes, for example, planning, set shifting, WM, and IC (e.g., Goldberg & Bilder, 1987; Luria, 1973; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Zelazo & Muller, 2002). Domains of EF, in particular WM and IC, have been argued to play a key role in the emergence and expression of ToM (Best et al., 2009; Carlson & Moses, 2001; Carlson et al., 2003; Hala et al., 2003; Hughes, 1998b). WM allows for the active maintenance of information in a state that is readily accessible. IC, on the other hand, is the ability to inhibit responses to irrelevant, but often salient, stimuli in order to pursue a goal (Rothbart & Posner, 1985). As suggested by Moses and Carlson (2004, p. 95), “effective social cognition is not possible unless one is able to hold in mind relevant perspectives (working memory) and to suppress irrelevant ones (inhibition).”

Two theoretical accounts of the relationship between ToM and EF, in particular IC and WM, have been proposed and are supported by extant data (Moses, 2001). For the Emergence Account, EF is considered a key factor that affects the very emergence of ToM. The account proposes that a certain level of inhibitory control and working memory must be in place before a child can even construct complex concepts about other minds. This account maintains that children first must have the ability to hold in working memory both their own and another's perspective, as well as to inhibit their own salient knowledge in order to even consider what another person may know, feel, or think.

In contrast, the Expression Account holds that EF is necessary for being able to express ToM understanding during task performance. Young children might already possess ToM concepts but in order to succeed on standard ToM tasks, children not only need to understand another's perspective, but be able to hold another's perspective in working memory as well as inhibit responding based on their own perspective. Without having some degree of executive control in place, children would be unable to express their ToM understanding on these tasks. As an example, in Wimmer and Perner's (1983) classic ToM task, the story character, Maxi, holds a false belief about the location of his chocolate. However, for children to be able to correctly report Maxi's perspective (i.e., *express* their understanding of Maxi's false belief), child participants must be able to maintain Maxi's perspective in working memory, inhibit the prepotent response to answer based on their own perspective which accurately represents reality, and ignore the highly salient stimuli in their environment (i.e., the true location of the chocolate). It is possible for children to fail false belief tasks and yet have false belief understanding if their inhibitory control and working memory are not well developed enough.

Empirical Research on the ToM-EF Relationship

Research examining the relation between ToM and EF provides evidence in support of both the emergence account and expression account. It is possible for both accounts to be valid because they are not mutually exclusive; they refer to different aspects of the developmental time course for ToM. The emergence account has been substantiated by longitudinal research. Several longitudinal studies have found that early

EF abilities predict later ToM abilities but not vice versa (Carlson et al., 2004; Flynn, 2007; Flynn, O'Malley, & Wood, 2004; Hughes, 1998a; Hughes & Ensor, 2007).

Evidence for the expression account comes from studies that manipulate the executive demands of a ToM task (Carlson et al., 1998; Hala & Russell, 2001; Leslie & Polizzi, 1998; Moses, 2001). For instance, a meta-analysis of ToM tasks examined whether seeing the true location or not of the chocolate at the time of reporting Maxi's false belief affected children's performance (Wellman et al., 2001). They found that when the child was not viewing the salient stimulus (seeing the true location of chocolate), the child was more likely to correctly report Maxi's belief. Thus, reducing the need to inhibit one's own salient knowledge in order to answer correctly allowed young children to be able to express their actual ToM understanding. Other studies that manipulated executive demands have found that as executive demands decrease, ToM performance increases, and conversely as executive demands increase, ToM performance decreases (Carlson et al., 1998; Hala & Russell, 2001; Leslie & Polizzi, 1998; Moses, 2001). These results indicate that EF influences the expression of ToM.

For the remainder of this section, I will focus on the specific relations that have been found among two domains of EF (WM and IC) on the one hand, and ToM on the other. In particular, I will review how facets of IC (i.e., delay and conflict IC) and facets of WM (i.e., verbal and non verbal WM) may differentially relate to ToM development.

Relations among facets of IC and ToM in young children. Research on typically developing young children suggests that IC plays a foundational role in the development of ToM (Best et al., 2009; Carlson & Moses, 2001; Carlson et al., 2003; Hala et al., 2003; Hughes, 1998a). Based on a principal components analysis, Carlson and

Moses (2001) found that there are two separable facets of inhibitory control, and that these facets are differentially related to ToM. They refer to one facet as delay IC, or the ability to simply inhibit a response for a period of time, and the other facet as conflict IC, or the ability to inhibit a prepotent (i.e., dominant or habitual) response in order to activate a conflicting response. An example of a delay IC measure is the Gift Delay task (Kochanska & Knaack, 2003), which requires children to turn away and, without peeking, wait for an experimenter to wrap a gift for them. A commonly used conflict IC task used with young children is the Day/Night task (Gerstadt, Hong & Diamond, 1994), in which children are instructed to say "day" when they see a picture of the moon and say "night" when they see picture of the sun.

The literature on inhibitory control in adults provides convergent evidence for a functional dissociation between delay IC and conflict IC. In the adult literature, a distinction is made between response inhibition and response selection (delay inhibitory control and conflict inhibitory control, respectively). In their theoretical paper on inhibitory control, Chambers et al. (2009) define response inhibition as, "the ability to *suppress* behaviours that are inappropriate, unsafe, or no longer required" (p. 632), whereas response selection involves the "selection of one motor response from numerous alternatives," (p. 638) with one of these alternatives possibly being a prepotent response (Mink, 1996). Adult data collected with a variety of techniques (i.e., neuroimaging, TMS, pharmacological) suggest that response inhibition and response selection are functionally distinct and supported at least in part by separate neural systems (Chambers et al., 2006; Chambers & Mattingley, 2005; Chambers et al., 2007; Rubia et al., 2001; Scheres et al., 2003; Wager et al., 2005).

These child and adult data on the functional dissociation between delay and conflict IC bring clarity to our understanding of the relationship between IC and ToM. Although studies have found that both delay IC and conflict IC tasks are significantly related to ToM performance in young children, conflict IC is more strongly correlated. However, delay IC tasks compared to conflict IC tasks have been found to have no or low correlation with each other (Carlson and Moses, 2001; Carlson, Moses, & Breton, 2002). Based on the assumption that delay and conflict IC are at least partially dissociable functions, it makes sense that they can be uncorrelated with one another but correlated with a third factor, such as ToM. Further, conflict IC has been found to significantly predict ToM performance over and above delay IC (Carlson & Moses, 2001; Carlson et al., 2002). Carlson and colleagues assert that conflict IC tasks relate strongly to ToM because standard ToM tasks require children to not only inhibit the prepotent response to answer based on their own accurate perspective of reality, but also to select a conflicting response based on another person's false perspective.

Relations among facets of WM and ToM in young children. In Baddeley's classic account (Baddeley & Hitch, 1974), WM is said to comprise two independent subsytems: a phonological loop primarily for verbal information processing (i.e., verbal WM) and a visuospatial sketchpad for visuospatial processing (visual WM). Similar to IC, research suggests that the two facets of WM, i.e., verbal WM and visual WM, may relate differentially to ToM (Carlson et al., 2002; Davis and Pratt, 1995; Gordon & Olson, 1998; Hughes, 1998a). In these studies, backward word span and backward digit span tasks are typically used as measures of verbal WM (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). Span tasks are commonly used measures of verbal

WM, and require participants first to listen to a series of items (i.e., words or digits) presented in a specific order and second to repeat back the items in reverse order (i.e., backward span). Verbal WM is most likely related to ToM because standard ToM tasks (i.e., Change-in-location task, Unexpected Contents task, Appearance-reality task) require participants to hold verbal information related to others' perspectives in verbal WM in order to respond correctly.

Most studies examining the relation between WM and ToM use measures of verbal WM. Those that include a measure of visual WM (e.g., self-ordered pointing task), however, incorporate it into an aggregate measure of WM that is composed primarily of verbal WM tasks (Hughes, 1998a; Hughes, 1998b). For this reason, there are no clear data that address the question of whether visual WM is correlated with ToM.

Evidence from studies of ToM in blind children suggests that visual WM might not play a necessary role in the development of ToM but could facilitate ToM understanding under certain circumstances. The few studies of ToM in blind children have found that performance on standard false belief tasks improves with age (McAlpine and Moore, 1995; Minter, Hobson, & Bishop, 1998; Peterson, Peterson, & Webb, 2000). These results indicate that the development of ToM in blind children may be delayed but it is not altogether deficient. McAlpine and colleagues speculate that delays in ToM development in blind children may be the result of limitations in their access to information that facilitates the development of ToM.

If visual WM were necessary for the emergence or expression of ToM, then impairments in ToM should perpetuate into later childhood and adulthood for blind individuals. However, this is not the case. These data support the hypothesis that visual

WM is not necessary for ToM development. However, visual WM may be necessary for ToM processing when an individual needs to make sense of complex social cues visually, such as when "reading" others' facial and body gestures. In addition, these data do not speak to the role that *spatial* WM may play in ToM development in blind children. Blind children generally have intact spatial WM. Thus, these findings do not clarify whether spatial WM is necessary for ToM development. Therefore, future research needs to clarify more directly whether a relationship between visual WM and ToM exists.

Relations among facets of ToM and EF in young children. Studies that have investigated the relation between ToM and EF in young children have primarily focused on examining cognitive aspects of ToM, or reasoning about others' beliefs and thoughts, via false belief tasks. ToM is a multifaceted construct, however, and understanding others' emotions and visual perspectives are crucial facets of a full-fledged ToM. To date, there are a limited number of studies that have examined how different facets of ToM relate to various facets of EF. A detailed analysis of the relations among these facets will allow us to assess whether the results of prior research can be generalized beyond cognitive aspects of ToM.

One study that has investigated the relation between emotional perspective taking and EF, found that emotion understanding and conflict IC were related in children 4 to 6 years of age (Carlson & Wang, 2007). In a study of visual perspective taking, children 3 years of age were asked to determine how drawings looked from another person's visual perspective (Carlson et al., 2004). Carlson et al. (2004) found no correlation between this visual perspective taking task and a battery of standard conflict IC measures. These negative results suggest that visual perspective taking may not be related to EF. On the other hand, a measure tapping both visual-perspective taking and cognitive perspective taking, the Appearance-Reality task, has been found to correlate with conflict IC measures in young children between 3 to 5 years of age (Carlson et al., 2001; Carlson et al., 2004). In the Appearance-Reality task, children are shown objects with misleading appearances, such as a sponge that looks like a rock. After revealing the true identity of the objects, children are asked what the object actually is, as well as what it looks like. The Appearance-Reality task relative to the visual perspective taking task used in Carlson et al. (2004) has greater executive demands. The greater salience of the visual appearance of the misleading objects in the Appearance-Reality compared to the Carlson et al. (2004) visual perspective taking task most likely requires more inhibitory control to suppress one's own visual perspective in order to respond correctly. Therefore, it is likely that as the executive demands of a visual perspective taking task increase, the stronger the correlation between the visual perspective taking task and EF tasks will be.

Relations among facets of ToM and EF in adolescence. As social situations become more complex during adolescence, EF may play a larger role in ToM processing. In everyday social interactions, adolescents need to keep track of multiple and often discordant perspectives while attending to increasingly subtler levels of verbal and nonverbal communication. The demands of social interactions increase dramatically during adolescence and likely increase the cognitive load on working memory and inhibitory control. Thus, examining the relation between ToM and EF in adolescence may elucidate what role EF plays in the maturation of ToM.

It is not clear whether ToM in and of itself is still developing during adolescence or whether the increased executive control required to understand complex social situations during adolescence constrains the expression of ToM in adolescence. Behavioral studies indicate that EF, specifically IC and WM, continue to mature during adolescence (Conklin, Luciana, Hooper, & Yarger, 2007; Hooper, Luciana, Conklin, & Yarger, 2004; Leon-Carrion, Garcia-Orza, & Perez-Santamaria, 2004; Luciana, Conklin, Hooper, & Yarger, 2005; Luna, Garver, Urban, Lazar, & Sweeney, 2004). For instance, in a verbal and visuospatial WM study of children and adolescents ranging in age from 9 to 17 years (Conklin et al., 2007), these WM facets continued to develop, as measured by forward and backward span tasks (i.e., digit, word, and spatial span tasks).

In addition to advances in WM, adolescents also appear to undergo development in conflict IC. For example, 6- to 17-year-olds continue to show improvement on the Stroop task (Leon-Carrion et al., 2004). This task (Stroop, 1935) requires participants under some conditions to read words that name different colors (e.g., green, red, blue) and, in other conditions, say the ink color the word is printed in. For the critical test of inhibitory control, participants are required to say the ink color that a word is presented in (e.g., red) while ignoring the meaning of the printed word (i.e., blue), which is incongruent with the color of the ink. This incongruent condition requires participants to inhibit their automatic response to read words.

Because EF abilities, specifically IC and WM, are still maturing during adolescence, the development of EF may place constraints on the development or at least expression of more sophisticated ToM reasoning that manifests itself during complex social interactions arising in adolescence. Research on adolescents and adults would clarify the nature of the relation between EF and ToM. Although emergence of ToM abilities is no longer an issue in adolescence, one question that remains unanswered is whether IC and WM are still necessary for the expression of ToM understanding past the preschool years. Research on this issue is limited but suggests that adolescents (Dumontheil et al., 2010; Epley et al., 2004) and adults (Apperly, et al., 2007; Samson, Apperly, Kathirgamanathan, & Humphreys, 2005) may still need to draw upon EF in order to express their understanding of others' minds.

Dumontheil et al. (2010) and Epley et al. (2004) both used Keysar's referential communication game in order to examine the influence EF may have on ToM processing in adolescents. Epley et al. found that children 4-12 years of age made significantly more errors than adults. However, eye-tracking data revealed that adults were equally likely as children to first interpret instructions egocentrically. The difference was that adults were quicker and more likely to correct this egocentric bias. Based on the findings from their series of studies using the referential communication task, Keysar and colleagues (Epley et al., 2004; Keysar, Lin, & Barr, 2003) argue that both adults and children suffer from an egocentric bias in their interpretation of other minds, but adults have more mature EF processes that allow them to correct their egocentric bias. Consistent with this view, Apperly and colleagues have found that some aspects of executive function may be necessary for the *expression* of belief reasoning in adults, especially in cases where they need to resist the interference of their own egocentric perspective (Apperly et al., 2007; Samson et al., 2005). In combination, these data suggest that ToM processing becomes more efficient as relevant EF abilities mature.

