Relationship between Social Cognition, Language, Executive Functioning and Theory of Mind Ability in High-Functioning Autism

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RELATIONSHIP BETWEEN SOCIAL COGNITION, LANGUAGE, EXECUTIVE FUNCTIONS, AND THEORY OF MIND ABILITY IN HIGH-FUNCTIONING AUTISM

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ABSTRACT

RELATIONSHIP BETWEEN SOCIAL COGNITION, LANGUAGE, EXECUTIVE FUNCTIONS, AND THEORY OF MIND ABILITY IN HIGH-FUNCTIONING AUTISM

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August, 2013

Thesis supervised by Diane L. Williams, PhD. CCC-SLP

Whereas it is generally accepted that individuals with autism spectrum disorders (ASD) have deficits in theory of mind, or the ability to understand that other people have thoughts and to infer or predict what those thoughts might be, the relationship of this deficit to other aspects of ASD is still debated. This study examined the relationship between measures of social cognition, language, and the specific executive functions of working memory and cognitive flexibility, and measures of ToM using a large sample of 272 children and adults with high-functioning autism (HFA). The results of a series of hierarchical linear regression models indicated that the strongest relationship occurred between a general measure of language ability (Verbal IQ) and two different measures of ToM. In both children and adults with ASD, ToM abilities appear to be related to overall language abilities rather than a more generalized ability in social cognition or executive function.
DEDICATION

I dedicate my thesis to Dr. Diane L. Williams who provided me with support, motivation, confidence, and the opportunity to advance my knowledge during my career at Duquesne University. I am extremely grateful for the patience, time, and effort she allotted me for the successful completion of this project.
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Introduction

Theory of mind (ToM), or the ability to understand that others have thoughts, desires, and intentions outside of one’s own and to predict and explain behavior based on these mental states, is a cognitive skill that is thought to be essential for social interaction with others (Farrant, Mayberry, & Fletcher, 2012). It is classified as either being first order or second order. First order ToM is the ability to understand another individual’s thoughts, whereas second order ToM requires understanding another person’s thoughts about a third party’s thoughts. Understanding the various perspectives of the people one is interacting with is a vital skill that helps one to determine appropriate social communication and behavior. Therefore, a deficit in ToM is thought to be closely related to the social and communicative deficits associated with autism or autism spectrum disorders (ASD). The current study aims to investigate the question: From where does the ToM deficit in ASD arise?

False belief tasks are frequently used to assess ToM abilities in individuals with ASD. These tasks are called “false belief” because they are assessing the ability to understand that a person will search for something in an incorrect location based on a false belief about the item’s location. Children with ASD have been reported to be impaired on these tasks, and investigators have argued that this is the result of impaired executive functioning (Russell, Saltmarsh, & Hill, 1999) or impaired social cognition (Baron-Cohen, Leslie, Frith, 1985), both of which have been argued to be the central underlying deficit in ASD.

ASD is a developmental disorder characterized by a triad of impairments including the lack of reciprocity in social interactions, difficulty with the communicative
use of language, and a restricted and repetitive repertoire of interests and behaviors (American Psychiatric Association, 2000) that is thought to be genetically or neurologically-based (Geschwind & Levitt, 2007). The social impairments associated with ASD include deficits in expression and comprehension of gestures, lack of eye contact, lack of both social and emotional reciprocity, limited facial expressions, and lack of desire to share interests or satisfaction with others. The ability to start and maintain a conversation is disordered even in verbal individuals with ASD, and spoken language is frequently used in a repetitive and echolalic manner. Another hallmark characteristic of the disorder includes atypical prosody. Speech may sound monotone and machine-like with a limited variety of intonation patterns. In addition, individuals with ASD have difficulty with understanding abstract concepts or abstract language as demonstrated by the absence of pretend play in young children with the disorder.

Even though ASD is defined by this triad of symptoms, it is a spectrum disorder, and includes individuals with a wide range of communicative abilities. Individuals with ASD can range from completely non-verbal to being excessively verbal with a desire to socialize but with pragmatic ineptitude. Individuals with ASD may also exhibit a wide range of cognitive abilities as indicated by the variability in IQ scores within the disorder. Those who obtain an IQ of less than 70 are considered to have low-functioning autism, whereas those who obtain an IQ score of 70 or greater are considered to exhibit high-functioning autism. In consideration of the spectrum nature of the disorder, the term ASD will be used throughout the remainder of this document to refer to both autism and autism spectrum disorders.
Baron-Cohen and colleagues (1985) are generally accepted as the first to promote the idea that ASD was the result of a ToM deficit. They not only proposed that a deficit in ToM is a characteristic of individuals with ASD, but that it is the primary or core cognitive deficit underlying ASD. Furthermore, Baron-Cohen argued that the ToM deficit in ASD arises from a specific impairment in social cognition (Baron-Cohen et al., 1985).

Whereas a deficit in ToM is now generally accepted as characteristic of ASD, the nature or meaning of this deficit is still a matter of contention. Some authors have argued that the ToM deficit can be explained by other models of ASD such as the executive dysfunction theory (Griffith, Pennington, Wehner, & Rogers, 1999; Ozonoff, Pennington, & Rogers, 1991; Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009). In addition, because of the close relationship between ToM development and language development in typically developing children (Astington & Jenkins, 1996), the ToM deficit in ASD has also been argued to be associated with the difficulty children with ASD have with the development of language (Tager-Flusberg, 2007).

**Social Cognition and ToM**

ASD has been considered a specific disorder of the social cognitive domain due to the intact physicality and high intelligence observed in some individuals diagnosed with ASD (Fogeot d’Arc & Mottron, 2012). Research results have consistently shown differences between groups with and without ASD on false-belief tasks requiring understanding of complex mental states, thereby demonstrating an atypical understanding of complex social situations within the high-functioning ASD population (Fogeot d’Arc, & Mottron, 2012). Furthermore, this atypical performance is seen in the social areas of comprehension, perception, and motivation (Fogeot d’Arc, & Mottron, 2012).
ToM is thought to be a skill that is part of the system of social cognition or the “social brain” (Baron-Cohen et al., 1985; Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). Manifestations of social cognition that begin to emerge in infancy, such as play, imitation, and joint attention, have been reported to be closely related to the development of ToM in typically developing children (Charman, Baron-Cohen, Swettenham, Baird, Cox, & Drew, 2000). Joint attention and imitation abilities are thought to indicate a social cognitive representational ability to interact and understand people, whereas the ability to play and imitate can indicate a cognitive representational ability to interact with objects. All of these abilities are all required to obtain mental representations of various persons’ perspectives. It is these perspectives, which allow an individual to have a fully functioning ToM.

Skills acquired as young as infancy including joint attention abilities such as protodeclarative pointing, following gaze, and following pointing, are all evidence that a child has an emerging understanding of others as intentional agents. This understanding is a social cognitive ability that is a piece of the foundation for ToM (Charman et al. 2000). Another skill that emerges in early childhood that is related to ToM is pretend play. Pretending is the cognitive capacity to represent and influence one’s own attitudes towards information (Leslie, 1987, 1994). Therefore, pretend play is thought to influence later development of ToM because it enables a child to not only manipulate their own thoughts about information but to represent and manipulate the thoughts of others. A third early emerging skill that is thought to be associated with the development of ToM is imitation of gestures. The age of emergence of imitative gestures has also been reported
to be moderately associated with the emergence of referential language (Carpenter et al., 1998).

Children with ASD have been reported to be impaired in all three areas, joint attention, pretend play, and imitation, proposed to be precursors to the development of a ToM (Charman et al., 2000). Because both play and imitation of gestures are associated with language abilities (Carpenter et al., 1998; Charman et al., 2000; Steiglitz Ham & Bartolo, 2012), this suggests that a deficit in these skill areas could result in language impairments. Further, ToM abilities would be negatively affected due to the close relationship between language and ToM (Astington & Jenkins, 1996; Pyers & Senghas, 2009; Tager-Flusberg, 2007). Frequency of joint attention during social situations has a strong correlation with performance on ToM tasks (Hughes, 1998). In addition, those with ASD have difficulty comprehending and using gestures as a means to express language; therefore, they do not use them to refer to people or objects and may lack communicative gestures as a means to express language (Steiglitz Ham & Bartolo, 2012). These underlying early deficits in social cognitive abilities have been argued to result in the later manifestation of a deficit in ToM in ASD (Baron-Cohen et al., 1985; Charman et al., 2000). When viewed in the perspective of Baron-Cohen’s theory, which states that an impairment in social cognition causes the ToM deficit, the characteristic symptoms of ASD including difficulty with pretend play and difficulty with nonliteral language are interpreted as resulting from the inability to represent an outside individual’s thoughts (Foget d’Arc & Mottron, 2012).
**Language and ToM**

Most individuals with ASD have a general delay in the acquisition of spoken language and continuing difficulties with the comprehension and use of language (Tager-Flusberg, 1993). If the development of language and ToM are highly related, the language difficulties experienced by the ASD population could negatively affect their ToM ability.

It has been argued for quite some that ToM is related to language development in typically developing children (Astington & Jenkins, 1996; Tager-Flusberg, 2007). More recently, Farrant and colleagues (2012) examined the cognitive and linguistic factors that might affect the development of ToM. The Cognitive Complexity and Control theory (CCC) and/or the Cognitive Complexity and Control Theory-Revised (CCC-r) argue that ToM development is dependent upon cognitive flexibility or flexible perspective taking in that one must be able to shift between sets of judgments based on the social situation at hand (Frye, Zelaro, & Burack, 1998). According to this theoretical model, the higher order tasks required to shift between various perspectives are formed linguistically via silent self-directed speech (Farrant et al., 2012). Therefore, the linguistic ability to formulate and comprehend both an individual’s perspective and an appropriate response is required, and language is thought to facilitate ToM development.

Farrant and colleagues (2012) also posed the idea that ToM and language acquisition are highly correlated. For example, “A number of studies have found delayed ToM development in children with SLI [specific language impairment]” (Farrant et al., 2012, p. 221). Additionally, Astington and Jenkins (1999) conducted a study and found that 3 year olds’ language ability was a significant predictor of ToM ability 7 months
later; however ToM ability at age 3 did not predict language ability (p. 224). This provides further evidence of a correlation between the development of language and the development of ToM. Moreover, this suggests language as a precursor for developing a fully functioning ToM.

Maternal linguistic input, which is the inclination of mothers to think of and describe their child based on their mental attributes and to treat their child as an individual with his/her own mind, has also been found to have an effect on ToM. This “maternal mind-mindedness” encompasses mothers using mentalistic language when talking to their child. Therefore, the comprehension and application of this input is thought to be necessary to develop a ToM. A study conducted by Farrant and colleagues (2012) compared typically developing children to children with SLI. They compared performance on false belief tasks, memory for false complements, cognitive flexibility tasks, and maternal language input using Peterson and Slaughter’s Maternal Mental State Input Inventory. The results supported the hypothesis that memory for false complements and cognitive flexibility contribute to explicit false belief understanding. In addition, memory for false complements predicted cognitive flexibility, and the relationship between maternal language input and the development of a child’s ToM was mediated by cognitive flexibility (Farrant et al., 2012). These results also indicated that executive functions including cognitive flexibility and working memory for false complements had a direct effect on ToM.

**Executive Dysfunction Theory**

The findings of the research conducted by Farrant and colleagues (2012) provide support not only for the role of language in ToM development but also for the role of
executive functions. This is consistent with earlier work that argued that the ToM deficit in ASD was the result of difficulty with executive functions (Joseph & Tager-Flusberg, 2004; Russell, Saltmarsh, & Hill, 1999; Tager-Flusberg, 2007). Executive functions are cognitive skills that are thought to arise from the frontal lobe of the brain, particularly the pre-frontal cortex (Baddeley & Wilson, 1988; Stuss & Benson, 1986). Executive functions are what are thought of as the higher order processes of the brain. They are the ability to guide actions and/or behavior and use cognitive skills to achieve a future behavior or future goal. Aspects of executive functioning include, but are not limited to, planning, impulse control, inhibition, working memory, set maintenance, problem solving, cognitive flexibility, set-shifting, organization, self-monitoring, awareness over time, mental representation of tasks, attention, self-correction, rapid retrieval of relevant information, and mental operations.

The theory of executive dysfunction has been proposed to explain the etiology of the symptoms associated with ASD. This theory originated in 1978 with Damasio and Maurer, who compared the symptoms of individuals with ASD to those of patients with frontal lobe injuries (Griffith, Pennington, Wehner, & Rogers, 1999). Behavioral similarities between individuals with ASD and patients who have acquired frontal lobe lesions include repetitive behaviors, a desire for consistency, a lack of impulse control, difficulty with initiation of unfamiliar activities, and a deficit in cognitive flexibility (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009). The general conclusion, based on extensive research, is that there are deficits in executive functioning in individuals with ASD, varying in both the degree of the deficit and the domains in which there are deficits (Hill, 2004). Furthermore, a number of neuroimaging studies have found that
individuals with ASD not only have abnormal pre-frontal cortex structure and function, but also have decreased functional connectivity between their frontal cortex and other cortical and subcortical structures (Carper & Courchesne, 2005; Hazlett, Poe, Smith, & Piven, 2005; Just, Cherkassky, Keller, Kana, & Minshew, 2006; Villalobos, Mizuno, Dahl, Kemmotsu, & Müller, 2005). Thus, a problem with executive functioning in ASD has been supported by both behavioral and neurofunctional research.

**Executive functioning and ToM abilities.** Individuals with ASD have been reported to be severely impaired on both executive function tasks and tasks involving ToM (Baron-Cohen et al., 1985; Hughes, Russell, & Robbins, 1994; Ozonoff, Pennington, & Rogers, 1991). Furthermore, performance in these two domains is highly correlated (Ozonoff et al., 1991), suggesting either a causal relationship between these two abilities or a shared underlying causal factor. Lastly, studies have demonstrated that ToM tasks require the application of executive functions to be completed (Moore, Jarrold, Russell, Lumb, Sapp, & McCallan, 1995; Russell, Mauthner, Sharpe, & Tidswell, 1991), also suggesting a strong association between these two skill sets.

Hughes (1998) explored the relationship of executive functions and young children’s ToM using the three factor model of executive functions (i.e., working memory, inhibitory control, and cognitive flexibility) from Welsh et al., (1991) to guide selection of tasks. Fifty nursery-school aged children were given a battery of six executive functioning tasks and six ToM tasks. Results of the study indicated that the type of task (e.g., predicting where a person would look vs. explaining what the person was thinking) and the structure of the task [e.g., object transfer (putting the object in a new location) vs. deceptive contents (putting a different object in the same location)
affected task performance. It could be argued that the verbal demands of the task impacted the performance in both the prediction and explanation tasks. Attentional flexibility was significantly correlated with deceit whereas working memory was significantly correlated with false belief prediction. Therefore, Hughes (1998) concluded that specific relations existed between ToM and working memory and attentional flexibility. Additional evidence of an association between ToM and executive functions, specifically working memory and cognitive flexibility has been provided from other research with preschool children with ASD (Mutter, Alcorn, & Maril, 2006).