Unlike Epley et al. (2004), Dumontheil et al. (2010) included a control condition in order to examine whether EF ability fully accounted for differences between adolescents and adults in ToM processing. The control condition was identical to the

Director condition, except for the absence of the director. Additionally, participants were told that a computer would administer instructions instead of the director, and that instructions would refer to shelves that did not have a grey background. The control condition involved the same EF demands as the Director condition but did not recruit ToM processing. Dumontheil et al. found that for adolescents between 14-17 years of age compared to children between 7-9 years of age, accuracy improved similarly on both conditions, suggesting that improvements in ToM may be accounted for by improvements in EF. On the other hand, these adolescents relative to adults did not differ in performance on the control condition, but made more errors than the adult group on the experimental condition. The researchers maintain that adolescents relative to adults are still developing a propensity to take others' perspectives.

Dumontheil et al. (2010) argue that improvements in EF may contribute to improvements in ToM during adolescence, but that EF improvements do not fully account for development in the propensity to take others' perspectives. Further research on adolescents is needed in order to test this hypothesis.

To date, there is no one study that has examined the IC and facets of WM in relation to ToM development in adolescents. The proposed dissertation research will assess ToM and EF in adolescents, in order to enrich our understanding of potential advances in ToM past middle childhood, as well as to provide insights into the role that EF may play in the expression and maturation of ToM.

Autism Spectrum Disorders

Adolescents with delays or impairments in EF and/or ToM will be at a grave disadvantage during social interactions. Essentially, they will be left behind, unable to keep up with the quick pace and increasing complexity of social interactions that arise during adolescence. Adolescents with Autism Spectrum Disorders (ASD), a developmental disorder characterized by impairments in both ToM and EF, may fall into this category. Teens with ASD tend to lack quality friendships, feel marginalized, and are often the target of bullies and victimization (Shtayermman, 2007; van Roekel, Scholte, & Didden, 2010; Whitehouse, Durkin, Jaquet, & Ziatas, 2009). Empirical research on ToM and EF in adolescents with Asperger's Syndrome would enrich our understanding of the relation between ToM and EF, as well as potentially provide greater insights on how to better prepare teens with EF and/or ToM deficits for the often stressful and socially demanding middle school and high school years.

Profile, Prevalence, and Etiology of ASD

Autism Spectrum Disorders (ASD), referred to as Pervasive Developmental Disorders in the DSM-IV, are a set of complex neurodevelopmental disorders that all share a triad of impairments in reciprocal social interaction, verbal and nonverbal communication, and repetitive and restricted interests and behaviors (APA, 1994). Autism is considered a spectrum disorder because symptoms may manifest in the lower-functioning end of the spectrum, with clinically significant delays in cognitive development, up to the higher functioning end, with no general delays in cognitive development. Those diagnosed with Asperger's Syndrome fall in the higher functioning category, with average to above average IQs.

Recently, the Centers for Disease Control (2009) reported that the prevalence of autism has reached nearly epidemic proportions, 1 in 110. Further, there is a clear gender difference; for every four boys diagnosed with an ASD, one girl receives an ASD diagnosis. There are many unknowns that surround this disorder, but what is known is that this is a prevalent disorder greatly impacting families, communities and educational systems. The etiology of autism is controversial. However, research suggests that both genes and environment play a causal role in the development of autism (Allred & Wilbur, 2002; Desmond, Wilson, & Melnick, 1967; Folstein & Rosen-Sheidley, 2001; Korvatska et al., 2002; Ritvo et al., 1990; Rutter, Bailey, Siminoff, Pickles, 1997). It is critical that future research efforts strive to uncover the causes and resulting impairments that characterize this complex neurodevelopmental disorder.

Theoretical Background on ASD Symptomatology

Both theory of mind and executive function deficits are present in individuals with autism (Colvert, Custance, & Swettenham, 2002; Joseph & Tager-Flusberg, 2004; Ozonoff, Pennington, & Rogers, 1991; Pellicano, 2007b). For this reason, the study of ASD provides insights into the development of the cognitive impairments that impact the lives of those with autism, as well as insights into the causal relation between ToM and EF. Russell (1996, 1997, 2002) set forth the Executive Dysfunction theory, which posits that EF deficits present early in life disrupt the development of ToM, leading to the social and communication symptomatology characteristic of ASD. Relatedly, Pennington and colleagues (1997) argue that, “executive dysfunction is basically a disruption in the planning and execution of complex behavior due to limitations in working memory, or perhaps in some cases, to a specific inhibitory deficit” (pp. 148). This theory aligns well with the emergence and expression accounts of ToM that suggest EF, in particular WM and IC, is necessary for the very emergence as well as ability to express ToM understanding. If impairments in EF exist early in life, as is the case with ASD, then as Russell and Pennington propose, ToM impairments should result.

In the following sub-sections, I will first review the literature on ToM deficits and then deficits in IC and WM in ASD. Subsequently, I will evaluate the Executive Dysfunction hypothesis by examining the evidence for impairments in EF relating to ToM impairments in the ASD population.

Theory of Mind Deficits in ASD

In their seminal paper, Baron-Cohen et al. (1985) found that children with higher functioning autism (i.e., IQ in the average to above average range) compared to children with Down's syndrome and typically developing controls performed significantly worse on ToM tasks, specifically false belief tasks. Following up on this study, Baron-Cohen, Leslie, and Frith (1986) examined the specificity of the ToM impairment in children with ASD using a picture sequencing task. In this task children read about three different types of stories involving non-mental state content (i.e., physical-mechanical and social-behavioral) and mental-state content (i.e., false beliefs). Compared to children with Down's syndrome and typically developing children, children with ASD were significantly impaired in their understanding of others' beliefs but not in understanding non-mental state content. Leslie and Frith (1988) extended their research beyond the concept of false belief to include the concept of limited knowledge, or understanding that one can be privy to information that others lack. In comparison to children with specific language impairment (SLI), children with ASD had a gross delay in their concept of limited knowledge.

Additionally, even individuals, such as those with High Functioning Autism and Asperger's Syndrome, who may pass ToM tasks like false belief, tend to fail more subtle tests of theory of mind, such as understanding faux pas, judging mental states from only the eyes or voice, and understanding stories involving advanced ToM concepts such as persuasion (Baron-Cohen et al., 1985; Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999; Brent, Rios, Happé, & Charman, 2004; Kaland, Callesen, Møller-Nielsen, Mortense, & Smith, 2008; Peterson, Wellman, & Slaughter (2012); Baron-Cohen, & Wheelwright, 2002).

One of the most widely used advanced measures of ToM was designed by Happé (1994) in order to assess ToM abilities in high functioning individuals with autism. These stories depict social situations involving, for instance, persuasion, white lies, misunderstandings, and double bluffs. The stories are followed by questions to assess participants' understanding of the psychological reasons for the character's words or actions. Happé found that compared to typically developing children and adults as well as children and adults with mental retardation, high functioning children and adults with autism performed worse on providing appropriate explanations of the story characters' nonliteral utterances. Even those individuals with autism who passed standard ToM tasks, showed impairments in their understanding of these more naturalistic and complex social situations. Taken together, these data suggest that the ToM deficit persists into adulthood even for those with high functioning autism.

Nonetheless, performance on ToM tasks does appear to improve with development in the ASD population. For example, Leslie and Frith (1988) found an age-related trend, such that older children with ASD were more likely to pass standard ToM tasks. There are two different possibilities that could account for these data. On the one hand, a subset of children with ASD may actually develop genuine ToM understanding and recruit the same brain mechanisms utilized by typically developing individuals during ToM processing. On the other hand, some children with ASD may learn compensatory skills that allow them to "solve" ToM problems, and thus may recruit separate or additional neural systems when engaged in ToM processing. Leslie and Frith favor the second alternative. They argue that children with ASD do not acquire a genuine ToM, but rather they learn compensatory skills to mask their disability. Several prominent autism researchers (Bowler, 1992; Happé, 1995; Leslie & Frith, 1988; Yirmiya, Sigman, Kasari, & Mundy, 1992) agree with this view. Happé (1995), for example, asserts that high functioning individuals with autism "solve theory of mind tasks in an unusually conscious and logical way, for example, looking as if they are doing 'mental arithmetic' before eventually giving the correct answer" (p. 852).

To examine this hypothesis, it is necessary to develop more sophisticated measures of ToM that involve novel social contexts for individuals with ASD so they will not have had the opportunity to develop compensatory strategies to handle the situations. Such measures would allow researchers to evaluate whether older children and adults with ASD are truly impaired in ToM or whether they can actually out-grow their impairments in ToM.

Executive Function in ASD

In the Executive Dysfunction hypothesis, Russell (1997) proposes that disruptions in the early development of EF abilities have cascading effects, leading to impairments in the ability to represents others' minds, or ToM. Russell applies this theory to the specific case of ASD, in which both EF and ToM impairments have been found. However, the Executive Dysfunction hypothesis is vague. It does not characterize the exact nature of the EF deficits responsible for ToM impairments. Pennington et al. (1997) argue that a deficit in WM and possibly IC disrupts the acquisition and use of concepts fundamental to ToM understanding. Although Pennington et al. help refine the Executive Dysfunction hypothesis, it is important to discriminate between the roles that particular facets of IC (i.e., delay IC and conflict IC) and WM (i.e., verbal and visual WM) may play in ToM development. I would argue that a specific deficit in only one facet of IC or WM critical to ToM development, such as conflict IC or verbal WM, would be sufficient to disrupt the acquisition and use of ToM. Future research that examines specific facets of IC and WM will help to refine the Executive Dysfunction hypothesis.

Many studies that have examined EF abilities in autism have used tasks that tap a variety of EF abilities in addition to WM and IC. For instance, several studies have assessed EF in higher functioning adolescents with autism with the Tower of Hanoi task, which taps WM and IC as well as planning, and the Wisconsin Card Sorting task, which involves set shifting in addition to WM and IC (Hughes, 1993; Hughes, Russell, & Robbins, 1994; Ozonoff et al., 1991; Ozonoff & McEvoy, 1994). In these studies, participants with higher functioning autism were found to be impaired relative to typically developing matched controls and a variety of other clinical control groups, including Tourette Syndrome and Attention-Deficit Hyperactivity Disorder (ADHD) groups.

Although executive dysfunctions appear to be present in the autism profile, the exact nature of those deficits is in need of further investigation. Unfortunately, the impurity of the EF measures used in the abovementioned autism studies does not allow for clear interpretation of WM or IC abilities in autism. Deficits in any one of the executive functions tapped by the EF tasks would result in poor performance. Therefore, based on these studies, one cannot clearly assess the specificity of the Executive Dysfunction hypothesis.

Although these studies do not specifically assess WM or IC deficits in the ASD population, a number of autism studies have used more pure measures of WM and IC that are not confounded with other executive functions, such as planning and set-shifting (Alloway, Rajendran, & Archibald, 2009; Bennetto, Pennington & Rogers, 1996; Burack et al., 2009; Fletcher-Watson et al., 2006; Goldberg et al., 2005; Ozonoff and Strayer, 2001; Williams, Goldstein, Carpenter, & Minshew, 2005). A review of this literature is presented below. These studies point towards an autism profile with deficits and possible strengths in aspects of working memory and inhibitory control.

Inhibitory control in ASD. In this section, I will review the literature on IC in ASD. Further, I will present an argument for how conflict IC and delay IC may differentially characterize the ASD profile. In particular, I will argue that individuals with ASD present with impairments in conflict IC, yet intact delay IC. Below I will provide evidence for this hypothesis. Further, I will relate how this dissociation in the IC profile of autism relates to the ToM deficit characteristic of ASD and provides support for the Executive Dysfunction hypothesis.

Delay IC in ASD. Traditional measures of delay IC, specifically the Stop-Signal task and Go/No-Go task, have been used to assess the ability to *inhibit* or stop a prepotent response in participants with ASD. Unlike many EF tasks that tap multiple EF abilities at the same time, these two IC tasks place minimal to no demands on set-shifting and planning abilities, and thus provide a purer measure of IC. In the Stop-Signal task (Logan, 1994), participants are instructed to identify as quickly as possible the target stimulus (e.g., stimulus presented is an X or O; target is an X). On the critical trials, a stop-signal occurs (e.g., auditory tone) which indicates participants should inhibit their response. This stop-signal occurs at random and infrequently and thus requires the participant to inhibit the automatic response of pressing a key every time the target stimulus appears. For this reason, accuracy on stop-signal trials is used as a measure of response inhibition. Based on a Stop-Signal paradigm, no differences in accuracy for the stop-signal condition were found between high functioning children with ASD compared to age and IQ matched typically developing controls (Ozonoff & Strayer, 1997).

The Go/No-Go paradigm has also been used to assess delay IC in ASD. In this classic paradigm, participants are instructed to press a button when one stimulus type appears (e.g., all letters except A) and withhold a response when the no-go stimulus appears (e.g., letter A). Given that a response is required on the vast majority of trials, participants must inhibit a habitual response when they are presented with the no-go stimulus. In three separate experiments employing a Go/No-Go task, high functioning children and adolescents with ASD performed equivalently to typically developing matched controls on the no-go trials (Christ, Holt, White, & Green, 2007; Happé, Booth, Charlton, & Hughes, 2007; Ozonoff & McEvoy, 1994). In summary, the results from the Stop-Signal and Go/No-Go tasks indicate that individuals with high functioning ASD most likely are not impaired in delay IC.

Conflict IC in ASD. On the other hand, there is evidence that individuals with ASD may be impaired in conflict IC. Traditional paradigms for conflict IC, such as the Eriksen Flanker task, Windows task, Detour Reaching task, and Luria's Hand-Game, have been used to investigate whether participants with ASD are able to inhibit a prepotent response in order to *select* an appropriate response. For example, on the Eriksen Flanker task, participants are shown a row of stimuli (e.g., arrows) and are instructed to identify the direction of the central arrow target, which may be flanked by arrows that point in the same direction as the central arrow (congruent condition) or distractor flanker arrows that point in the opposite direction (incongruent condition). The incongruent condition assesses conflict IC because it requires participants to withhold from responding based on the salient distractor stimuli and instead select a response according to the direction of the target stimulus. The difference in reaction times on the incongruent versus congruent conditions provides a measure of conflict IC. On an Eriksen Flanker task, high functioning children and adolescents with ASD were found to have longer reaction times than typically developing matched controls, suggesting that in the ASD population conflict IC may be dysfunctional (Christ et al., 2007).

Further research on response selection in ASD has examined the ability of individuals with ASD to inhibit a strongly desired response option in favor of a task-relevant response option. For example, high functioning children and adolescents with ASD performed significantly worse than children with moderate learning difficulties on the Windows task (Hughes & Russell, 1993). This is a task in which children must point to an empty box, rather than a box baited with chocolate, in order to actually receive the candy. Similarly, a Detour Reaching task, requiring children to reach for a candy reward indirectly rather than directly, revealed poorer performance in higher functioning children and adolescents with ASD compared to typically developing controls matched on verbal mental age (Hughes et al., 1993).

In addition, performance on a classic measure of response selection, Luria's Hand Game, was examined in high functioning 5-6 year old children with ASD compared to typically developing children matched on age and IQ (Pellicano, 2007b). In this task children are given two conditions: the imitative condition and the conflict condition. In the imitative condition, children are instructed to make the same hand gestures (i.e., point a finger or make a fist) as the researcher, whereas in the conflict condition children are supposed to make the opposite hand gesture (e.g., point a finger when the researcher makes a fist). Pellicano (2007b) found that young children with ASD compared to matched controls performed significantly worse on Luria's Hand Game. In summary, the data on response selection in ASD suggest that individuals with ASD have a deficit in this executive ability.

Delay and conflict IC: Implications for the ASD profile. Differentiating between delay IC and conflict IC helps to clarify why mixed results have been found for inhibitory control tasks in participants with ASD. The evidence presented above underscores a distinction in the IC profile of ASD, with intact delay IC on the one hand and deficits in conflict IC on the other. This ties in elegantly with the typically developing literature on young children regarding the relation between EF and ToM. The typically developing literature suggests that delay and conflict IC are differentially related to ToM, and that conflict IC is necessary for the emergence and expression of ToM. It follows then that intact delay IC but impaired conflict IC would generate deficits in ToM. I hypothesize that this is the case for individuals with ASD. It is important to examine conflict IC and ToM within the same ASD sample in order to test this specific hypothesis.

To my knowledge, there is only one study that has investigated the specific relation between conflict IC and ToM in the ASD population (Pellicano, 2007b). High functioning children with autism between four to seven years of age participated in the study. Pellicano (2007b) found that a ToM battery, comprised of a Change-in-location task, Unexpected Contents task, and a second-order Change-in-location task, was correlated with a measure of conflict IC, Luria's hand game, even after age was controlled. Other studies that have examined the relation between ToM and EF impairments in individuals with ASD, used aggregate measures of EF, including conflict IC as well planning and set-shifting tasks (Pellicano, 2006; Pellicano, 2010a). For this reason, Pellicano (2007b) is the only study that has explored the specific relation between conflict IC and ToM in the ASD population. Given the understudied nature of this area of research, it is important that future investigations examine the relation between ToM on the one hand and conflict IC on the other in individuals with ASD compared to typically developing individuals.

Working memory in ASD. Just as different facets of IC may be differentially related to the ASD profile, so too may different facets of WM be differentially related to the ASD profile. The general pattern of findings suggests that verbal WM may be impaired in ASD whereas visual WM may be spared. However, in both domains, there are inconsistent results. In this section, I will present a review of the WM literature on autism and highlight potential strengths and weaknesses in the WM profile of autism. I will further explain how the general pattern of results for WM abilities in ASD is consistent with the Executive Dysfunction hypothesis.

Verbal working memory in ASD. A handful of studies have specifically examined verbal working memory in autism. However, only one of these studies included a typically developing control group and found no deficits in verbal WM in higher functioning children and adults with ASD (Williams et al., 2005). The other two studies used clinical control groups, making it somewhat difficult to interpret the data, but suggesting that verbal WM is impaired in higher functioning ASD (Alloway et al., 2009; Bennetto et al., 1996). Overall, these studies do not provide a clear picture of the verbal WM abilities in ASD.

In a study on verbal WM comparing higher functioning children, adolescents, and adults with ASD to typically developing controls matched in terms of age, verbal IQ, and performance IQ, participants were administered an N-Back Letter task and a Letter-Number Sequencing test (Williams et al., 2005). The N-Back task requires participants to view a continuous stream of items, such as letters, and respond when the current item matches the stimulus presented a designated number (N) of stimuli back. For the Letter-Number Sequencing Test, the participant is read strings of letters and numbers ranging in span from 2 to 8 items, and is instructed to recall the letters in alphabetical order and the numbers in ascending numerical order. Neither of the verbal WM tests revealed statistically significant differences for the ASD Child/Adolescent Group compared to the Control Child/Adolescent Group, or for the ASD Adult Group relative to the Control Adult Group.

Contrary to these findings, two other studies utilizing clinical comparison groups did find impaired performance on verbal WM in higher functioning ASD groups. In Bennetto et al. (1996) higher functioning children and adults with ASD were matched on gender, age, and full-scale IQ to a clinical comparison group consisting of individuals with various psychiatric and learning disorders (i.e., borderline intellectual functioning, dyslexia, ADHD, genetic disorder, unspecified learning disorder). The researchers employed a battery of verbal WM tasks, including forward, backward, and complex span tasks. Bennetto et al. (1996) found that the high functioning ASD group relative to the clinical comparison group performed significantly worse on the complex span tasks but equivalently on the forward and backward span tasks. Similar to Bennetto et al. (1996), another study of verbal WM utilizing clinical comparison groups found that children with Asperger's Syndrome performed worse than an ADHD group on an aggregate measure of forward and backward span tasks and performed better than the ADHD group on a set of complex span tasks.

Taken together, these two studies suggest that individuals with higher functioning ASD may be impaired in verbal WM. However, on certain verbal WM tasks, the higher functioning ASD group performed equivalently to or better than the clinical comparison groups. It is important to note that this does not mean individuals with ASD may have intact verbal WM. It may be the case that the clinical group itself has challenges with EF and thus performing equivalently or better than them may still mean worse performance than a typically developing group. Clearly there is a need for further research that incorporates a typically developing matched control group to properly address the question of whether children and adults with ASD are impaired in verbal WM.

Visual working memory in ASD. The typically developing literature suggests that visual WM may not be necessary for ToM development. If this is the case, then it is possible for the ASD profile to consist of impairments in ToM with intact visual WM. Research on visual WM deficits in ASD provides mixed results. A number of studies indicate that individuals with ASD have intact visual WM (Alloway et al., 2009; Burack et al., 2009; Fletcher-Watson et al., 2006; Ozonoff & Strayer, 2001), whereas other studies suggest that individuals with ASD have impaired visual WM abilities (Goldberg et al., 2005; Russell, Jarrold, & Henry, 1996; Williams et al., 2005).

Two studies using a visual forward span task, in which the participants had to recall in correct order the location of presented target stimuli, found that high functioning children and adults with ASD did significantly worse than typically developing controls on these tasks (Russell et al., 1996; Williams et al., 2005). Additionally, Goldberg et al. (2005) revealed that children with high functioning ASD compared to typically developing children and children with ADHD were impaired on a test of visual WM as measured by a box search task in which participants were instructed to search through colored boxes for treasures while being careful not to search the same box twice. These three studies suggest that visual WM may be impaired in ASD.

Conversely, several other studies suggest that visual WM is intact in ASD (Alloway et al., 2009; Fletcher-Watson, Leekam, Turner, & Moxon, 2006; Burack et al., 2009; Ozonoff & Strayer, 2001). One study explored visual WM in a group of children with Asperger’s Syndrome compared to three other clinical groups, i.e., ADHD, Specific Language Impairment, Developmental Coordination Disorder (Alloway et al., 2009). In the study they used three measures of visual forward span tasks. The group with

Asperger's Syndrome outperformed the ADHD group and did not significantly differ from the other two groups. These data suggest that visual WM in individuals with ASD may be intact. However, a typically developing control group is needed to draw sound conclusions about whether visual WM abilities are intact in the ASD cognitive profile.

More convincing data for intact visual WM in ASD comes from a study that included a typically developing control group and a battery of well-established visual tasks (Ozonoff & Strayer, 2001). The battery consisted of a visual N-Back task, a visual span task, and the Box Search task. The visual N-Back task is identical to the verbal span task except the participant must indicate whether a geometric shape (e.g., square), rather than a letter or number, on the current trial matches the shape presented a certain number of trials ago. Using this variety of visual WM tasks, Ozonoff and Strayer found no differences on any of the tasks between higher functioning children and adolescents with ASD and typically developing children as well as children with Tourette Syndrome.

Additional studies that provide confirmatory evidence for intact visual WM in ASD utilized a change detection paradigm (Burack et al., 2009; Fletcher-Watson et al., 2006). In these studies, participants were presented with one sample array at a time for a brief period (e.g., 250 ms), and then after a short delay, were shown a target array in which they had to respond as to whether there was a small change in the target array compared to the sample array. In order to respond correctly, the participant needed to be able to hold the sample image in visual WM. The higher functioning participants with autism performed equally as well as typically developing matched controls on this visual measure of WM.

In sum, although these studies have laid the groundwork for research on visual WM in autism, the fact that they have provided mixed results underscores the need for further exploration in this area. In order to elucidate the nature of visual WM in the autism profile, it will be necessary to employ more pure measures of visual WM. Further, the relation specifically between visual WM and ToM has yet to be examined in the autism population.

Evaluating the Executive Dysfunction Hypothesis Through the Lens of ASD

The study of ASD has the potential to provide great insights into our understanding of the causal nature of the relation between ToM and EF. Based on the Executive Dysfunction hypothesis, Russell and other researchers maintain that if EF is necessary for the emergence and expression of ToM, those who present with a deficit in EF, such as individuals with ASD, must also present with a deficit in ToM. Further, they argue that it would not be possible for an individual to develop a fully functional ToM with impaired EF (Ozonoff & McEvoy, 1994; Pellicano 2007a; Russell, 1996, 1997, 2002). On this account, it would however be possible for an individual to have intact EF but impaired ToM because EF is necessary but not sufficient for ToM to develop fully. From an alternative theoretical perspective, Perner and colleagues argue that deficits in ToM lead to deficits in EF (Perner, 1998, 2000; Perner & Lang, 1999, 2000). Thus, early impairments in ToM development would disrupt development of EF.

To date, the majority of data favor the theoretical perspective that impaired EF contributes to impaired ToM. For example, Pellicano (2007b) examined the relationship between ToM as measured by false belief tasks and components of executive function (inhibition, planning, set shifting) in young children with ASD. A significant correlation between ToM and EF was found. Further, some individuals with ASD manifested impairments in EF and ToM but no participants showed a pattern of intact ToM and deficits in EF. These findings suggest that executive deficits may be the primary cognitive deficit in ASD. Consistent with this hypothesis, a training study on children with ASD demonstrated that improved ToM performance was related to training on executive functions two months prior but the reverse pattern was not found (Fisher & Happé, 2005). In addition, longitudinal studies of young children with high functioning ASD revealed that EF skills (i.e., planning ability and cognitive flexibility) were longitudinally predictive of later ToM ability but the opposite pattern was not found (Pellicano, 2010b). Taken together, these data indicate that executive function deficits may lead to social impairments in individuals with ASD. Moreover, these findings elucidate our understanding of the relationship between ToM and EF by suggesting that EF is key to the emergence and expression of ToM.

However, these studies tend to use complex tasks that tap multiple EF abilities, such as set-shifting tasks which place demands on working memory and inhibitory control in addition to set shifting (Pellicano, 2007b, 2010a, 2010b). Given the clear role that IC and WM play in the development of ToM in typically developing young children, it is necessary to examine whether impairments in IC and WM are related to deficits in ToM in ASD. Examining the pattern of deficits in the ASD population regarding ToM and EF may shed light on the validity of the Executive Dysfunction hypothesis. Moreover, examining the specific relations among facets of IC and WM and ToM will help provide evidence necessary for the refinement of the Executive Dysfunction hypothesis regarding what is meant by EF deficits.

Research Goals

The purpose of the current study on ToM and EF was two-fold. First, I aimed to investigate *typical development* of ToM and EF in older children and adolescents. The focus of ToM research has for the most part been on the first five years of life, and only a limited number of studies have explored ToM development in adolescence. Even fewer studies have explored the relation between ToM and EF in adolescence. Second, I aimed to extend this line of research to older children and adolescents with AS/HFA. This atypical population is of particular interest because further clarification is needed regarding the specific nature of *impairments* in ToM and EF and their interrelations.

I tested a total of 80 participants, half TD and half with AS/HFA, on a battery of ToM tasks tapping facets of emotional and cognitive perspective taking and a battery of EF tasks assessing verbal WM, visual WM, and IC. These data allowed me to address the following research questions regarding ToM (emotional and cognitive perspective taking) and EF (verbal WM, visual WM, and IC):

- ***Research Question 1*: *Group Differences in ToM and EF***

  Are older children and adolescents with AS/HFA impaired in ToM and/ or EF relative to their TD peers?

- ***Research Question 2: Development of ToM and EF***

  Are there age-related improvements in ToM and EF in older children and adolescents who are TD or have AS/HFA?

- ***Research Question 3: Individual Differences in ToM and EF***

  Do individual differences in ToM relate to individual differences in EF in older children and adolescents who are TD or have AS/HFA?

CHAPTER II

METHOD

Participants

In total, 80 older children and adolescents participated in the study; 40 typically developing (20 male; 20 female) and 40 with Asperger's syndrome or high functioning autism (AS/HFA) (20 male; 20 female). Typically developing participants were matched to the participants with AS/HFA on chronological age and gender. Participants were tested across two test sessions. See Table 1 for information regarding participant characteristics. For Session 1, the TD participants ranged in age from 10.1 to 17.9 years (M = 14.68, SD = 2.05), and the participants with AS/HFA ranged in age from 10.2 to 17.9 years (M = 14.64, SD = 2.19). Approximately one year after their Session 1, TD participants (M = 15.60, SD = 2.39) and participants with AS/HFA (M = 15.92, SD = 2.16) came in for their Session 2. Regarding participant retention, 3 TD males, 4 AS/HFA males, and 4 AS/HFA females declined to participate in Session 2. The subset of participants who returned for Session 2 did not differ from the participants in Session 1 in terms of IQ, autistic traits, or ADHD traits.