**Cognitive flexibility and ToM.** As mentioned above, it has been proposed that the ToM deficit in ASD is related to a more general impairment in executive functions such as cognitive flexibility and working memory. Cognitive flexibility is a higher order executive function which refers to the ability to change or shift a mental set, to appropriately shift one’s thinking in response to dynamic environmental stimuli. Numerous studies focusing on executive functioning related to ASD indicate that there is a deficit in cognitive flexibility (Bennetto, Pennington, & Rogers, 1996; Ozonoff, 1995; Ozonoff & McEvoy, 1994; Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998; Prior & Hoffman, 1990; Rumsey & Hamburger, 1988, 1990; Szatmari, Tuff, Finlayson, & Bartolucci, 1990). Cognitive flexibility is thought to be an important underlying cognitive process for ToM, which requires the ability to shift from one’s own perspective to that of another person. The argument is made that, if an individual with ASD has difficulty switching mental sets, it could result in difficulty with changing perspectives or incorporating new information. The difficulty with cognitive flexibility would then result in a deficit in ToM.
Previous research has provided some evidence of a relationship between cognitive flexibility and ToM in typically developing children (Hughes, 1998) and those with SLI (Farrant et al., 2012). Farrant and colleagues (2012) argued that to develop ToM one must master the power of representation, or an ability to take on other perspectives which may conflict with one’s own. According to the Cognitive Complexity and Control theory, being able to reason correctly in social situations is accomplished by flexibly shifting between various perspectives. In order to flexibly shift, different judgment sets must be embedded within one another. This theory claims that ToM development, in fact, relies on the development of the basic skill of cognitive flexibility (Farrant et al., 2012). The development of ToM relies on one’s ability to engage with others socially and to understand the perspective of another individual outside of one’s own. Cognitive flexibility allows for escaping a personal perspective to gain knowledge about another individual’s thoughts. Therefore, without cognitive flexibility, we would lack the ability to escape our own minds and shift to another individual’s thoughts. Thus, it can be hypothesized that cognitive flexibility would directly affect the development of ToM.

Further support for the predominance of cognitive flexibility in the development of ToM in ASD is provided by research in which the relationships between ToM, verbal ability, and cognitive flexibility, and maternal linguistic input were examined (Farrant et al., 2012). The results of this research indicated that memory for false complements and explicit false belief understandings were primarily mediated by cognitive flexibility. Cognitive flexibility was also found to both contribute to the development of false belief understanding and to mediate the relationship between maternal linguistic input and a child’s ToM development. Maternal linguistic input and false belief understanding both
have a direct effect on ToM, and, therefore, cognitive flexibility has both a direct and indirect effect on this ability.

However, executive functioning is not necessarily separable from linguistic functioning making it potentially difficult to assess the differing effects of these two processes on ToM in ASD. According to Sanders and colleagues (2008), deficits in executive functioning were reported to have an impact on the function of lower-order processes such as language (Sanders, Johnson, Garavan, Gill, & Gallagher, 2008). Moreover, the perseverative tendencies or lack of cognitive flexibility within the ASD population are thought to be attributable to the level of verbal abilities rather than the ASD diagnosis per se (Liss, Fein, Dunn, Feinstein, & Morris, 2001).

**Working memory and ToM.** Working memory is the ability to hold information “on line” within the brain and recall that information at a later time when appropriate. According to Gabig (2008), it involves both storage and processing of information. It is a regulatory control, which may be influenced by a limited capacity. It is the limited capacity nature of working memory that may be related to ToM. For example, the “Smarties” [a brand of small candies] task has frequently been used to assess ToM but performance on the task may be affected by the child’s working memory capacity. In this task, the child is shown a box labeled “Smarties,” in which lies an item that is not a piece of candy, such as a coin. The child is then asked what a novel person would think is in the box. This requires that the child recall an original erroneous belief (that the box contained candy) via working memory and apply it to another’s thoughts, despite information that may be most salient in the working memory (i.e. coin). Therefore, the child may perform poorly on the ToM component not because of a deficit in this area but
because of a deficit in working memory, resulting in the child having difficulty recalling his or her earlier (but discarded) thoughts.

Mutter and colleagues (2006) conducted a study looking at the relationship between false-belief tasks and executive functioning abilities, specifically working memory capacity and inhibitory control in preschool children ages 2.8 to 5.4 years. They examined working memory as it relates to ToM or false-belief using a variation of the “Smarties” task described above. The results of the study were interpreted to indicate that a child’s performance on false-belief tasks was dependent not only on the development of a ToM but also on the child’s ability to apply this knowledge with the latter being related to the child’s working memory capacity. Furthermore, their findings suggested that as children age, their working memory abilities increase with a concurrent increase in ToM abilities. The thought is that individuals must possess the working memory capacity to obtain the rules associated with ToM, in addition to the complex ability to maintain these rules in a hierarchical structure. In other words, it is not enough to realize that other people have thoughts and to make inferences about what these thoughts might be. One needs to be able to hold information on-line to accomplish the associated reasoning task. Mutter and colleagues explain that multiple studies with children with typical development have found evidence of improvement in false belief task execution as working memory capacity improves, suggesting a strong relationship between working memory and ToM (Mutter et al., 2006).

Just as cognitive flexibility is difficult to separate from language, similar close connections have been found between language and verbal working memory in ASD. Gabig (2008) indicated that deficits in verbal working memory may result in deficits in
language learning and competence. Gabig investigated verbal working memory in 15 school-aged children with ASD using 3 verbal working memory tasks, including nonword repetition, memory for digits span, and sentence imitation. She also assessed story recall using *The Renfrew Bus Story*. Her results support the theory that an increase in the complexity of information results in poorer performance on verbal memory tasks. According to Gabig (2008), “It appears children with ASD have a significant difficulty in tasks that require the parallel construction and processing of complex linguistic and cognitive representations to support their verbal working memory performance” (p. 508). She suggested that poor performance on these verbal working memory tasks can be explained with a connectionist model, meaning that verbal working memory and language processing both fall under the “language processing competence” category, thus a language processing deficit, such as one experienced by those with ASD, will cause impairments in verbal working memory skills as well.

Further evidence of the connectedness of language and verbal working memory skill in ASD was provided by Kjelgaard and Tager-Flusberg (2001). They found that children with ASD who had more difficulty with language tasks also had increased difficulty on tasks requiring phonological working memory. This result supports a link between working memory ability and language ability in ASD.

Based on the results of neuropsychological studies with children and adults with ASD, Williams, Goldstein, and Minshew (2006) argued that the cognitive profile in ASD suggests a constraint in information-processing with the most affected domains being the ones which placed the highest demands on information processing (Williams et al., p. 9). Therefore, working memory tasks involving complex information processing and
integration of information, such as integrating and applying a ToM to conversation, would be difficult for those who are diagnosed with ASD. Not only must one recognize that others have their own individual thoughts, but one must also use this information to come to a conclusion about the nature of the thoughts of the other individual, and then integrate these potential abstract ideas of his/her communication partner into a social interaction in order to make it appropriate. Linguistic skills are required to formulate someone else’s ideas in one’s mind via silent self-talk. Following the formation of these linguistic concepts in one’s mind, these concepts must then be held “on line” and applied to someone else’s thinking. This would require adequate verbal working memory to accomplish within a social interaction.

Prior research evidence indicates that working memory impairments in ASD are related to the complexity of the information or language required to hold the information “on-line” (Williams, Carpenter, Goldstein, & Minshew, 2005). Therefore, based on the complex processes and linguistic skills required for ToM, it is hypothesized that verbal working memory impairment will correlate with a disordered ToM.

**Conclusion**

Individuals with ASD experience impairments in the areas of social cognition, executive functioning, and language. The current study aims to look at the effects of these abilities (i.e. social cognition, executive functioning, and language) on the ToM deficit within the ASD population. Any examination of the effects of these individual skills is complicated because these skills are not entirely disassociated, making them difficult to view as completely separate elements within a ToM framework. For example, ToM deficits appear to have a direct effect on the social cognitive and social communicative
deficits, while linguistic and executive functioning deficits may have a direct effect on ToM and be related to social communicative deficits. Examination of all of these factors within a coherent sample of individuals with ASD may help to illuminate the relationships between them.

Evidence has suggested that ASD presents with atypical or low social cognitive and social communication skills (Baron Cohen et al., 1985; Charman et al., 2000; Fogeot d’Arc, & Mottron, 2012; Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). Baron Cohen’s theory (1985) proposes that the social cognition deficit in ASD directly correlates with the ToM impairment. If the ToM deficit is specific to an impairment in social cognition or the social brain, one would expect to find a strong relationship between ToM performance and social interaction measures, which would ultimately represent an underlying problem with social functioning. However, social cognition impairments may not cause the ToM deficit, but rather the ToM deficit may be caused by some other aspect (i.e. language delay, executive dysfunction) which may then contribute to the social cognitive problems seen within the disorder.

Evidence also suggests executive functioning deficits may also contribute to the problem with ToM (Baron-Cohen et al., 1985; Hughes, Russell, & Robbins, 1994; Joseph, Tager-Flusberg, 2004; Ozonoff, Pennington, & Rogers, 1991; Russell, Saltmarsh, & Hill, 1999; Tager-Flusberg, 2007). For example, it has been proposed that verbal working memory and cognitive complexity are executive function skills which affect ToM (Farrant et al., 2012). Similar to the “higher-order mental representations” (i.e. rules, generalizations, and concepts) (Ridley, 1994), Farrant and colleagues (2012) describe higher order rules which must be formed linguistically via silent self-directed
speech, and which are required for flexible perspective shifting. If individuals with ASD are unable to linguistically form these concepts due to their language impairments, the concepts would not exist. In addition to forming these concepts, they may lack adequate verbal working memory to hold these concepts within their brain for use. This would result in a lack of flexible perspective taking, presenting as a deficit in cognitive flexibility. Thus, based on this theory, it is hypothesized that verbal working memory would also have a direct effect on cognitive flexibility and an indirect effect on TOM.

Verbal working memory, or the ability to hold verbal information within the brain for later use, is required for a sufficient ability to understand others’ perspectives. These perspectives are most likely formulated within the brain using the language system, therefore they are formed verbally. A verbal working memory is essential to recall these various thoughts and ideas of other individuals after they have been silently verbalized within the brain. After linguistically coding them, they must be accurately recalled in order to apply a perspective to respond appropriately. Consequently, the brain must formulate a verbal response to the stimuli. Once this verbal response is formulated, it must be accurately recalled and used within conversation appropriately. Furthermore, throughout conversation, it is possible that the communication partner may have changes within his or her thinking. To maintain social appropriateness, verbal working memory is also required to recall the information exchanged linguistically within the conversation and continue creating the new ideas of the communication partner based on the information shared. Therefore, the following functions require verbal working memory in order to an individual to present with a fully functioning ToM: formulating and
understanding individuals’ perspectives, producing appropriate responses to each perspective, and recalling shared information to infer a novel thought or idea.

Cognitive flexibility, or the ability to shift mind-sets based on certain situations, is an imperative skill for ToM. It is the executive function which allows you to react differently to each communication situation or task based on the ability to infer ideas. Without possession of cognitive flexibility, appropriate social communication in various settings would pose as difficult. Novel responses are required based on the communication setting, communication partner, and communication atmosphere. The ability to generate novel responses stems from cognitive flexibility, as a variety of responses would require a variety of mind-sets and to elicit shifting between mind-sets. Therefore, if only one individual’s thoughts and ideas are focused on (i.e. one’s own), the result in perseverative behavior. The general task forming the concept of ToM, thinking outside of one’s own mind, requires cognitive flexibility in itself. Therefore, this is an imperative task in order to generate novel responses based on various communication situations and understand thoughts outside of one’s own head, causing a direct effect on ToM ability.

As discussed earlier, researchers believe language ability may correlate with ToM abilities (Astington & Jenkins, 1996; Pyers & Senghas, 2009; Tager-Flusberg, 2007). Because verbal working memory requires verbal skills and linguistic coding, it is hypothesized that language skills would have an effect on ToM. A decrease in language ability would result in a decreased ability to linguistically form individuals’ thoughts and ideas within the brain, verbally form novel and appropriate responses, and comprehend and apply linguistic information exchange within a conversation. Related to cognitive
flexibility, to understand various perspectives, one must be able to shift mind-sets and decode these linguistically stored mind-sets within the brain. A deficit in language would result in a lack of ability to comprehend the mind-sets of other individuals. Without understanding different perspectives, one cannot change mind-sets, resulting in perseverative behavior. Moreover, research has supported that language development and ToM development exhibit a close relationship (Astington & Jenkins, 1996; Pyers & Senghas, 2009; Tager-Flusberg, 2007). Therefore, delayed language skills may result in deficient ToM skills.

The relationships between measures of ToM and factors such as social cognition, language, and executive function have been examined in previous studies. However, these studies have primarily focused on investigation of one of these factors and the sample sizes have generally been limited and the primary focus has been on either children or adults with ASD but rarely a wider range of ages in a single study. Two sizeable samples of well-diagnosed children and adults with ASD with ages ranging from 8 to 55 years were available as part of larger programs of research. These samples included basic measures of social interaction, language, verbal memory, and ToM on all the participants. Furthermore, subgroups within these samples had more specific measures of language, verbal working memory, and cognitive flexibility making it possible to examine relationships between these variables in a cohesive set of individuals. Detailed information about each of these samples is provided in the Methods section.

It was hoped that this study would provide further understanding about the underlying factors which contribute to the ToM deficits within the ASD population. More specifically, the goal was to further clarify the relationships between social
cognition, language, executive functioning and ToM. If ToM is primarily related to social cognition, a high correlation between ToM measures and social interaction measures on the *Autism Diagnostic Observation Schedule* (ADOS; Lord, Rutter, DiLavore, & Risi, 2001) and *Autism Diagnostic Interview-Revised* (ADI-R; Le Couteur, Lord, & Rutter, 2003) (representing an underlying problem with social functioning) would occur. If ToM is primarily related to language functioning, a high correlation with language measures, and/or the communication measures from ADOS and ADI, and Verbal IQ would occur. If ToM is primarily related to executive functioning, a high correlation with executive function measures, particularly measures of working memory and cognitive flexibility would occur.

The hypotheses tested were:

**Hypothesis 1:** Theory of Mind performance is related to measures of social cognition in children and adults with high-functioning autism.

**Hypothesis 2:** Theory of Mind performance is related to measures of language in children and adults with high-functioning autism.

**Hypothesis 3:** Theory of Mind performance is related to measures of working memory and cognitive flexibility in children and adults with high-functioning autism.

**Methods**

**Participants**

The above hypotheses were tested using previously collected data from two samples or groups of individuals with ASD ranging in age from 5 to 55 years. The data were collected as part of two program project grants at the University of Pittsburgh Center for Autism Research (CeFAR), the Collaborative Programs of Excellence in Autism (CPEA) and the Autism Centers of Excellence (ACE). The studies were funded
by the National Institute of Child Health and Development (NICHD). The data analyses were separated into three separate sets of analyses to address each of the hypotheses.

The diagnostic procedures and criteria for each of the samples were the same. All participants met criteria for autism or autism spectrum disorder on the ADOS and ADI-R administered by clinicians trained to research reliability on the diagnostic instruments. The diagnosis was verified by expert clinical opinion using *DSM-IV-TR* (APA, 2000) criteria. In addition, all participants had Full Scale, Performance, and Verbal IQs greater than or equal to 70 as measured by the *Wechsler Abbreviated Scale of Intelligence* (WASI; Wechsler, 1999). Exclusions were based on neurological history and examination, physical examination, chromosomal analysis, and metabolic testing if indicated. Potential participants were excluded if found to have evidence of an associated neurological, genetic, infectious, or metabolic disorder, such as tuberous sclerosis, fragile X syndrome, or cytomegalovirus. The diagnostic measures are described in more detail in the section below.

Sample #1 (CPEA) consisted of 115 individuals with ASD (73 individuals ages 8 to 15 years and 42 individuals ages 16 to 54 years), mean age 16.6 (SD = 8.3; range 8.7 to 53.8). It included 103 males and 12 females with mean VIQ 100.1 (SD = 13.2; range 73 to 133), mean PIQ 103 (SD = 14.7; range 66 to 134), and mean FSIQ 101.6 (SD = 13.3; range 73 to 133) as measured by the WASI.

Sample #2 (ACE) consisted of 157 individuals with ASD (93 individuals ages 5 to 15 years and 64 individuals ages 16 to 55 years), mean age 15.9 (SD = 7.6; range 6.0 to 45.1). It included 136 males and 21 females with mean VIQ 108.1 (SD = 14.5; range
74 to 141), mean PIQ 108.7 (SD = 13.9; range 76 to 144), and mean FSIQ 109.2 (SD = 13.6; range 76 to 146).

When possible, the two samples were aggregated to increase the power of the analyses. This dataset contained 272 participants with ASD (166 individuals ages 5 to 15 years and 106 individuals ages 16 to 55 years) mean age 16.2 (SD = 7.9; range 6.0 to 53.8). It included 239 males and 33 females) with mean VIQ 104.7 (SD = 14.5; range 73 to 141), mean PIQ 106.3 (SD = 14.5; range 66 to 144), and mean FSIQ 106 (SD = 13.9; range 73 to 146).