Based on the DSM-IV, an IQ of $\leq$ 70 is considered the cut off point for mental retardation. All participants in the study had a composite IQ > 70, except one girl with AS/HFA, who received a composite IQ score of 68. Both her verbal and nonverbal scores, however, were $\geq$ 70. Therefore, I elected to keep her in the study. The AS/HFA group had significantly lower verbal IQ and composite IQ scores than the TD group (ps < .05), but they did not significantly differ in nonverbal IQ. Further, there was a gender effect, such that the girls as a whole had lower nonverbal IQ ($p < .05$). One parent

Table 1

Participant Characteristics for both Typically Developing Children and Children with AS/HFA

	TD			AS/HFA				
	Males	Females	Total	Males	Females	Total	Group Effect	
Variable	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	*F*	η^2
Age T1	14.55 (1.99)	14.72 (2.41)	14.638 (2.19)	14.40 (1.76)	14.90 (2.35)	14.64 (2.05)	<.01	<.01
Age T2	15.64 (2.21)	15.56 (2.61)	15.60 (2.39)	15.49 (1.81)	16.38 (2.74)	15.92 (2.16)	.36	.01
IQ								
V.	114.76 (14.44)	112.44 (16.34)	113.69 (15.18)	104.67 (14.24)	99.58 (18.72)	102.25 (16.50)	10.19**	.12
N.V.	110.86 (12.20)	107.22 (11.68)	109.18 (11.94)	111.10 (12.43)	102.05 (18.79)	106.80 (16.22)	.61	.01
Comp.	114.95 (13.66)	111.61 (14.94)	113.41 (14.17)	109.48 (13.19)	101.00 (20.33)	105.45 (17.27)	5.16*	.07
ASD								
ASDS	45.24 (11.40)	48.50 (12.85)	46.74 (12.04)	116.24 (16.72)	114.79 (16.26)	115.55 (16.31)	440.96***	.86
KADI	61.94 (8.25)	62.44 (7.41)	62.19 (7.75)	89.24 (19.45)	87.73 (12.31)	88.53 (16.26)	72.86***	.53
AQ	14.05 (6.62)	13.67 (7.78)	13.87 (7.08)	34.14 (8.92)	32.05 (7.70)	33.15 (8.33)	119.61***	.62
ADHD								
Inatn.	50.89 (7.04)	51.29 (9.77)	51.09 (8.35)	69.59 (15.13)	68.60 (13.37)	69.13 (14.11)	39.88***	.39
Hyper.	53.06 (12.01)	50.71 (10.18)	51.91 (11.06)	73.53 (15.38)	67.33 (13.42)	70.63 (14.60)	34.72***	.36
Comb.	51.97 (8.37)	51.00 (9.35)	51.50 (8.74)	71.56 (12.89)	67.97 (12.06)	69.88 (12.44)	48.20***	.43

Note. ADHD traits indexed by Connors 3 Parent Report. Age T1 = age at Session 1; Age T2 = age at Session 2; V. = verbal IQ; N.V. = nonverbal IQ; Comp. = composite IQ; Inatn. = inattention; Hyper= hyperactivity; Comb. = Combination of inattention and hyperactivity. *Ns* for Total scores ranged from 67 – 80 and *ns* broken down by group and gender ranged from 15 - 21.
$*p \leq .05$. $**p \leq .01$. $***p \leq .001$.

typically the mother, of each of the 80 participants also participated in the study. Child participants received monetary compensation of $25 for their participation in the study, $10 for Session 1 and $15 for Session 2.

Typically developing participants were screened for a variety of neurological and developmental disorders (Appendix A) before being accepted into the study. For participants with AS/HFA, parents reported the type of professional(s) who diagnosed/ identified the child as being on the autism spectrum and provided secondary confirmation of the diagnosis by completing three separate measures of autistic traits: *Asperger's Syndrome Diagnostic Scale* (ASDS; Myles, Bock, & Simpson, 2001), *Krug Asperger's Disorder Index* (KADI; Krug & Rick, 2003), and *Autism-Spectrum Quotient - Adolescent Version* (AQ; Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006). These three measures revealed strong group differences in autistic traits, with the AS/HFA group demonstrating significantly more autistic traits than TD group, $ps < .001$ (see Table 1). Further, the AS/HFA group reached the threshold for Asperger's Syndrome on all three measures, whereas the TD group did not.

In addition, the AS/HFA group scored significantly higher than the TD group on scales of inattention and hyperactivity/ impulsivity from the *Conners Third Edition* (Conners, 2008), a measure of Attention Deficit Hyperactivity Disorder (ADHD) traits. Moreover, the AS/HFA group scored in the 97 percentile or higher for these two ADHD scales, while the TD group scored in the average range. These scores strongly suggest that the AS/HFA group had clinical levels of ADHD traits and confirm that the TD group was typically developing in terms of ADHD traits. These findings are consistent with clinical studies, which report between 50% to 95% of higher functioning children with ASD demonstrate clinical levels of ADHD traits of inattention and hyperactivity/ impulsivity (Goldstein & Schwebach, 2004; Sturm, Fernell, & Gillberg, 2004).

Typically developing participants were recruited from Eugene, Oregon, through three sources: (1) the developmental database maintained by the Department of Psychology at the University of Oregon, (2) a contact list including parents of typically developing children who had participated in previous research in my lab and expressed an interest in being contacted for future studies, and (3) fliers posted in the community.

Participants with AS/HFA were recruited from both Eugene and Portland, Oregon, through four sources: (1) the autism database maintained by the Department of Psychology at the University of Oregon, (2) a contact list including parents of children with AS/HFA who had participated in my previous study and expressed an interest in being contacted for future studies, (3) fliers posted in the community, especially agencies that provide services to children with autism, and (4) recruitment announcements emailed to parents through the monthly online newsletter of a local non-profit agency that serves families of children with AS/HFA.

Measures

Parent Measures

Parents completed the *Confirmation of Autism Spectrum Disorder Diagnosis Survey* (Appendix B). This measure inquires about whether the child has been either formally diagnosed with an ASD or identified as being on the autism spectrum by the school system and, if so, the type of professional(s) who did the assessment. As secondary confirmation of diagnosis, every parent completed three measures of autistic traits: *Asperger's Syndrome Diagnostic Scale* (ASDS; Myles, Bock, & Simpson, 2001), *Krug Asperger's Disorder Index* (KADI; Krug & Rick, 2003), and *Autism-Spectrum Quotient - Adolescent Version* (AQ; Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006).

The ASDS is a 50-item, yes-or-no instrument developed to evaluate in 10 to 15 minutes whether a child has traits associated with Asperger's Syndrome. This instrument covers five areas of behavior: cognitive, maladaptive, language, social, and sensorimotor. Example items include: "Avoids or limits eye contact", "Displays limited interest in what other people say or what others find interesting", and "Has difficulty understanding the feelings of others". The KADI is an instrument designed to distinguish individuals with Asperger's disorder from those who have other forms of high functioning autism. The KADI takes approximately 15 to 20 minutes to complete. The KADI is comprised of 32 items, and can be used to evaluate individuals from 6 through 22 years of age. Sample items for the KADI include: "Fixates (obsesses) on ideas or activities", "Easily becomes impatient with others", "Thinks it important that people accept his or her ideas". The AQ - Adolescent Version is a parent-report instrument that measures autistic traits in adolescents on a 4-point Likert scale from "definitely agree" to "definitely disagree" (see Appendix C). It takes 15 to 20 minutes to complete and is comprised of 50 questions, made up of 10 questions assessing 5 different areas: social skill, attention switching, attention to detail, communication, and imagination. Sample items include: "In a social group, s/he can easily keep track of several different people's conversations", "S/he finds it easy to 'read between the lines' when someone is talking to her/him", and "S/he tends to notice details that others do not".

Lastly, parents completed the *Conners Third Edition Parent Rating Scales Long Version* (Conners, 2008), a parent report measure of attention deficit and hyperactivity traits. This parent report contains 80 items, including scales of inattention and hyperactivity/impulsivity. I created a Combined ADHD score, which was the average score of the Inattention and Hyperactivity/Impulsivity scales of the Conners-3. The Conners-3 takes approximately 20 minutes to complete. Sample items include: "Has trouble staying focused on one thing at a time", "Fidgeting", "Blurts out answers before the question has been completed".

Child / Adolescent Participant Measures

The child and adolescent participants who were TD or had AS/HFA completed a battery of ToM and EF tasks in addition to a cognitive abilities test.

Theory of mind battery

Emotional perspective taking. The *Reading the Mind in the Eyes* test (Figure 1) was used as a measure of emotional perspective taking. The current study utilized the adapted child-version (Baron-Cohen, Wheelwright, Scahill, Lawson, & Spong, 2001) of the task (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). This paradigm assesses participants' ability to understand what another may be feeling or thinking by "reading" facial expressions in the eye region of another person's face. The stimuli consist of one practice trial and 28 test trials of photographs containing male and female faces, showing only the eye region. Participants were asked to choose from four options (e.g., kind, shy, not believing, sad) the word that best describes what the person in the photograph is thinking or feeling. The test trials were presented in random order on a laptop, and the experimenter pressed the computer key corresponding to the participant's verbal response. This task took approximately 5 to 10 minutes to complete.

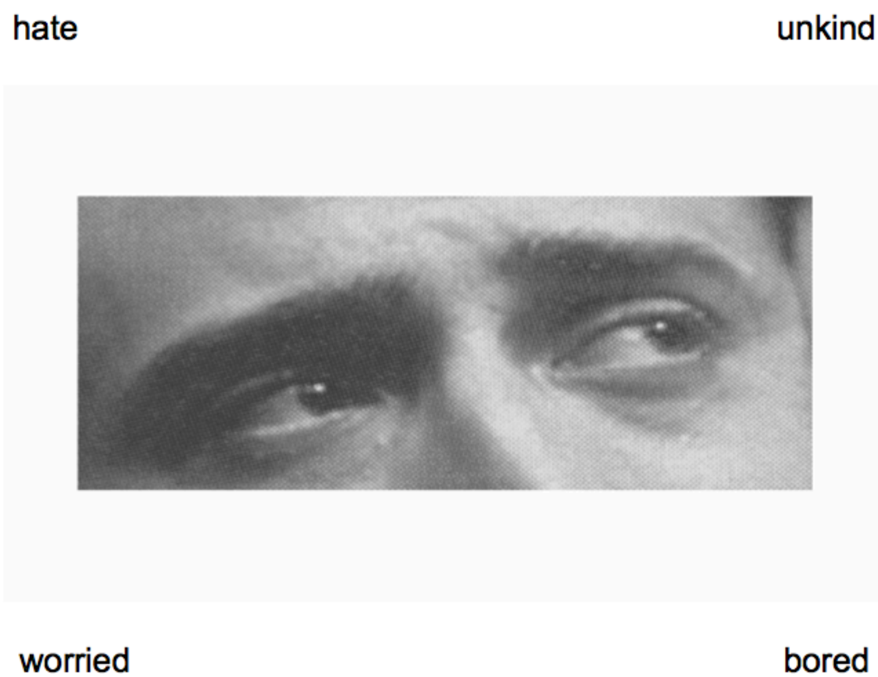

Figure 1. Sample stimulus from the Reading the Mind in the Eyes test. In this task, participants are instructed to select one of four options that best describes what the person is feeling or thinking in the photograph.

Cognitive perspective taking. Two tasks, *Happé's Strange Stories* (Happé, 1994) and *Advanced Theory of Mind Vignettes*, were used to evaluate cognitive-perspective taking. Happé (1994) designed the original Strange Stories task, but for the current study, I used the set of Strange Stories adapted for children (White, Happé, Hill, & Frith, 2009). The stimuli consists of eight short vignettes (see Table 2) that were designed in order to examine the participants' understanding of other people's intentions, desires, beliefs, and thoughts. There are four types of stories that assess different ToM concepts: double bluff, persuasion, white lies, and misunderstanding. The stories were adapted for the current study by replacing British colloquialisms with phrases familiar to American children. Additionally, the context of one story about animal abuse was modified to reduce the emotionally provocative nature of the story. The theme of persuasion, however, was conceptually retained in the story. Stories were presented on a laptop in 26-point font size. Each story was followed by one question to assess participants' understanding of the psychological reasons for the character's words or actions, such as why a woman acted scared when a man approached her in the dark. This task required approximately 15 minutes to complete. Participants provided a verbal response. Two coders rated each participant response on a 0–2 scale: "0" for an incorrect answer, "1" for a partially or implicitly correct answer, and "2" for a fully correct answer. Inter-rater reliability was substantial, Cohen's Kappa = .70, $p < .001$.

A second paradigm, the *Advanced Theory of Mind Vignettes* (ADV ToM task; see Table 2), designed by the researcher, was used as a measure of advanced cognitive perspective taking. While Happé's Strange Stories were designed to assess group differences, I developed my ADV ToM task to assess *individual differences* as well as

Table 2

Happé's Strange Story and Advanced Theory of Mind Vignette Samples

	Happé's Strange Story Sample	ADV ToM Vignette Sample
Sample Vignette	Late one night old Mrs. Peabody is walking home. She doesn't like walking home alone in the dark because she is always afraid that someone will attack her and rob her. She really is a very nervous person! Suddenly, out of the shadows comes a man. He wants to ask Mrs. Peabody what time it is, so he walks toward her. When Mrs. Peabody sees the man coming toward her, she starts to tremble and says, ‘‘Take my purse, just don't hurt me please!’’	Fernando and his cousin are getting ready to play the cool new video game that the cousin rented, when Fernando's mom tells them to go play outside instead. Later Fernando asks, "How about you come over to my house again tomorrow?" His cousin answers, "Let's go over to my house tomorrow, since I can't play indoors at your house." Fernando says, "I could go bowling or to a movie because both of those are indoors."
Test Question		
1.	Why did she say that?	The cousin says, "Let's go over to my house tomorrow, since I can't play indoors at your house". What is the cousin's reason for saying this to Fernando? Please explain.
2.	N/A	Fernando says, "I could go bowling or to a movie because both of those are indoors". Based on this, does it seem like Fernando understands what his cousin meant? Please explain.
3.	N/A	What were Fernando and his cousin getting ready to do when Fernando's mom entered the room?
4.	N/A	What did Fernando's mom ask them to do?

group differences in the populations of both older children and adolescents who are TD or have AS/HFA. The paradigm consists of twelve short vignettes, with four vignettes for each of the following ToM story types: Indirect Request, Evasion, and Backhanded Compliment. These stories involve two primary characters engaged in a complex social interaction in which one character uses *non-literal language*, specifically *indirect language*, to convey their intentions or thoughts to the second character. For instance, one character may use a technique of evasion to avoid being impolite toward the second character. Based on the second character's response, the participant must infer whether the second character understood the first character's intentions (*True Belief Story*) or did not understand the first character's intentions (*False Belief Story*). The participant must employ sophisticated ToM reasoning in order to understand the social implications of the non-literal language.

Following each story are four questions. Question 1 prompts *first-order* ToM reasoning, i.e., reasoning about the intentions of one character. Question 2 prompts *second-order* ToM reasoning, i.e., reasoning about whether the second character *understands* the first character's *intentions*. I used a fully crossed design for *belief* and *order*, resulting in the four question types: *True Belief First-Order, True Belief Second-Order, False Belief First-Order*, and *False Belief Second-Order*. Questions 3 and 4 assess story comprehension by examining the participant's comprehension of important details that provide the building blocks for understanding the psychological reasons for the characters' behaviors.

Within each ToM story type (i.e., Indirect Request, Evasion, and Backhanded Compliment), gender of characters (male and female), relationship between characters (siblings, friends, cousins, and classmates), and belief (true and false) were counterbalanced. Unlike Happé's Strange Stories, my new set of vignettes did not include ToM terms (e.g., intend, want, think, know), which are direct indicators of the characters' theory of mind states. In real life, people often do not directly state what they are thinking or feeling, and instead make use of indirect language to convey their intentions. My goal was to develop a more ecologically valid measure of ToM that requires participants to make ToM inferences without direct assistance from being told what characters are thinking or feeling.