For other analyses, the groups were separated into children and adults because these age groups had been administered different measures or in order to examine more closely possible developmental differences. Subgroups from the two large samples were also used for some of the analyses based on the specific measures that were available.

**Diagnostic Measures**

*Autism Diagnostic Observation Schedule (ADOS).* The ADOS (Lord et al., 2001) is an assessment tool that was developed to provide objective standards for the diagnosis of autism and pervasive developmental disorder across ages, developmental levels, and language skills. It consists of 4 modules, designed for differing developmental and language levels based on an individual’s age and use of expressive language and chronological age. The participants in the two samples were assessed using either Module 3 or Module 4 as age appropriate. Results of the ADOS are based on standardized behavioral observation and coding, and it contains cutoff scores for a narrow diagnosis of autism and a broader diagnosis of autism spectrum disorder.
**Autism Diagnostic Interview – Revised (ADI-R).** The Autism Diagnostic Interview – Revised (ADI-R; Le Couteur et al., 2003) was developed to diagnose autism, plan treatment, and distinguish between autism and other developmental disorders based on reports of case history information and current functioning levels. It is appropriate for children and adults with a mental age above 2.0 years and targets the three functional domains of language/communication, reciprocal social interactions, and restricted, repetitive, and stereotyped behaviors. The assessment contains a standardized interview focusing on eight areas including the participant's background (i.e. family, education, previous diagnoses, and medications), overview of the participant's behavior, early development and developmental milestones, language acquisition and loss of language or other skills, current functioning in regard to language and communication, social development and play, interests and behaviors, clinically relevant behaviors, such as aggression, self-injury, and possible epileptic features. The interviewer then codes the informant’s responses and domain scores are calculated for the three functional domains and age at onset of developmental problems.

**Wechsler Abbreviated Scale of Intelligence (WASI).** The Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was designed as a short version of the Wechsler Intelligence Scale for Children—third edition (WISC-III; Wechsler, 1991) and the Wechsler Adult Intelligence Scale—third edition (WAIS-III; Wechsler, 1997a), and it targets the population ranging in age from 6.0-89.0. This assessment provides scores for a verbal IQ, performance IQ, and full scale IQ, and was used to obtain the aforementioned IQ scores for the study’s participants. It consists of 4 subtests, all chosen based on the
WISC-III and the WAIS-III. According to Buros (2012), it is an excellent instrument for a quick estimate of one’s intellectual functioning.

**ToM Measures (Dependent Variables)**

The *dependent variables* in all analyses were the measures of ToM derived from the performance on the traditional measures of ToM, the *Sally and Anne, John and Mary*, and *Peter and Jane* tasks. In both administration to participants in CPEA and ACE, the *Sally and Anne* and the *John and Mary* stories were represented with real objects/props. The *Peter and Jane* story was presented verbally without props. Participants in Sample #2 had an additional ToM measure, the *Reading the Mind in the Eyes Test-Revised* (Eyes test) that was included in relevant analyses as described below.

**Sally and Anne.** The Sally and Anne task (Baron-Cohen et al., 1985) is used to assess *first order* ToM because the individual must only identify one other person’s thoughts about something. The Sally and Anne story is as follows:

*This is Sally and this is Anne. Sally first placed a marble into her basket. Then she left and the marble was moved, by Anne, into her hidden box. Then Sally returned.*

(Baron-Cohen et al., 1985; adapted from Wimmer & Perner, 1983)

Belief Question: *Where will Sally look for her marble?*

Reality Question: *Where is the marble really?*

Memory Question: *Where was the marble in the beginning?*

If the individual recognizes that Sally will look in the basket for her marble, then he or she has a ToM because they have obtained an understanding of Sally’s perspective. However, if they believe Sally will look in the box for her ball, the examinee lacks the understanding of Sally’s perspective, and thus lacks the ToM ability.
John and Mary. The John and Mary task (Perner & Wimmer, 1985) is used to assess second order ToM in ASD (Baron-Cohen, 1989) because it requires the examinee to identify someone else’s thoughts about another individual’s false-belief ideas. The John and Mary story is as follows:

This is John and this is Mary. They live in this village. Here they are in the park.
Along comes the ice cream man. John would like to buy an ice cream but he has left his money at home. He is very sad. “Don’t worry,” says the ice cream man, “you can go home and get your money and buy some ice cream later. I’ll be here in the park all afternoon.” “Oh good,” says John, “I’ll be back in the afternoon to buy an ice cream.” So John goes home. He lives in this house. Now, the ice cream man says, “I am going to drive my van to the church to see if I can sell my ice creams outside there.” The ice cream man drives over to the church. On his way he passes John’s house. John sees him and says, “Where are you going?”
The ice cream man says, “I’m going to sell some ice cream outside the church.” So off he drives to the church. Now Mary goes home. She lives in this house. Then she goes to John’s house. She knocks on the door and says “Is John in?” “No,” says his mother, “he’s gone out to buy an ice cream.” (Baron-Cohen, 1989; adapted from Wimmer & Perner, 1985)

Belief Question: Where does Mary think John has gone to buy an ice cream?

Reality Question: Where did John really go to buy his ice cream?

Memory Question: Where was the ice cream man in the beginning?

Because the examinee must infer what John’s thoughts are about Mary’s thoughts, this is considered second order ToM. Therefore, if the examinee answered “the park,” he
or she has accurately understood John’s perspective about Mary’s thoughts and therefore has a ToM.

**Peter and Jane.** The Peter and Jane Shopping Story (Bowler, 1992) is a second-order false belief task. The story involves two friends shopping for a coat for Peter. Each friend learns information about the availability of a particular coat but from different sources. The child is then asked some standard questions to determine whether he or she understands what information is shared by the two friends. It is a second-order task because the child is asked to infer what Jane thinks about what Peter knows. The Peter and Jane story is as follows:

*Peter and Jane are out shopping on their lunch hour. Peter wants to buy an overcoat and the nicest one he has seen is at Wal-Mart. But before he makes up his mind, he would like to go to K-Mart to see what they have in stock. So they both go to K-Mart where they look at some coats. These are not as nice as the ones as Wal-Mart, so Peter decides to go back to Wal-Mart that evening after work to buy his coat. At 5:00 that afternoon Peter phones Wal-Mart to make sure that they have a coat of his size still in stock. Unfortunately they tell him that they have just sold the last one and that they don’t know when they will be getting any more in. By 5:20 Jane has not arrived at Peter’s office, so Peter decides that he had better go alone to buy his coat before the shops close. At 5:25 Jane arrives at Peter’s office. She is late because she popped in to Wal-Mart on her way and found out that they had no more of the coats Peter liked in stock.* (Bowler, 1992)

Belief Question: *Where does Jane think Peter has gone to buy his coat?*

Reality Question: *Where has Peter really gone to buy his coat?*
Memory Question: *In which shop did Peter see the coat he liked best?*

**Aggregated measure from traditional measures of ToM.** A single measure of ToM was constructed from the three different traditional ToM measures using a scale in which points are awarded to the questions which test for ToM and added to create a total score. The questions selected from the ToM tasks to be included in scoring the ToM measure were the belief question, the reality question, and the memory question. The selection of these specific questions was based on a study completed by D.M. Bowler (1997), who used the exact same Peter-Jane task and John-Mary task to assess ToM in HFA. Bowler (1997) credited his subject with passing the belief task only if they had answered the reality and memory question correctly. Participants in this study were awarded one point for each selected question answered correctly (i.e. belief, memory, reality), making a maximum score of three possible for each individual task. After each participant’s scores were calculated for the individual tasks, they were added to create the total ToM score. Therefore, the total maximum score for the ToM measure was nine.

**Reading the Mind in the Eyes Test-Revised (Eyes test).** The *Reading the Mind in the Eyes Test-Revised* (Baron-Cohen, Wheelwright, Hill, Rask, & Plumb, 2001) was administered as a measure of ToM that is supposed to be more appropriate for use with verbal, high-functioning individuals with ASD. It determines the ability of an individual to recognize the feelings of someone while only viewing the information provided by their eyes, a task that is thought to “detect subtle differences in social sensitivity” (Baron-Cohen et al., 2001, p. 241). The examinee is asked to attribute a feeling or thought to another individual by reading only part of their facial expression. Each item contains a photo of a person’s eyes accompanied by four written choices (e.g. distrusting, amused,
confident, shy). The examinee is asked to choose which feeling best matches the photo. The paper version of the test was used. For the adult administration, the adults independently read and completed all items. Definitions were available if the participant indicated they were unfamiliar with any of the words. For the children, the written words were read aloud to them by the examiner. In both cases, the selection was made by marking one of the four choices. Both the child and adult versions of the Eyes test were administered, with total possible scores of 28 and 36 respectively. This was accounted for via running separate models with the subgroups of children and adults in addition to models with the entire group of participants.

**Independent Variables**

For all analyses, the independent variables included measures of social cognition (taken from the ADOS and/or ADI-R as described below), language, verbal and spatial working memory, and cognitive flexibility. These measures differed for each sample of participants as described in the different analyses for testing each of the null hypotheses. A description of each of these measures is provided below.

**Social cognition.** In some studies, the ToM measures described above are used as “measures of social cognition”; however, for the purposes of our analyses we used other independent indicators of social cognition and then examined the relationship of those measures to the measures of ToM. Because we were most interested in measures of social cognition that relate to actual social functioning, we used measures derived from relevant sections of the ADOS and ADI-R. The complete scores from these instruments were not used because they include additional items that measure general communication abilities (such as use of gestures) as well as measures of restricted, repetitive behaviors. It
is acknowledged that the use of partial measures from a formalized instrument is not without its limitations. However, this approach provided us with the best solution for an independent measure of social cognition for the available participant groups. The items chose from each instrument to construct the separate measures of social cognition were ones that the test authors indicated were measures of this area as well as ones related to the social use of communication.

Depending on the age of the participant either module 3 or 4 of the ADOS was administered; however the relevant questions selected to construct the measure of social cognition were consistent across both modules. The following areas were selected from the ADOS to create a score for social cognitive ability: offers information, requests information, conversation, eye contact, facial expressions directed to others, shared enjoyment in interaction, empathy/comments on other’s emotions, insight, quality of social overtures, quality of social response, amount of reciprocal social communication, overall quality of rapport. The score assigned for each individual item was the actual score given by the administrator (usually a value from 0 to 3 with a score of 3 indicating a more significant impairment). In cases in which a score of 8 was assigned by the administrator (indicating that an item was not administered or was not applicable), it was treated as a null value, not adding to the overall total score for that individual. The maximum score which could be achieved on the social cognition score derived from the ADOS was 32, with a score closer to 0 representing a more intact social cognitive system. To distinguish this partial measure from the overall ADOS score, it will be referred to as ADOS-SocCog.
The following areas were selected from the ADI-R to create a second score for social cognitive ability: social verbalization/chat, reciprocal conversation (within subject’s level of language), attention to voice, spontaneous imitation of actions, imaginative play, imaginative play with peers, direct gaze, social smiling, showing and directing attention, offering to share, seeking to share his/her enjoyment with others, offering comfort, quality of social overtures, appropriateness of social responses, imitative social play, interest in children, response to approaches of other children, group play with peers, friendships, and social disinhibition. As for the ADI-R, the score for each item was the score assigned by the administrator (a value from 0 to 3 with a score of 3 indicating a more significant impairment). In cases in which a score of 8 or 9 was assigned by the administrator (indicating that an item was not administered or was not applicable), it was treated as a null value, not adding to the overall total score for that individual. As a result, the maximum score which could be obtained on the ADI-R measure was 58, with a score closer to 0 indicating more intact social cognitive skills. To distinguish this partial measure from the overall ADI-R score, it will be referred to as ADI-SocCog.

Language measures. Several different language measures were used across both of the larger samples of participants. These measures are described in more detail below. Clinical Evaluation of Language Fundamentals – 3rd or 4th Edition (CELF-3 or 4; Semel, Wiig, & Secord, 2003). The CELF-3 was designed to identify, diagnose, and provide follow-up evaluation of communication disorders in children and adolescents aged 6 to 21 years of age. The CELF-4 was developed with these same intentions for children and adolescents aged 5 to 21 years with revised subtests and the addition of an
Observation Rating Scale and a Pragmatics Profile. The Semantic Relations subtest (CELF-3 & 4) was administered to both the child and adult participants of sample #1. Word Classes 1 or 2 (CELF-4) and Recalling Sentences (CELF-4) were administered to approximately 23 child participants in sample #2. The objectives of the Semantic Relationships subtest include evaluating the individual’s ability to interpret the meaning of sentences that make comparisons, identify location or direction, specify time relationships, include serial order, or are expressed in passive voice. The examinee is given a verbally presented stimulus with four visually presented options, two of which must be selected as the correct choices. This subtest can help identify difficulties with perceiving and interpreting semantic relationships in sentences and in discourse, which may occur as a result of poor ability to analyze and synthesize critical concepts and key words, difficulty forming internal images of objects/events which are being compared, rigid word associations, and/or difficulty with retaining and recalling word order within a sentence (Semel et al., 2003).

The objective of the Recalling Sentences subtest is to evaluate the individual’s ability to listen to spoken sentences of increasing length and complexity and repeat the sentences without changing word meanings, inflections, comparisons, or sentence structure. This provides a measure of the individual’s verbal memory skills, as individuals with language disorders often have difficulties remembering verbal sentences with increasing structural complexity, word length, and conceptual density. The examiner provides a verbal stimulus by reading a sentence aloud, and the examiner is expected to repeat the sentence exactly (Semel et al., 2003).
The objective of the Word Classes 1 and 2 is to measure the ability to perceive, understand, and explain relationships between pictures or spoken words which are associated by semantic class features. The Word Classes 1 subtest targets individuals ages 5 to 7 years, and the examinee is provided with 3 pictorial stimuli which correlates with the verbal stimuli presented by the examiner. The Word Classes 2 subtest targets ages 8 to 21 years, and the examinee is presented with 4 verbal stimuli. In both subtests, the participant must choose the 2 stimuli which are semantically related and describe the semantic class features which result in association of the words. Therefore, receptive language skills are measured by having the examinee comprehend the choices and choose the related words, and expressive language skills are measured by having the examinee explain why two words are related. This subtest can identify problems with word association skills, understanding different categories of words, identifying various relationships among words, word-finding, and explanations requiring organization of language output (Semel et al., 2003).

*Test of Language Competence – Expanded Edition (TLC-E; Wiig & Secord, 1989).* The TLC-E was administered to both the child and adult participants in Sample #2. Its target populations are ages 5.0 – 9.11 years (Level 1), and 9.0 - 18.11 years (Level 2), and its purpose is to evaluate delays in the emergence of linguistic competence and in the use of semantic, syntactic, and pragmatic strategies. Language competence, as defined by the authors, is “the understanding and/or expression of language content to the communicative demands of specific contents” (Buros). Four subtests were administered: 1) Ambiguous Sentences, 2) Listening Comprehension: Making Inferences, 3) Oral Expression: Recreating Speech Acts, and 4) Figurative Language. Due to the age range
targeted by this assessment (5.0-18.11) compared with the age range of the population assessed (8-55 years), raw scores were not converted to scaled scores in order to avoid reaching a ceiling level, and the raw scores themselves were compared.

**Children’s Communication Checklist-2nd Edition (CCC-2; Bishop, 2006).** This measure targets the population aged 4 to 16 years and was used to assess language and communication skills of the child participants (ages 8 to 15 years) in Sample #2. These skills are assessed via a checklist completed by the child’s primary caregiver or a familiar adult. Responses are based on a 4-point rater scale and depend upon the frequency of communication behaviors observed. Purposes of the CCC-2 include the identification of pragmatic language impairment, screening of receptive and expressive language skills, and assistance in screening for ASD. Bishop designed the test to assess children's communication skills in the areas of pragmatics, syntax, morphology, semantics, and speech. It provides scores for 10 communication domains (i.e. speech, syntax, semantics, coherence, initiation, scripted language, context, nonverbal communication, social relations, and interests) in addition to a General Communication Composite (GCC) and a Social Interaction Difference Index (SIDI). Derived scaled scores and percentile ranks are provided for each scale. The GCC provides a normalized standard score, confidence interval, and percentile rank. The SIDI is the sum of performance on the scales assessing language and non-language features associated with ASD, and it is intended for descriptive use.