The task took approximately 25 to 30 minutes to complete. Stories were presented on a laptop in 20-point font size. Participants received in random order the 12 ADV ToM vignettes, which consisted of three *story types* (i.e. Indirect Request, Evasion, and Backhanded Compliment). Per *story type* there were two True Belief and two False Belief stories. After *each* story the participant was asked four questions; Questions 1 and 2 assessed ToM and Questions 3 and 4 indexed story comprehension. Participants provided a verbal response for each question.

The ToM questions (Questions 1 and 2) were coded on a 0-2 scale: "0" for an incorrect or irrelevant answer, "1" for a literal ToM interpretation, and "2" for a non-literal ToM interpretation (see Appendix D). The story comprehension questions (Questions 3 and 4) were coded categorically as "Correct" or "Incorrect". Two coders, one naïve to group membership, coded all trials. Inter-rater reliability was substantial for the ToM questions, Cohen's Kappa = .68, $p < .001$, and the story comprehension questions, Cohen's Kappa = .76, $p < .001$.

Five indices were created from the ADV ToM measure. The first four indices represented the following four conditions: *True Belief First-Order, True Belief Second-Order, False Belief First-Order*, and *False Belief Second-Order*. The True Belief First-Order index was generated by averaging across the coded responses for Question 1 from the six True Belief stories (2 per story type). The True Belief Second-Order index was produced by averaging across the coded responses for Question 2 from the six true belief stories. A similar procedure was used to calculate the False Belief indices, except that the coded responses were averaged across the False Belief stories. Further, participant responses on story comprehension questions had to meet a set criterion for the responses to the corresponding ToM questions to be included in their respective ADV ToM index. Specifically, for any story in which a participant provided an incorrect answer to at least one of the two story comprehension questions, responses for that entire story were excluded from the participant's ADV ToM index scores. I used the criterion of two out of two correct because *both* story comprehension questions needed to be understood to possibly give an accurate ToM interpretation of the respective story.

In order to confirm the internal consistency of my measure, I explored intercorrelations among the vignettes. Among the vignettes there were some marginal intercorrelations for the TD group and several significant intercorrelations for the AS/HFA group (see Table 3). Happé's Strange Stories, a well-established measure of ToM, had relatively fewer and less strong correlations among its vignettes (see Table 4).

Table 3

Raw Correlations Among Advanced Theory of Mind Vignettes by Group

ADV ToM Vignette	BC-FB	EV-TB	EV-FB	IR-TB	IR-FB
BC-TB					
TD	.27†	.13	-.04	-.13	.09
AS/HFA	.29	.40*	.52**	.59***	.57***
BC-FB					
TD		< .01	.06	.08	.07
AS/HFA		.45**	.26	.40*	.36*
EV-TB					
TD			-.11	.32†	.27†
AS/HFA			.31†	.58***	.02
EV-FB					
TD				.48**	.10
AS/HFA				.59***	.51**
IR-TB					
TD					.23
AS/HFA					.21

Note. These data collapse across Question 1 and Question 2 and Story Type by Belief (e.g., Evasion TB Story 1 and Evasion TB Story 2). BC = Backhanded Compliment Story; EV = Evasion Story; IR – Indirect Request; TB = True Belief; FB = False Belief. The *n* for the TD group was 36 and the *n* for the AS/HFA group was 31.
†$p \leq .11$. *$p \leq .05$. **$p \leq .01$. ***$p \leq .001$.

Executive function battery

Inhibitory control. The Erickson Flanker Task was used as a measure of conflict inhibitory control (IC; Eriksen & Schultz, 1979). In this task, participants are expected to respond to a centered and directed stimulus, such as an arrow, surrounded or flanked by

Table 4

Raw Correlations Among Happé's Strange Stories by Group

Happé Story	Persuasion	White Lie	Misunderstanding
Double Bluff			
TD	.14	.03	.10
AS/HFA	.34*	.26	.20
Persuasion			
TD		-.02	.08
AS/HFA		.30†	.13
White Lie			
TD			.26†
AS/HFA			.25

Note. The *n* for the TD group was 39 and the *n* for the AS/HFA group was 35.
$^{\dagger}p \leq .11$. $^{*}p \leq .05$.

distracting stimuli, such as other arrows. Participants were instructed to press a button corresponding to the direction of the center arrow. Accuracy and reaction time data were collected on a laptop. For the current study, five stimuli were presented .3° apart horizontally, with each item subtending 1°. In the *Neutral Condition*, the central arrow is flanked by non-arrow stimuli, specifically the letter "x" (e.g., x x < x x), in order to obtain a reaction time baseline for the study. In the *Incongruent Condition*, the four flanking arrows point in a different direction from the central arrow (e.g., < < > < <). Typically, the Incongruent Condition generates slower reaction times and less accurate performance than the Neutral Condition because the participant has to inhibit the prepotent response to push the button that corresponds to the direction of the visually salient flanker arrows.

There were 20 trials per condition for this IC task. The Neutral and Incongruent Conditions were intermixed. Five trials per condition were randomly administered in a test block, with a total of four test blocks in the task. The IC score was calculated by subtracting the Neutral Condition reaction time from Incongruent Condition reaction time. Thus, higher scores indicate greater difficulty in inhibiting prepotent responses.

Verbal working memory. A reading span task adapted for children was used as a measure of verbal WM (Towse, Hutton, & Hitch, 1997). Participants read aloud short sentences and supplied the missing final (sentence-terminal) word. For instance, the participant read, "A fire is very _____", and they needed to supply the word "hot". Participants were also instructed to remember the sentence-terminal words that they supplied for a subsequent recall exercise. Participants were initially tested on two sentences. If participants met the criterion of correctly recalling in serial order the sentence-terminal words on two out of three occasions, then span length was increased by one, otherwise testing was terminated. Based on performance, participants could be given a maximum span length of 6 (i.e., six sentence-terminal words to recall). Participants were given practice on the two-sentence condition and were required to accurately complete one two-sentence condition before proceeding to the test trials. Sentences were presented in a large font size (42 point font) on a laptop. The experimenter wrote down on a scoring sheet the participant responses. Verbal WM was indexed by summing the total number of trials recalled correctly.

Visual working memory. A change detection task, consisting of three conditions, was used to assess visual WM capacity (Fukuda & Vogel, 2009; Luck & Vogel, 1997). For each condition, participants viewed a display for 150 ms of differently-colored geometric shapes (i.e., memory array) on a laptop and after a short delay (900 ms), were shown one geometric shape (i.e., test array) and asked to respond by pressing "Yes" or "No" as to whether the test array matched the color of the object that was in the same location in the memory array. The computer program recorded participant responses and reaction times. There were 60 trials per condition, with a block of thirty trials presented at a time. The conditions were presented in the following order: Set Size 2, Set Size 4, and Set Size 6. In the three conditions (i.e., Set Size 2, Set Size 4, Set Size 6), participants were shown two, four, or six colored square targets in the memory array, respectively (see Figure 2). The visual WM index was calculated by averaging the WM capacity for Set Size 4 and Set Size 6.

Cognitive abilities test. The Kaufman Brief Intelligence Test—Second Edition (KBIT–2) was administered to participants in order to assess verbal, non-verbal, and composite IQ (Kaufman & Kaufman, 1990). The verbal scale (i.e., crystallized scale) contains two item types: verbal knowledge and riddles. The nonverbal scale (i.e., fluid intelligence scale) contains one item type; a matrices subtest. The Matrices subtest is comprised of three sections, which increase in difficulty. The first section requires participants to select a drawing that is conceptually similar to the target drawing. The second section involves selecting a drawing that completes the analogy indicated by the target drawing. The third section, involves choosing the drawing which maintains the

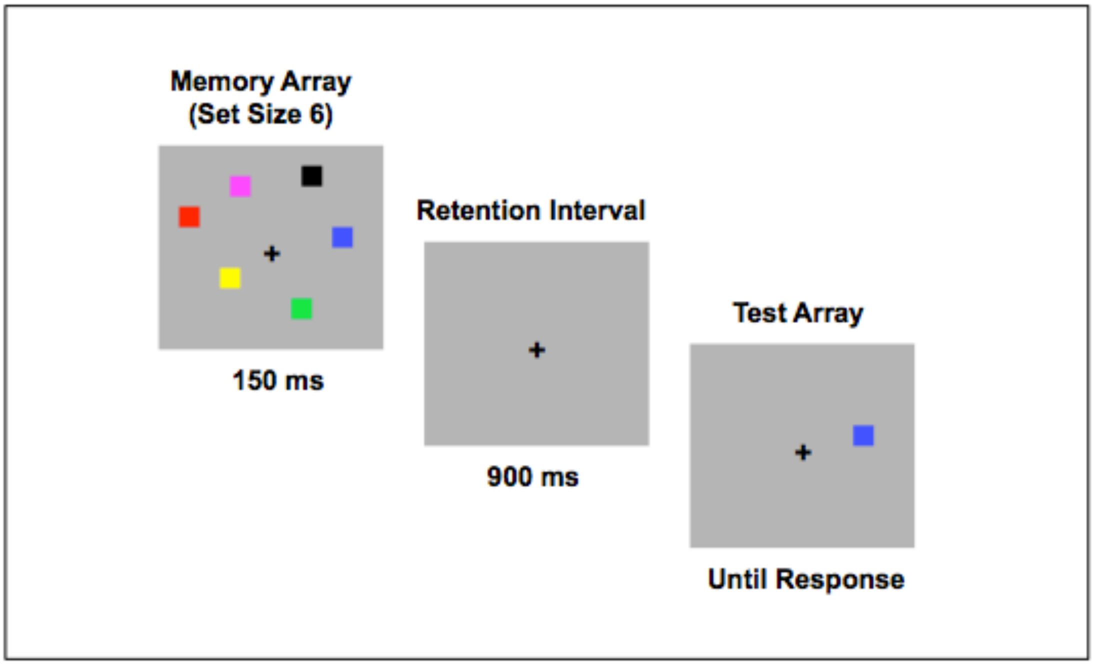

Figure 2. Sample trial for Set Size 6 of visual working memory paradigm.

pattern if inserted in the missing section of the matrix. The test provides standard scores (M=100, SD=15) and percentile ranks by age.

<u>Procedure</u>

The study consisted of two test sessions lasting approximately 2 hours each. The test sessions were video recorded for coding purposes. Participants were administered the battery of ToM and EF tasks as well as the cognitive abilities test across the two test Sessions. In addition, as part of another study, measures of emotional development were given to the participants. Although there was a set order for the presentation of behavioral tasks, in several cases this was adjusted based on the individual needs of participants in order to reduce fatigue and maintain participant focus.

In Session 1, most participants completed Happé's Strange Stories, the visual working memory task, and the KBIT. In Session 2, the majority of participants completed the verbal working memory task, the Mind in the Eyes test, the Flanker task, and the Advanced Theory of Mind Vignettes. The behavioral tasks were presented on a laptop using SuperLab version 4.0 (Cedrus Corporation), except the visual WM task, which was presented using the computer program Presentation (Neurobehavioral Systems). In Session 1, most parents completed the Confirmation of Diagnosis Survey, ASDS, and AQ. In Session 2, most parents completed the Conners-3 and the KADI. These were paper questionnaires and the parents handwrote responses and circled options.

In Session 1, upon arriving at the lab, the parent and child participants were oriented to the lab space and shown the video recording equipment. Next, the parent took a seat in the video monitor room which contained a closed-circuit monitor that provided video feed of the testing room, allowing parents to view their children's test sessions. The child was seated in the adjoining testing room. During the consent procedure, it was made clear to both the child participants and their parents that they could withdraw assent or consent, respectively, at any point and discontinue participation without penalty. Also, it was stressed to the child participants that they could take breaks at any point throughout their test sessions. For both Sessions 1 and 2, while parents completed their questionnaires in the video monitor room, the child participants completed their behavioral tasks in the testing room.

CHAPTER III

RESULTS

I first conducted preliminary analyses with the full set of EF (verbal WM, visual WM, and IC) and ToM data, including outliers. Then I removed the outliers and re-ran the analyses. A case met my criterion for an outlier if its value was more than 1.5 interquartile ranges below the first or above the third quartile, respectively. This is equivalent to +/- 2.7 standard deviations in a normal distribution. There were only minor differences between the results for the full data set and for the data set with outliers removed; thus only the results of the data set with outliers removed are presented.

In addition, I examined whether the measures of the ToM battery held together as a single construct, thereby validating the use of a composite ToM score. For the TD group, the three separate ToM measures, i.e., Mind Eyes test, Happé's Strange Stories, and the indices from the ADV ToM Vignettes, did not intercorrelate based on raw or partial correlations controlling for composite IQ and age (see Table 5). Therefore, I did not include a ToM composite variable in the analyses. Similarly, I assessed whether the three EF measures, i.e., verbal WM, visual WM, and IC, held together as a single construct for the TD group. Both raw correlations and partial correlations, controlling for composite IQ, age, and lag time, did not reveal significant correlations for the TD group (see Table 5). Therefore, I did not include an EF composite variable in the analyses.

Group Differences in ToM and EF

Concerning *Research Question 1*, I examined whether the AS/HFA group was impaired in ToM (emotional and cognitive perspective taking) and/ or EF (Verbal WM,

Table 5

Raw Correlations and Partial Correlations, Controlling for Composite IQ, Age, and Lag Time, Among Theory of Mind and Executive Function Measures for Typically Developing Children

Index	Happé	TB 1st	TB 2nd	FB 1st	FB 2nd	ADV Comb.	VBWM	VLWM	IC
Mind	.13 (.02)	-.27 (-.26)	-.20 (-.18)	.09 (.08)	.03 (.03)	-.12 (-.12)	.27 (.22)	-.12 (<.01)	-.26 (-.25)
Happé		-.08 (-.12)	-.17 (-.23)	.32† (.27)	.26 (.28)	.11 (.06)	.15 (-.14)	-.05 (-.09)	-.17 (-.08)
TB 1st			.76 (.71***)	.15 (.09)	.26 (.25†)	.46** (.47**)	<.01 (-.04)	.38* (.32†)	.13 (.15)
TB 2nd				.35* (.49**)	.40* (.38**)	.67*** (.66***)	.26 (.25†)	.35† (.30)	.25 (.28)
FB 1st					.71*** (.62***)	.49** (.42**)	.27 (.09)	.12 (.14)	.16 (.23)
FB 2nd						.59*** (.52***)	.39* (.36*)	-.19 (-.13)	.18 (.18)
Comb.							.30† (.24†)	.24 (.23)	.24 (.27)
VBWM								.07 (.06)	.13 (.25)
VLWM									-.23 (-.16)

Note. Partial correlations in parentheses. Mind = Mind Eyes; Happé = Happé's Strange Stories. For the Advanced Theory of Mind indices: 1st = first-order; 2nd = second-order; FB = false belief; TB = true belief; ADV Comb. = combined score; VBWM = verbal working memory; VLWM = visual WM; IC= inhibitory control. To avoid inflating the correlation between any given ADV ToM index and the ADV Combined score, the contribution of a given ADV ToM index was removed from the Combined score when the respective index was correlated with the Combined score. Degrees of freedom ranged from 26 - 35.
†$p \leq .10$. *$p \leq .05$. **$p \leq .01$. ***$p \leq .001$.

Visual WM, and IC) relative to the TD group. I conducted preliminary 2 x 2 (Group x Gender) analysis of covariance (ANCOVA) tests on the separate ToM and EF measures, controlling for Composite IQ and Age, and including an Age x Group interaction term. For these preliminary analyses, there were no significant results for the Age x Group interaction term. Thus, I reran the ANCOVAs without the Age x Group interaction term and report the results below. The ANCOVAs revealed significant group differences for ToM (see Table 6). Specifically, the AS/HFA group performed worse on Happé's Strange Stories and all the indices of the ADV ToM Vignettes. It is important to note that although I controlled the effects of inaccurate story comprehension from the ADV ToM analyses by excluding data for stories in which at least one of the story comprehensions questions was incorrect, both the TD group (M = 11.86; SD = .26) and AS/HFA group (M = 11.48; SD = .70) performed at near ceiling on story comprehension (i.e., highest possible score was 12). Regarding EF, there were no significant group differences for verbal WM, visual WM, or IC. In summary, these data indicate that older children and adolescence with AS/HFA are impaired in ToM but not EF compared to their typically developing peers.

Further, I tested whether the AS group provided evidence for the Executive Dysfunction Hypothesis. The Executive Dysfunction Hypothesis predicts that individuals with AS/HFA will show a pattern of deficits in both ToM and EF or will show impairments only in ToM. This account does not, however, predict the pattern of impaired EF but intact ToM. For my study, a participant was considered to show "impaired" performance on a ToM measure (Mind Eyes, Happé's Strange Stories, and

Table 6

Mean Performance on the Theory of Mind and Executive Function Measures by Group and Gender

	TD			AS/HFA				
	Males	Females	Total	Males	Females	Total	Group Effect	
Measure	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	*F*	h^2
Mind Eyes	.69 (.08)	.70 (.08)	.69 (.08)	.71 (.11)	.72 (.10)	.72 (.11)	2.51	0.04
Happé	13.50 (1.43)	12.68 (1.80)	13.10 (1.65)	11.35 (2.21)	10.11 (3.16)	10.76 (2.74)	15.42***	0.18
ADV TB 1st	1.69 (.23)	1.71 (.22)	1.70 (.22)	1.48 (.32)	1.23 (.51)	1.37 (.43)	16.97***	0.22
ADV TB 2nd	1.71 (.20)	1.71 (.21)	1.74 (.21)	1.58 (.28)	1.36 (.47)	1.48 (.34)	13.61***	0.19
ADV FB 1st	1.73 (.15)	1.68 (.25)	1.70 (.21)	1.50 (.27)	1.30 (.40)	1.41 (.34)	19.25***	0.24
ADV FB 2nd	1.70 (.20)	1.68 (.20)	1.69 (.20)	1.47 (.33)	1.25 (.41)	1.37 (.38)	18.44***	0.24
ADV Comb.	1.71 (.15)	1.71 (.17)	1.71 (.16)	1.51 (.21)	1.29 (.40)	1.41 (.33)	27.18***	0.31
Verbal WM	20.94 (7.57)	20.44 (6.83)	20.69 (7.11)	20.44 (7.22)	19.27 (9.05)	19.87 (8.04)	0.03	<.01
Visual WM	3.04 (1.07)	2.88 (1.02)	2.97 (1.03)	2.47 (1.08)	2.18 (1.14)	2.33 (1.11)	2.55	0.04
IC	61.79 (17.28)	85.63 (19.88)	74.41 (21.53)	67.54 (29.92)	81.33 (40.16)	74.32 (35.19)	<.01	<.01

*Note. N*s for Total scores ranged from 55 - 77 and *n*s broken down by group and gender ranged from 14 - 20.
***$p < .001$.

the 5 ADV ToM Indices) or EF measure (Verbal WM and Inhibitory Control) if the participant's score was at least one standard deviation *lower* than the TD group's mean score for the respective measure, except for IC. Because a higher score indicated worse performance only on the IC measure, a participant was considered to demonstrate "impaired" performance on IC if the participant's score was at least one standard deviation *greater* than the TD group's mean score for this measure. Further, the participant was deemed impaired on ToM or EF if they were impaired on any one ToM measure or EF measure, respectively. Based on these criteria, of the participants with AS/HFA who completed all measures, 14 were impaired on both ToM and EF, 8 were impaired on ToM with intact EF, 2 had intact ToM and EF, and none were impaired on EF with intact ToM. Overall, these data provide strong support for the Executive Dysfunction Hypothesis because none of these participants with AS/HFA demonstrated the pattern (i.e., impaired EF with intact ToM) that is inconsistent with the Executive Dysfunction Hypothesis.

Gender Effects and Group x Gender Interactions in EF and ToM

Although I did not have specific predictions about gender effects or interactions, I explored whether any such effects existed. Table 6 shows that I only found a gender effect for IC, such that girls performed worse on the measure of IC compared to boys, with higher scores indicating greater difficulty inhibiting prepotent responses, $F(1, 50) = 5.52$, $p = .02$, $\eta^2 = .15$. Regarding Group x Gender interactions, I only found significant interactions for some of the ADV ToM indices (see Table 7). The pattern of means

Table 7

ANCOVA Results for Group x Gender Interactions on the Advanced Theory of Mind Vignettes

Measure	*F*	*p*	η^2
ADV ToM TB First-Order	3.14	.08	.05
ADV ToM TB Second-Order	4.47	.04	.07
ADV ToM FB First-Order	1.61	.12	.03
ADV ToM FB Second-Order	1.84	.18	.03
ADV ToM Combined	4.33	.04	.07

Note. Controlling for composite IQ and age. The within-groups degrees of freedom was 60.

suggests that girls with AS/HFA performed worse than boys with AS/HFA and both typically developing boys and girls (see Table 6). This was confirmed by simple contrasts, which revealed the female AS/HFA group performed worse on every ADV ToM index relative to the TD boys ($ps \leq .01$), the TD girls ($ps \leq .001$), and the AS/HFA males (p-values ranged from .08 to .02).

Given that I found significant Group x Gender interactions, such that the girls with AS/HFA performed significantly worse on the ADV ToM indices compared to all other participants, the question arose whether the Group effect would remain if the ANCOVAs were rerun only with the boys included in the AS/HFA group. Thus, for the ADV ToM indices I conducted one-way ANCOVAs with Group as the factor plus age and composite IQ as covariates, including only the males in the AS/HFA group and both the males and females in the TD group. The Group effects remained significant for all of the ADV ToM indices, except for ADV ToM TB Second Order index, $F(1, 48) = 2.37$, $p = .13$, $\eta^2 = .05$. Based on these results, the Group effects were generally not qualified by the Gender x Group interaction.

<u>Development of ToM and EF</u>

Regarding *Research Question 2*, I investigated whether there were age-related improvements in ToM (emotional and cognitive perspective taking) and EF (verbal WM, visual WM, and IC) in the TD group and/ or AS/HFA group. As mentioned above, my preliminary ANCOVA analyses revealed no significant results for the Age x Group interaction term, and thus the results of only the ANCOVAs without this interaction term are reported. As Table 8 shows, regarding the EF measures, there were main effects of Age for both verbal WM and visual WM, but not for IC. In addition, there were main effects of Age for some measures of ToM. In particular for ToM, there was a significant main effect of Age for the ADV ToM True Belief Second Order index and there was a marginally significant main effect of Age for both the ADV ToM True Belief First Order index and the ADV ToM Combined index. See Table 9 for the mean scores of EF and ToM performance as a function of younger and older age groups, based on a median split for Age.

Counter to our expectations, we did not find that Age was related to the False Belief indices of the ADV ToM Vignettes. We followed up on this surprising finding by examining whether most false belief stories were related to Age and this null result was driven by an idiosyncratic story. Thus, I conducted a 2 x 2 (Group x Gender) multivariate

Table 8

Main Effects of Age for the Theory of Mind and Executive Function Measures

Measure	F	p	η^2
Mind Eyes	.22	.64	<.01
Happé's Strange Stories	.12	.73	<.01
ADV ToM TB First-Order	3.95	.06	.13
ADV ToM TB Second-Order	8.12	<.01	.24
ADV ToM FB First-Order	2.02	.17	.07
ADV ToM FB Second-Order	.07	.80	<.01
ADV ToM Combined	3.90	.06	.13
Verbal WM	5.53	.02	.08
Visual WM	7.39	<.01	.10
Inhibitory Control	2.04	.16	.04

Note. Controlling for composite IQ. The within-groups degrees of freedom ranged from 49 to 71.

analysis of covariance (MANCOVA) test on the separate False Belief ToM stories, collapsing across first and second order and controlling for Composite IQ and Age. Four of the six False Belief stories tended to relate to Age (*p*s ranged from .03 to .12). Therefore, this null Age finding for the False Belief indices appeared to be driven primarily by two stories (i.e., Ben and Ryan).

In summary, age-related improvements in ToM, verbal WM, and visual WM were found for older children and adolescents, irrespective of group membership. These data support of the theory that ToM is still developing during adolescence.

Table 9

Mean Performance of Younger and Older Age Groups Based on Median Split for the Theory of Mind and Executive Function Measures

Measure	Younger Age		Older Age	
Mind Eyes	.71	(.08)	.70	(.10)
Happé's Strange Stories	12.08	(1.91)	11.75	(2.98)
ADV ToM TB First-Order	1.49	(.36)	1.59	(.37)
ADV ToM TB Second-Order	1.56	(.33)	1.66	(.33)
ADV ToM FB First-Order	1.50	(.31)	1.61	(.31)
ADV ToM FB Second-Order	1.53	(.33)	1.55	(.34)
ADV ToM Combined	1.52	(.28)	1.60	(.30)
Verbal WM	18.96	(7.04)	21.23	(7.76)
Visual WM	2.47	(1.02)	2.76	(1.18)
Inhibitory Control	70.06	(30.61)	75.98	(27.40)

Note. Standard deviations in parentheses. Data is collapsed across all participants because we did not find a Group x Age interaction.

Relation Between ToM and EF

With respect to *Research Question 3*, I explored whether individual differences in ToM (emotional and cognitive perspective taking) related to individual differences in EF (Verbal WM, Visual WM, and IC) in the TD group and/ or AS/HFA group. Separately for the TD (see Table 5) and AS/HFA groups (see Table 10) I examined raw correlations and partial correlations among the ToM measures and EF measures, controlling for composite IQ, age, and lag time. The lag time variable was the absolute score resulting

Table 10

Raw Correlations and Partial Correlations, Controlling for Composite IQ, Age, and Lag Time, Among Theory of Mind and Executive Function Measures for Children with AS/HFA

Index	Happé	TB 1st	TB 2nd	FB 1st	FB 2nd	ADV Comb.	VBWM	VLWM	IC
Mind	.20 (.05)	.51**(.42*)	.45** (.33†)	.30† (.15)	.22 (.13)	.44* (.32†)	.10 (-.15)	.05 (-.19)	.02 (-.08)
Happé		.55**(.41*)	.48**(.34†)	.36* (.29†)	.28 (.12)	.48** (.32†)	.11 (-.42*)	.20 (-.02)	-.23 (-.22)
TB 1st			.85 (.82***)	.69*** (.51**)	.48** (.41**)	.78*** (.67***)	.30† (-.11)	.21 (-.09)	-.14 (-.37*)
TB 2nd				.70*** (.54**)	.42* (.24)	.75*** (.61***)	.39* (-.09)	.22 (.03)	-.02 (-.31†)
FB 1st					.85*** (.80***)	.87*** (.75***)	.37* (.02)	.32† (.05)	-.29 (-.50**)
FB 2nd						.62*** (.57***)	.40* (.15)	.35† (.10)	-.22 (-.38*)
Comb.							.41* (-.01)	.34† (.03)	-.18 (-.48*)
VBWM								.44** (.21)	-.02 (-.03)
VLWM									-.28 (-.33)

Note. Partial correlations in parentheses. Mind = Mind Eyes; Happé = Happé's Strange Stories. For the Advanced Theory of Mind indices: 1st = first-order; 2nd = second-order; FB = false belief; TB = true belief; ADV Comb. = combined score; VBWM = verbal working memory; VLWM = visual WM; IC= inhibitory control. To avoid inflating the correlation between any given ADV ToM index and the ADV Combined score, the contribution of a given ADV ToM index was removed from the Combined score when the respective index was correlated with the Combined score. Degrees of freedom ranged from 19 - 31.
$^{\dagger}p \leq .10$. $^{*}p \leq .05$. $^{**}p \leq .01$. $^{***}p \leq .001$.

from subtracting the age at which the time that one measure was administered from the time at which the other measure was administered.

TD Group

Overall for the TD group, regarding both the raw and partial correlations, I found that some aspects of ToM related separately to verbal WM and visual WM, but not to IC (see Table 5). Specifically, for the raw correlations, visual WM only significantly correlated with the two True Belief indices of the ADV ToM. For the partial correlations, however, the relation between visual WM and these two separate ToM indices dropped to marginally significant. In contrast, for both raw and partial correlations, verbal WM correlated with some of the ADV ToM indices. In particular, verbal WM correlated with the ADV ToM Combined index and the two ADV ToM indices that assessed second-order ToM. Second-order ToM processing is more complex than first-order. Specifically, for the ADV ToM vignettes, the questions that assess second-order ToM are more syntactically complex and require processing linguistic content about the relation between two characters' minds rather than one. Thus, this finding supports the hypothesis that verbal WM is especially recruited for more complex ToM reasoning in typically developing older children and adolescents.

AS/HFA Group

Relative to the TD group, the AS/HFA group tended to show stronger relations among facets of EF and ToM (see Table 9). For partial but not raw correlations, IC correlated with all five ADV ToM indices in the AS/HFA group. Visual WM marginally correlated with the two False Belief indices of the ADV ToM. For the partial correlations, however, these relationships became non-significant. Regarding raw correlations, verbal WM correlated with all five ADV ToM indices for the AS/HFA group, but this finding did not hold up in the partial correlations. This may be because verbal WM in the AS/HFA group strongly correlated with composite IQ, $r(31) = .62$, $p < .001$, which was used as a covariate in the partial analyses. Thus, controlling for composite IQ in the partial analyses likely wiped away any effects of verbal WM. In order to assess whether composite IQ was removing the effects of verbal WM from the partial correlations, I reran the analyses controlling for nonverbal IQ rather than composite IQ. The relations between verbal WM and the separate ADV ToM indices remained significant when I controlled for nonverbal IQ. In combination, these findings suggest that the ADV ToM task tends to place greater demands on verbal WM and IC for the AS/HFA group in comparison to the TD group.