**Executive function measures.** The measures of executive function included measures of verbal and spatial working memory and separate measures of cognitive flexibility. These are described in more detail below.
**Working memory.** *Wechsler Memory Scale –third edition* (WMS-III; Wechsler, 1997b). 62 adult participants from Sample #2 were administered the Digit Span and Spatial Span subtests from the WMS-III. Because we wanted to use a measure of working memory that included the important level of maintenance of information while a second cognitive process was performed, we used only the performance of the participants on the Digit Span Backwards and Spatial Span Backwards portions of these subtests as working memory measures. The Digit Span Backwards assesses the individual’s ability to receive and process verbal information in addition to manipulating that information while holding it on line within the brain. For example, the examinee is provided with a string of digits verbally and then required to hold the digits within his/her memory and manipulate this information in order to verbally produce the span of digits backwards. The total possible score for the Digit Span subtest is 14. Spatial Span Backwards operates with the same principles; however the examinee is provided with visuo-spatial information to process, hold on line, and manipulate. Because no separate standardized score is available for these portions of the working memory subtests, we used the raw scores that were the points awarded for correct performance of these items. The total possible score for Spatial Span subtest is 16.

*Children’s Memory Scale* (CMS; Cohen, 1997). A subgroup of 21 children from Sample #2 was administered the Number Memory task from the CMS 5-8 and a subgroup of 66 children from Sample #2 was administered the Number Memory task from the CMS 9-16 as a measure of working memory ability. Similar to the Digit span subtest from the WMS-III, the participant is provided with a string of digits verbally and then required to hold the digits within his/her memory and manipulate this information to
verbally produce the span of digits backwards. The maximum score for each of these assessments is 14.

**Cognitive flexibility.** *Twenty Questions* (Olver & Hornsby, 1966). The *Twenty Questions* procedure is a measure of verbal reasoning and conceptual thinking; it is also considered a measure of cognitive flexibility. During the *Twenty Questions* test, the examinee is provided with a stimulus page containing 30 photos, and he or she must ask the least amount of yes/no questions in order to conclude what the target object is. This assesses visual attention and perception, object recognition, and object naming, in addition to requiring the examinees to identify categories and subcategories to place the objects in while formulating yes/no questions to either eliminate or include objects. This shifting among categories within the brain while formulating questions based on different properties of various objects requires the ability to shift mind-sets, or cognitive flexibility. If one focuses on only one category or one property (e.g. color) when formulating questions and is unable to shift mind-sets, limited information is received and reaching a conclusion about the correct item will pose as impossible. A total of 60 participants (41 children, 19 adults) from Sample #1 were administered this test. The total number of questions asked by the participant was used as a measure of cognitive flexibility.

*Modified Vygotsky Concept Formation Test* (Wang, 1983). The *Modified Vygotsky Concept Formation Test* was administered to 20 participants from Sample #1 (5 adults, 16 children), and the number of perseverative errors will be used as one of the sources used to determine cognitive flexibility measures during analysis of data. The test is based on one of the first tests used by Lev Vygotsky (1934) to measure cognitive
reasoning skills. It consists of 22 different blocks, all varying in 4 different dimensions (e.g. height, color, shape, width). It looks at both convergent and divergent thinking. To measure convergent thinking, the trained examiner shows a block to the examinee, and the examinee must then identify other blocks belonging in a specific category based on feedback provided by the examiner. After three consecutive errors, the examiner shows another block within the same category. The convergent test uses four kinds of information including total errors, perseverative errors (three consecutive errors based on the same erred dimension), number of cues provided by the examiner, and principles described by the examiner (transcribed verbal statements made by the examinee). There are a total of four trails, one for each dimension. To assess divergent thinking, the examinee is instructed to organize the blocks based on a dimension of his or her choice, and there are eight possible sortings. This is repeated as many times as necessary (Wang, 1983)

Data Analyses

The three hypotheses represent different models of the relationship between the dependent variable of ToM and the independent variables of social cognition, language, working memory, and cognitive flexibility. To test the three hypotheses of the relationship between the variables, three different hierarchical multiple regression models were used. In each model, the ToM measure was the outcome or predicted variable. As described above, a single measure of ToM was constructed from the three different traditional ToM measures and was used as the dependent variable for the first group of analyses. A second set of analyses was also conducted using the Eyes test as the dependent variable. The availability of this measure for a sizeable number of the participants provided the
opportunity to determine whether the results from the first set of analyses using the traditional ToM measures could be replicated with a different ToM measure.

In hierarchical multiple regression, as in multiple regression analysis, several independent variables predict a dependent variable (in this case the measures of ToM). In standard multiple regression analysis, this is done in a single equation that estimates the effect of each independent variable on the dependent variable, controlling for all other independent variables. Hierarchical multiple regression allowed us to enter independent, or sets of independent, variables in successive steps estimating separate models and the effects of different sets of independent variables. A hierarchical regression model indicates if subsequent independent variables add any predictive power to the model.

Prior to running the regression models, we evaluated the independent variables for multicollinearity (to determine if the variables were highly correlated) by running a correlation matrix that included all the independent variables that were being considered for entry into the hierarchical multiple regressions. A high correlation suggested that particular variables were redundant and, therefore, would result in no added variance or effect on the dependent variable if added to the model (Tabachnick & Fidell, 2001). These redundant variables would not all be needed in the same analysis. A correlation matrix was run separately for Sample #1 (CPEA) and Sample #2 (ACE) because the two sets of data had different measures.

The correlation matrix for Sample #1 (CPEA) included the following independent variables: ADOS-SocCog, ADI-SocCog, Semantic Relations subtest (CELF-3 or CELF-4), Verbal IQ, Twenty Questions, and the Modified Vygotsky Concept Formation test. Verbal IQ was determined to have significant correlation at the $p \leq 0.01$ level (2-tailed)
with the Semantic Relations subtest \( r = .445 \). Twenty Questions was significantly correlated at the \( p \leq 0.05 \) level (2-tailed) with the Semantic Relations subtest \( r = -.260 \); however, the value of \( r \) or the coefficient of correlation was well below the level of .50 which indicates a potential problem with multicollinearity (Gujarati, 1978).

The correlation matrix for Sample #2 (ACE) included the following independent variables: ADOS-SocCog, ADI-SocCog, CCC-2, Recalling Sentences subtest (CELF-3 or CELF-4), Word Class subtest (CELF-3 and CELF-4), Verbal IQ, TLC total raw score, CMS 5-8 Numbers Backward subtest, CMS 9-16 Numbers Backward subtest, WMS Spatial Span Backward subtest, and WMS Digit Span Backward subtest. Verbal IQ was significantly correlated at the \( p \leq 0.01 \) level (2-tailed) (and with an \( r \) value above .50) with the Recalling Sentences \( (r = .759) \), Word Class \( (r = .656) \), TLC total raw score \( (r = .554) \), CMS 5-8 Numbers Backward \( (r = .576) \). Word Class subtest and CMS 5-8 Numbers Backward were significantly correlated at the \( p \leq .05 \) level (2-tailed) \( (r = .532) \).