Relation Between Autistic Traits and ToM

Additionally, I examined how autistic traits within the TD and AS/HFA groups related to ToM performance. In both groups I found several correlations among domains of autistic traits and separate ToM measures in the TD and AS/HFA groups (see Table 11). Overall, these data suggest that autistic traits are negatively related to ToM understanding.

Controlling for ADHD Traits

Given the preponderance of ADHD traits in the AS/HFA group, I examined whether ADHD traits influenced the ToM and EF results. Therefore, I reran the analyses that addressed Research Questions 1 - 3 and included an additional covariate controlling for Combined ADHD traits. Overall, I found that additionally controlling for ADHD traits minimally affected the findings.

Table 11

Partial Correlations Between Domains of Autistic Traits and Theory of Mind Measures within the Typically Developing and AS/HFA Groups

	Mind Eyes		Happé's Strange Stories		ADV ToM Combined	
Autistic Traits	TD	AS/HFA	TD	AS/HFA	TD	AS/HFA
KADI	.03	.21	-.05	-.06	.27	-.06
ASDS						
Language	-.05	.36†	-.42*	.17	-.19	.09
Social	-.19	-.08	.16	-.05	-.33†	-.34†
Maladaptive	.07	.17	-.28	.07	-.40*	-.34†
Cognitive	-.04	.28	-.06	-.01	-.07	.01
Sensorimotor	-.18	-.08	.34†	.08	.06	-.20
Total	-.05	.16	-.22	.09	-.21	-.26
AQ						
Social Skills	.01	-.06	.37*	-.39*	-.29†	.01
Attention Switching	.06	.14	-.07	-.39*	.07	-.05
Attention to Detail	.08	-.04	-.17	-.11	.18	-.31
Communication	-.10	.07	.07	-.25	-.30†	-.02
Imagination	-.03	-.19	.12	-.30	-.17	-.06
Total	.01	-.04	.09	-.39*	-.14	-.13

Note. Controlling for Composite IQ and Age. ADV ToM Comb. = Theory of Mind Combined Score. The *n* for the TD group was 36.
†$p \leq .10$. *$p \leq .05$.

Summary of Results

In summary, I found that the AS/HFA group, especially the girls with AS/HFA, performed worse on ToM measures tapping cognitive perspective taking. In addition, the TD and AS/HFA groups did not differ in their verbal WM, visual WM, or IC abilities. Yet, the AS/HFA group in comparison to the TD group exhibited more correlations between the facets of ToM and the facets of EF. These data indicate that ToM processing may require more effortful executive processing for children and adolescents with AS/HFA relative to their TD peers. Further, my data indicate that ToM, verbal WM, and visual WM continue to develop during later childhood and adolescence for both typically developing individuals and individuals with AS/HFA.

CHAPTER IV

DISCUSSION

In the present study I explored three research questions regarding (1) *group* differences, (2) *development*, and (3) *individual* differences in ToM (emotional and cognitive perspective taking) and EF (verbal WM, visual WM, and IC) among older children and adolescents who are TD or have AS/HFA. In order to investigate these research questions, I employed a battery of ToM and EF measures, and compared the performance of girls and boys with AS/HFA to TD controls matched on age and gender.

Summary of Research Questions

Research Question 1

First, I examined whether *group differences* in ToM (emotional and cognitive perspective taking) and EF (verbal WM, visual WM, and IC) exist between the TD and AS/HFA populations. Most relevant prior research has investigated these constructs separately. In addition, these studies have tended to examine different EF domains, such as planning or set shifting. My decision to examine specifically verbal WM, visual WM and IC was theory driven, based on previous studies finding a significant relation between ToM and the EF domains of verbal WM and IC in young typically developing children (Carlson & Moses, 2001; Carlson et al., 2002). Further, including visual WM in the study allowed me to examine discriminant validity of working memory, specifically how separate facets of WM differentially relate to ToM. The present study is novel in that it is the first to explore, within the same set of participants, how the AS/HFA population may differ from the TD population in terms of these specific EF constructs and ToM.

Research Question 2

Second, I explored whether the *developmental trajectories* of ToM (emotional and cognitive perspective taking) and EF (verbal WM, visual WM, and IC) for older children and adolescents with AS/HFA are similar to their TD peers. Prior studies have revealed improvement with age in ToM abilities for the AS/HFA population. Some researchers, however, argue that individuals with AS/HFA do not develop genuine ToM understanding, but rather develop compensatory strategies that allow them to "solve" ToM problems. To test these separate accounts of ToM development in the AS/HFA population, a sophisticated measure of ToM is needed that involves novel social contexts for which individuals with AS/HFA have not had the opportunity to develop compensatory strategies to understand. I designed a new ToM measure, therefore, to do exactly this.

Research Question 3

Third, I directly examined whether *individual differences* in ToM (emotional and cognitive perspective taking) relate to EF (verbal WM, visual WM, and IC) in later childhood and adolescence in both the TD and AS/HFA populations. The majority of related research has focused on young children. The current study is among the first to examine these relations in a developmentally older population. One of the main hindrances in the field has been the lack of advanced ToM measures that can be used as individual measures of ToM in older children and adolescents. Thus, as part of the design of the study, I aimed to develop a measure that would serve as an individual measure of ToM in older children and adolescents.

Summary of Findings

Research Question 1: Group Differences in ToM and EF

Consistent with my predictions, I found that the AS/HFA group in comparison to the TD group demonstrated impairments in cognitive perspective taking as measured by Happé's Strange Stories and ADV ToM Vignettes, independent of composite IQ, age, ADHD traits, and story comprehension abilities. There were no group differences, however, in emotional perspective taking as measured by the Mind Eyes Task. These findings indicate that older children and adolescents with AS/HFA may have deficits in cognitive perspective taking, but not in emotional perspective taking. Notably, the girls with AS/HFA were more impaired in cognitive perspective taking, as measured by the ADV ToM Vignettes, than the boys with AS/HFA or the typically developing girls or boys combined. Further, there were no group differences in verbal WM, visual WM, or in IC. These data suggest that verbal WM, visual WM, and IC are intact in older children and adolescents with AS/HFA.

Research Question 2: Development of ToM and EF

In sum, I found that ToM continues to develop during later childhood and adolescence for both typically developing individuals and individuals with AS/HFA. Further, both the TD and AS/HFA groups made developmental gains in verbal WM and visual WM. Additionally, age did not interact with group.

Research Question 3: Individual Differences in ToM and EF

In general, ToM correlated with verbal WM in both the TD and AS/HFA groups, whereas ToM correlated with IC only for the AS/HFA group. Confirming my hypothesis that ToM is related to verbal WM specifically and not WM in general, neither the TD nor AS/HFA groups showed significant correlations between facets of ToM and visual WM, when composite IQ and age were controlled.

In particular for the TD group, verbal WM was correlated with ToM for the most complex ADV ToM condition, i.e., second-order ToM involving false belief, even after controlling for age and IQ. This ToM condition is the most linguistically complex because it requires the participant to process information about the relation between two characters' minds rather than one, and how one character does not understand the intentions of the second character. It may be the case that by later childhood and adolescence, much of ToM processing is intuitive, but more complex levels of ToM processing still place strong demands on verbal WM.

ToM performance in the AS/HFA group compared to the TD group tended to correlate more with verbal WM and IC. Even though the AS/HFA and TD groups did not differ on verbal WM and IC performance, it appears that these abilities are involved more for ToM processing in the AS/HFA group. These data suggest that ToM may require more effortful cognitive processing for the AS/HFA children and adolescents than their TD peers.

Implications

The findings from my study suggest that older children and adolescents with AS/HFA are impaired in the cognitive facet of ToM (i.e., cognitive perspective taking), relative to their TD peers. Similarly, we found that autistic traits in both the TD and AS/HFA groups correlated with the cognitive perspective taking measures. Notably, even though I did not find group differences in verbal WM or IC, these EF abilities tended to correlate more strongly with cognitive perspective taking in the AS/HFA group. Thus, children and adolescents with AS/HFA may require more effortful executive processing when engaged in complex cognitive perspective taking in comparison to their TD peers. This is in alignment with the view that individuals with AS/HFA do not possess a well-developed, intuitive ToM, but instead "hack out" strategies for solving ToM problems (Frith et al., 1991). Consistent with this view, a recent study found that the eye movements of individuals with Asperger's Syndrome did not show anticipation of an actor's behavior based on her false belief, suggesting a lack of spontaneous mental state attribution in individuals with Asperger's Syndrome (Senju, Southgate,White, & Frith, 2009). Alternatively, it is also possible that individuals with AS/HFA may use similar cognitive mechanisms to understand ToM concepts, but these mechanisms do not operate as efficiently in the AS/HFA population, requiring more executive resources. In support of this hypothesis, prior neuroimaging research has found that individuals with ASD exhibit underconnectivity between frontal and posterior areas of ToM circuitry and the frontrol ToM regions are also less activated during a ToM task (Kana, Keller, Cherkassky, Minshew, & Just, 2009).

The results of this study provide evidence to support the Expression Account. The Expression Account proposes that EF is necessary for an individual to *express* their ToM understanding. My findings suggest that the more complex a ToM task is, the more likely typically developing older children and adolescents will need to employ EF resources in order to express their ToM understanding. Further, older children and adolescents with

AS/HFA appear to require more EF resources than their TD peers to express ToM concepts. In addition, they do not seem to understand advanced ToM concepts as fully as their TD peers, even though they are employing more executive resources while engaged in ToM reasoning.

Notably, the ADV ToM Vignettes task revealed that the girls with AS/HFA performed worse on every ADV ToM index relative to boys with AS/HFA, TD boys, and TD girls, even after controlling for composite IQ and age. These data suggest that there may be subtle gender differences in advanced ToM in older children and adolescents with AS/HFA. Although gender difference studies in ASD are limited, there has been a pattern of findings suggesting that girls with AS/HFA may have greater social and communication deficits than boys with AS/HFA (Hartley & Sikora, 2009; Holtmann, Bölte, & Poustka, 2007; Koyama, Kamio, Inada, & Kurita, 2009; Lord, Schopler, & Revicki, 1982).

Counter to my expectations, older children and adolescents with AS/HFA did not exhibit deficits in the emotional perspective taking facet of ToM, as measured by the Mind in the Eyes task. The original study that presented the Mind in the Eyes – Adolescent Version task (Baron-Cohen et al., 2006) assessed younger children in general than my study. Their participants with Asperger's syndrome ranged in age from 8 to 14 years, with a mean age of 13.35 (SD = 1.18). My study was shifted toward later adolescence and the participants with AS/HFA ranged in age from 10-17 years, with a mean age of 14.64 (SD = 2.05). It may be the case that emotional perspective taking develops dramatically during middle and later adolescence in the AS/HFA population, such that they developmentally "catch up" to their TD peers in terms of this ability. Many of the participants with AS/HFA in my study, however, have received social skills training involving explicit instruction on reading emotional expressions in photographs of faces, similar to the Mind in the Eyes task. Thus, even though they perform on par with their TD peers for the Mind in the Eyes task, it may be the case that older children and adolescents with AS/HFA engage different cognitive mechanisms to arrive at the same answer to the task.

The new ToM measure I designed, the ADV ToM Vignettes task, appeared to go above and beyond the other ToM measures, specifically Happé's Strange Stories and Mind Eyes, in its ability to serve as an individual difference measure. The ADV ToM Vignettes task was the only ToM measure that meaningfully correlated with verbal WM and IC. Although Happé's Strange Stories correlated with verbal WM in the TD group, it was in the wrong direction (i.e., negative correlation). Thus, Happé's Strange Stories did not appear to serve as a valid individual difference measure of ToM because it was not sensitive enough to detect differing levels of ToM abilities that related with individual differences in EF abilities. Happé's Strange Stories, however, was designed to assess group difference in ToM ability rather than individual differences, which it successfully did. I designed the ADV TOM Vignettes task, on the other hand, to assess *both* group differences and individual differences in ToM. I achieved these aims by writing vignettes that placed greater demands on ToM processing than Happé's Strange Stories. Unlike Happé's Strange Stories, my vignettes did not explicitly use ToM terms, such as belief, want, think, and thus participants were required to make ToM inferences based on implicit information. Further, my task not only assessed whether participants grasped the perspective of one person, like Happé's Strange Stories, but also whether they grasped if a second person understood the intentions of the first person (i.e., Second Order ToM). The findings from my study provide validity for the ADV ToM Vignettes instrument as a measure of both group and individual differences.

Further, my ADV ToM Vignettes Task was the only ToM measure that detected developmental change in ToM and was able to discriminate gender differences within the ASD group. Thus, my findings indicate that the ADV ToM Vignettes task may be used in future research to assess developmental advances in ToM for both the typically developing population and the population with AS/HFA. In addition, the ADV ToM task may be employed to detect subtle gender differences in ToM for the AS/HFA group. Of the three ToM measures, the Mind Eyes task was the least effective measure of ToM in that it did not reveal group differences, individual differences, or developmental differences in either the TD or AS/HFA groups.

Although there were numerous strong intercorrelations among my ADV ToM vignettes for the AS/HFA group, this was not the case for the TD group. The internal validity of my ADV TOM Vignettes task may be called into question because of the few intercorrelations among the vignettes for the TD group. With respect to this critique, there were more and stronger correlations among my vignettes than among the vignettes from Happé's Strange Stories for both the TD and AS/HFA groups. Second, researchers argue that to examine the factor structure of a measure with my number of test items requires at least 300 participants (Rouquette, & Falissard, 2011). Given that my sample size for the TD group was considerably smaller than 300 participants, the lack of numerous strong intercorrelations among the ADV TOM vignettes for the TD group does not provide convincing evidence that the measure had low internal validity.

The present study sheds light on the Executive Dysfunction Hypothesis. In particular, the Executive Dysfunction hypothesis postulates that EF is necessary for the emergence and expression of ToM (Ozonoff & McEvoy, 1994; Pellicano 2007a; Russell, 1996, 1997, 2002). Based on this hypothesis, it would be possible for an individual to have intact EF but impaired ToM because EF is necessary but not sufficient for ToM to develop fully. Of the few studies that have directly examined the relation between ToM and EF in ASD, these studies have focused on early childhood. Most of these studies provide confirmatory evidence for the Executive Dysfunction hypothesis, finding that young children with ASD exhibited deficits in both EF and ToM (Pellicano, 2007a) and EF skills (i.e., planning ability and cognitive flexibility) were longitudinally predictive of later ToM ability but not the reverse (Pellicano, 2010a). My data, which is from an older developmental ASD population, also supports the Executive Dysfunction hypothesis. Based on a group analysis, I found that the AS/HFA group compared to the TD group did not demonstrate impairments in the EF domains of verbal WM or IC, but exhibited deficits in the cognitive perspective taking facet of ToM. Following up with a more detailed analysis specifically of the participants with AS/HFA, I found that 14 were impaired on both ToM and EF, 13 were impaired only on ToM, and only 1 was impaired soley on EF. Overall these data are consistent with the pattern of findings predicted by the Executive Dysfunction Hypothesis.

Limitations

Regarding limitations, although I had a considerable sample size of participants with AS/HFA relative to the ASD literature, correlation analyses in particular often need a large number of data points for correlation coefficients to stabilize and to find statistical significance for small correlation coefficients. It is possible that with a larger sample size for each group, I would have found additional significant correlations. Further, a larger sample size of TD participants would have allowed me to examine the internal validity of my ADV ToM Vignettes task.

On a related point, the EF battery consisted of only one representative measure for a given psychological construct. As an example, for the assessment of verbal WM, I only had one verbal WM measure, the reading span task. Further, I assessed the visual facet but not the verbal facet of inhibitory control. It is important to examine how verbal inhibitory control may be related to advanced ToM given the potentially strong demands placed on verbal processing during ToM reasoning. Having more than one measure to assay a given construct would have given me the opportunity to look at construct validity and ensure the measures were indeed tapping the respective construct. Given this limitation, I took care to select measures that were well established in the field as valid and reliable instruments. Both the verbal WM and IC tasks I selected worked well for my sample because there was a good range of scores across participants in each group, suggesting the task was neither too easy nor too difficult for the participants.

Similarly, I only included one measure to index emotional perspective taking, i.e., the Mind Eyes task. Although I did not have ceiling or floor effects with the Mind Eyes task, it proved to be relatively challenging for both the TD and AS/HFA groups. Although participants in general scored above chance, no participant scored over 86% correct on the measure and the average score in both groups was approximately 70% correct. Therefore, the Mind Eyes task may not be most suitable for detecting differences in emotional perspective taking between the TD and AS/HFA adolescent populations.

I did not deem it feasible to test the children on additional measures because many children by the end of their two-hour long test sessions (and up to three hours for some children) were showing signs of physical and cognitive fatigue. Many of the tasks, such as reaction time measures, placed high demands on executive resources. Extending the length of the test sessions would likely have led to poor quality data and lower retention rates. When testing developmental populations, especially clinical developmental populations, it is necessary to balance quantity of data collection with quality of data collection.

In the current study, although I found that the AS/HFA group performed significantly worse than the TD group on both Happé's Strange Stories and the ADV ToM Vignettes, they did not demonstrate floor effects. Thus, they are capable to some extent of ToM reasoning. To further understand the degree of ToM impairments in the AS/HFA population, however, participants with AS/HFA would need to be tested on ToM paradigms that have greater ecological validity than the measures I used. The advanced ToM tasks used in this study did not involve live social interactions. In comparison to static pictures of facial expressions or vignettes about social interactions, real life social interactions likely place greater demands on social and executive processing in both typical and atypical populations. For instance, real life social interactions involve several more social cues, such as tone and gesture. Further, tracking these social cues potentially places greater demands on EF, such as increasing the visual and verbal working memory load and increasing the number of distractors that need to be inhibited to focus on the pertinent details of the social interaction. Thus, greater impairments in ToM and EF may arise when individuals with AS/HFA are faced with live social interactions.

Future Directions

The present study is among the first to assess the interrelations among facets of ToM and EF in the typically developing adolescent population, as well as the population with autism. Research on the development of ToM during adolescence has been severely limited in the past by the lack of age-appropriate ToM measures available. This provided the impetus to design an advanced ToM measure. It is my hope that my newly designed measure will be used in studies on social development in adolescents and possibly even adults. Further, my data suggest that it may be an appropriate individual difference measure of ToM in adolescents. Future studies could examine how individual differences on my ADV ToM task relate to a multitude of factors during adolescence and adulthood, such as friendship quality, empathy, social functioning, mood disorders, executive functioning, academic achievement, and adult life outcomes.

Developing advanced ToM paradigms with greater ecological validity is necessary for further refining our understanding of both typical and atypical ToM development during adolescence. It may be the case that ToM and EF impairments manifest more strongly in adolescents with AS/HFA during real life social interactions in comparison to laboratory experiments involving pictures of static facial expressions or social interaction vignettes. My ADV ToM Vignettes could be built upon to provide a social context that is more reflective of real life interactions. For instance, the vignettes could be acted out. This would likely increase both the social and executive demands of the task. New vignettes could also be created that include a larger number of individuals involved in a given social interaction. This would both increase the complexity of the task and mimic more closely multi-peer interactions characteristic of adolescence.

It is essential for future studies to examine more fully the relation between EF and ToM. Although we found that EF and ToM were related in both the TD group and the AS/HFA group, we were limited in the number of EF and ToM measures we could include in the study. Future studies that contain a more comprehensive battery of EF and ToM measures are necessary for clarifying the relation between EF and ToM. Specifically, it is important to map out the executive space in both the TD and AS/HFA adolescents populations to determine which facets (e.g., verbal and visual) of WM and inhibitory control are related to ToM and under what conditions. For instance, researchers could explore whether WM and inhibitory control of verbal stimuli is more important for verbally based ToM tasks. The current study did not include a verbally based measure of inhibitory control, but a standard Stroop task (Stroop, 1935) could be used in future studies to examine how the inhibition of verbal information may relate to ToM processing.

The design of the current study, however, did not allow for causal interpretations. A crucial next step is to examine how ToM causally relate to impairments or strengths in EF domains for both TD adolescents and adolescents with AS/HFA. In understanding the causal nature of these relationships, I can develop interventions to train abilities, such as EF abilities, that are key to the development of critical social understanding skills. Even within the typically developing domain, there are many children who are marginalized because of poor social skills. They would likely benefit from interventions that help them build skills to understand and appropriately respond during complex social interactions.

My findings highlighted a potential gender difference in ToM for the AS/HFA population. In particular, this gender difference was observed only for cognitive perspective taking, and specifically for the more advanced measure of ToM (ADV ToM task). Therefore, I suggest that future research explore the possibility of gender differences in the AS/HFA population for advanced ToM.

Conclusions

The findings of the current study have brought greater clarity to our understanding of the relation between ToM and EF during typical adolescent development and of the specific nature of impairments in ToM and EF in the cognitive profile of individuals with AS/HFA. In summary, I found that older children and adolescents with AS/HFA, especially the girls with AS/HFA, performed worse on ToM measures tapping cognitive perspective taking relative to TD peers. Although the AS/HFA group did not differ from the TD group in terms of verbal WM, visual WM, or IC, ToM reasoning seemed to place greater executive demands on the AS/HFA group. Given that verbal WM and IC were more strongly associated with ToM in the AS/HFA group, it may be the case that when individuals with AS/HFA are engaged in ToM reasoning they use different cognitive mechanisms from their TD peers or they recruit the same mechanisms but use them less efficiently.

In addition, I found that ToM, verbal WM, and visual WM continue to develop during later childhood and adolescence as part of both typical and atypical development. This is notable for two main reasons. First, the main focus of ToM research has been on the first five years of life, as some researchers believe there are few important advances that take place in the conceptual development of ToM after the age of five. My results strongly suggest that ToM becomes increasingly sophisticated during adolescence and may still place demands on EF during more complex social interactions, such as second order false belief scenarios. Second, the fact that ToM is still developing during later childhood and adolescence in both TD individuals and individuals with AS/HFA suggests that the brain regions supporting ToM processing are still plastic, and can therefore be targeted for intervention.

In conclusion, the present study combines theories and research methodology from across developmental, cognitive, and clinical areas of psychology in order to weave together a coherent picture regarding the development and nature of some of the most complex cognitive abilities inherent to man. This study has helped lay a stronger foundation for future research endeavors examining the relations among ToM and EF in both typical and atypical adolescent populations. In addition, the current study contributes a new measure of ToM to the field of psychology that will hopefully be used in future research to advance our knowledge of ToM.

APPENDIX A

SCREENING TYPICALLY DEVELOPING ADOLESCENTS FOR

MEDICAL HISTORY

Does your child have one or more of the following and please answer yes or no after each option:

- an autism spectrum disorder
- attention deficit and hyperactivity disorder?
- an anxiety disorder?
- recurrent major depression?
- a conduct disorder?
- serious emotional disturbance?
- obsessive compulsive disorder?
- learning disability (e.g., dyslexia)?
- orthodontia?
- a seizure disorder?
- schizophrenia?
- a bipolar disorder?
- Tourette's syndrome?
- drug dependency?
- speech delays?
- mental retardation?
- habitual involuntary movement or twitching of the face, arms, or legs?
- a significant visual impairment (strabismus, visual handicap)?
- color blindness?

APPENDIX B

THE CONFIRMATION OF ASD DIAGNOSIS SURVEY

Date: ____________

(Please place a check by correct answer)

My child is *currently*…

____ not diagnosed with an Autism Spectrum Diagnosis

____ diagnosed with Asperger's Syndrome (AS)

______diagnosed with High Functioning Autism (HFA)

____ diagnosed with *another* Autism Spectrum Diagnosis (for example, PDDNOS)
(please specify)___________________________

How is your child <u>currently</u> schooled?

_____ Traditional school
_____ Montessori school
______Other private school
_____ Home School
_____ Other, please list ____

Please continue to next page…

Has your child **<u>ever</u>** been diagnosed with any mental or neurological disorders (for example, ADHD, learning disability, obsessive compulsive disorder, anxiety, depression, Tourette's Syndrome, bipolar disorder, or other)? Please Note:

____

____

If so, please list. Please add in any medications or treatments ***CURRENTLY*** used for the disorders.

Disorder	Medication/Treatment Currently Being Taken	Purpose of Medication	Approximate date began Medication/Treatment

At approximately what **age** was your child identified as having an Autism Spectrum Disorder?

____

Over the course of your child's life, please tell us the professional(s) who identified/ confirmed that your child has autism (please circle **ALL** options that apply):

- o autism specialist/consultant
- o behavioral pediatrician
- o early interventionist
- o general physician
- o neurologist
- o pediatrician
- o psychiatrist
- o psychologist
- o school psychologist
- o special educator
- o speech/language pathologist
- o therapist
- o other, please list ____

APPENDIX C

AUTISM-SPECTRUM QUOTIENT - ADOLESCENT VERSION

Response Options:
"Agree"
"Slightly Agree"
"Slightly Disagree"
"Definitely Disagree"

1. S/he prefers to do things with others rather than on her/his own.
2. S/he prefers to do things the same way over and over again.
3. If s/he tries to imagine something, s/he finds it very easy to create a picture in her/his mind.
4. S/he frequently gets so strongly absorbed in one thing that s/he loses sight of other things.
5. S/he often notices small sounds when others do not.
6. S/he usually notices car number plates or similar strings of information.
7. Other people frequently tell her/him that what s/he has said is impolite, even though s/he thinks it is polite.
8. When s/he is reading a story, s/he can easily imagine what the characters might look like.
9. S/he is fascinated by dates.
10. In a social group, s/he can easily keep track of several different people's conversations.
11. S/he finds social situations easy.
12. S/he tends to notice details that others do not.
13. S/he would rather go to a library than a party.
14. S/he finds making up stories easy.
15. S/he finds her/himself drawn more strongly to people than to things.
16. S/he tends to have very strong interests, which s/he gets upset about if s/he can't pursue.
17. S/he enjoys social chit-chat.
18. When s/he talks, it isn't always easy for others to get a word in edgeways.
19. S/he is fascinated by numbers.
20. When s/he is reading a story, s/he finds it difficult to work out the characters' intentions.
21. S/he doesn't particularly enjoy reading fiction.
22. S/he finds it hard to make new friends.
23. S/he notices patterns in things all the time.
24. S/he would rather go to the theatre than a museum.
25. It does not upset him/her if his/her daily routine is disturbed.
26. S/he frequently finds that s/he doesn't know how to keep a conversation going.
27. S/he finds it easy to ''read between the lines'' when someone is talking to her/him.

28. S/he usually concentrates more on the whole picture, rather than the small details.
29. S/he is not very good at remembering phone numbers.
30. S/he doesn't usually notice small changes in a situation, or a person's appearance.
31. S/he knows how to tell if someone listening to him/her is getting bored.
32. S/he finds it easy to do more than one thing at once.
33. When s/he talks on the phone, s/he is not sure when it's her/his turn to speak.
34. S/he enjoys doing things spontaneously.
35. S/he is often the last to understand the point of a joke.
36. S/he finds it easy to work out what someone is thinking or feeling just by looking at their face.
37. If there is an interruption, s/he can switch back to what s/he was doing very quickly.
38. S/he is good at social chit-chat.
39. People often tell her/him that s/he keeps going on and on about the same thing.
40. When s/he was younger, s/he used to enjoy playing games involving pretending with other children.
41. S/he likes to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).
42. S/he finds it difficult to imagine what it would be like to be someone else.
43. S/he likes to plan any activities s/he participates in carefully.
44. S/he enjoys social occasions.
45. S/he finds it difficult to work out people's intentions.
46. New situations make him/her anxious.
47. S/he enjoys meeting new people.
48. S/he is a good diplomat.
49. S/he is not very good at remembering people's date of birth.
50. S/he finds it very to easy to play games with children that involve pretending.

APPENDIX D

ADVANCED THEORY OF MIND SAMPLE VIGNETTE AND CODING

Fernando and his cousin are getting ready to play the cool new video game that the cousin rented, when Fernando's mom tells them to go play outside instead. Later Fernando asks, "How about you come over to my house again tomorrow?" His cousin answers, "Let's go over to my house tomorrow, since I can't play indoors at your house." Fernando says, "I could go bowling or to a movie because both of those are indoors."

1. The cousin says, "Let's go over to my house tomorrow, since I can't play indoors at your house". What is the cousin's reason for saying this to Fernando? Please explain.
2. Fernando says, "I could go bowling or to a movie because both of those are indoors". Based on this, does it seem like Fernando understands what his cousin meant? Please explain.
3. What were Fernando and his cousin getting ready to do when Fernando's mom entered the room?
4. What did Fernando's mom ask them to do?

Coding Scheme

<u>Non-Literal interpretation:</u>

Question 1. The cousin wants to be able to play video games

Question 2. No, Fernando thinks his cousin just wants to play indoors

<u>Literal interpretation:</u>

Question 1. The cousin wants to play indoors.

Question 2. Yes, this is why Fernando gives indoor options, like bowling.

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