The high level of correlation between VIQ and the language measures was not unexpected; it indicated that both VIQ and the language measures should not be entered into the regression model. Therefore, it was decided to use Verbal IQ as the language measure for all the planned analyses because all participants in Sample #1 and Sample #2 were assigned a VIQ score, it is a generalized measure of language skills, and it was highly correlated with all other language measures in both correlation matrices. Because the specific language measures used varied between both the CPEA and ACE groups, and the children and adults, the use of the VIQ score also had the advantage of allowing a collapse of the data across both participant groups and both age groups for some of the analyses.
Other significant correlations were also revealed for Sample #2 (ACE); however, these were all below an $r$ value of $.50$ which indicates a potential problem with multicollinearity (Gujarati, 1978). They are reported here for completeness. Verbal IQ was significantly correlated at the $p \leq 0.01$ level (2-tailed) with ADOS-SocCog ($r = -.337$), CCC-2 ($r = .321$), WMS Digit Span Backward ($r = .334$), and WMS Spatial Span Backward ($r = .349$). Verbal IQ was significantly correlated at the $p \leq 0.05$ level (2-tailed) with the ADI-SocCog (-.157). Other significant correlations at the $p \leq 0.01$ level (2-tailed) included the following: TLC and WMS Spatial Span Backward ($r = .416$) and WMS Digit Span Backward ($r = .392$), and WMS Digit span Backward and WMS Spatial Span Backward ($r = .433$). Additional significant correlations at the $p \leq 0.05$ level (2-tailed) included the following: ADOS-SocCog and TLC ($r = -.182$) and WMS Spatial Span Backward (-.269), ADI-SocCog and Verbal IQ ($r = -.157$) and TLC ($r = -.180$), TLC and CCC-2 ($r = .300$) and CMS 9-16 Numbers Backward ($r = .274$), and CMS 5-8 Numbers Backward and Recalling Sentences ($r = .475$).

A description of the mean values within each sample of participants is provided below. When a model was run using the hierarchical regression analyses, it was ensured that all the participants included in that model possessed a score for each independent variable (IV) entered. For example, although all participants were administered the ADOS and VIQ in Sample #1, only 62 participants were administered the WMS. When the WMS was included as an independent variable, the model only included those 62 participants who had a score assigned to each IV entered into that specific model. Unless otherwise indicated below, all participants were administered an assessment.
Sample #1 (CPEA) mean values for the previously described assessments are as follows: mean ADOS-SocCog 17.1 (SD = 4.1; range 7 to 28), mean ADI-SocCog 40.0 (SD = 8.8; range 17 to 60), mean ToM score 7.34 (SD = 1.4; range 3 to 9), mean Twenty Questions 45.1 (SD = 12.3; range 27 to 80; 63 participants), mean MVCF 2.4 (SD = 3.3; range 0 to 12; 20 participants). Only the traditional ToM tasks were utilized as dependent variables for Sample #1 secondary to the lack of participants administered the Eyes test.

Sample #2 (ACE) mean values for the previously described assessments are as follows: mean ADOS-SocCog 13.4 (SD = 4.4; range 3 to 30), mean ADI-SocCog 39.2 (SD = 9.2; range 13 to 67), mean ToM score 7.5 (SD = 1.6; range 3 to 9), mean Eyes test 19.2 (SD = 5.4; range 7 to 32; 156 participants), mean WMS spatial span 7.7 (SD = 2.1; range 2 to 13; 62 participants), mean WMS digit span 6.8 (SD = 2.5; range 2 to 13; 63 participants), mean CMS 9-16 5.3 (SD = 1.8; range 2 to 10; 66 participants), and mean CMS 5-8 4.0 (SD = 1.2; range 2 to 6; 21 participants).

Mean values for the previously described assessments within the aggregated sample are as follows: mean ADOS-SocCog 14.9 (SD = 4.7; range 3 to 30), mean ToM score 7.4 (SD = 1.5; range 3 to 9), mean Eyes test 19.0 (SD = 5.4; range 5 to 32; 177 participants). VIQ and ADOS-SocCog were the only IVs used within this dataset due to the fact that all participants from each sample did not have scores for ADI-SocCog and executive functioning measures were inconsistent between samples.

Results

Following the preliminary examination of the available variables, different combinations of the participants from the two samples were used to test the hypothesized models of prediction of ToM using hierarchical multiple regression, as described for each
hypothesis/model below. For all of the models, age was used as a control, entering that in the first step to determine if it was significant by itself. This was done because of the wide age range of the participants and also because age is known to affect both ToM performance and performance on the independent variables such as language and social cognition. Subsequently, based on the theoretical models of the relationship between ToM and the independent variables, additional variables were entered as appropriate to test each of the hypothesized models. Dependent variables (DVs) included the traditional ToM tasks and the Eyes test (when scores from this latter measure were available for all the participants included in the model being run).

Model 1—Social Cognition as the Main Predictor of ToM

_Hypothesis 1: Theory of Mind performance is related to measures of social cognition in children and adults with high-functioning autism._

In this model, it was hypothesized that social cognition would make a unique contribution to ToM performance with indices of language and working memory explaining significant additional variance. In its most complete form, the social cognition measures (ADOS-SocCog, ADI-SocCog) were entered at step 1 with the language measure (Verbal IQ) at step 2, followed by a cognitive flexibility (Sample #1; Twenty Questions or MVCF) or working memory (Sample #2; WMS Digit Span, WMS Spatial Span, CMS 5-8 Numbers Backward, or CMS 9-16, Numbers Backward) score at step 3. With respect to hypothesis 1, the expectation was that all of the measures would be significant, with the greatest predictive power, or highest r-square, coming from the first set of social cognition variables, the next highest coming from the language variable, and finally, an additional increment coming from the executive functioning variables.
Model 1 with aggregated sample (DV = traditional ToM). With the aggregated sample using the traditional ToM measures as the DV, the ADOS-SocCog measure was entered at step 1 followed with the Verbal IQ (language) measure at step 2. [Note: the second social cognition measure, ADI-SocCog was not entered in this version of the model because scores were not available for everyone in the aggregated set of participants.] No executive function variable was added in this version of the model as no common measures were available for the aggregated sample. In this version of the model, general social cognition skills were not a significant predictor of ToM ($p = 0.397$). The language variable was a significant predictor of ToM ($p \leq 0.0001$), uniquely explaining an additional 12.5% of the variance (adjusted $R^2 = 0.163$).

The aggregated sample was then sub-divided into adults and children to determine if the results were different by developmental group. Age was retained as a control variable given the wide range even within these sub-groups. For the adult participants ($n = 106$), the social cognition variable was not a significant predictor of the ToM measure ($p = 0.940$). The language variable was significant ($p \leq 0.0001$), predicting an additional 15.1% of the variance (adjusted $R^2 = 0.165$).

For the child participants ($n = 166$), the social cognition variable was a significant predictor of the ToM measure ($p = 0.047$) and predicted 5.8% of the variance (adjusted $R^2 = 0.152$). The language variable was also significant ($p \leq 0.0001$), predicting an additional 12.7% of the variance (adjusted $R^2 = 0.279$). Table 1 provides a summary of results for Model 1 with the aggregated sample using the traditional tasks as the DV.
Table 1

Model 1 with aggregated sample (DV = traditional ToM)

<table>
<thead>
<tr>
<th>IV</th>
<th>Entire Sample n = 272</th>
<th>Adults n = 106</th>
<th>Children n = 166</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>ADOS-SocCog</td>
<td>VIQ</td>
<td>ADOS-SocCog</td>
</tr>
<tr>
<td></td>
<td>0.397</td>
<td>≤ 0.0001</td>
<td>0.940</td>
</tr>
<tr>
<td>Δ R²</td>
<td>0.038</td>
<td>0.163</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Model 1 aggregated sample, with different ToM measure (DV = Eyes test).

With the aggregated sample (n = 177) using Eyes test as the DV, the ADOS-SocCog measure was entered at step 1 followed with the VIQ (language) measure at step 2. In this version of the model, the social cognition variable was again not a significant predictor of ToM (p = 0.894). The language variable was again significant (p ≤ 0.0001); however, with the Eyes test as the DV, language only explained an additional 5% of the variance (adjusted R² = 0.286).

For the adult participants (n = 67), the social cognition variable was not a significant predictor (p = 0.177) for the ToM measure. The language variable was significant (p = 0.006), predicting an additional 9.1% of the variance (adjusted R² = 0.169).

For the child participants (n = 110), the social cognition variable was not a significant predictor of ToM as measured by the Eyes test (p = 0.521). However, the language variable was significant (p = 0.003), predicting an additional 5.6% of the variance (adjusted R² = 0.278). Table 2 provides a summary of results of Model 1 with the aggregated sample using the Eyes Test as the DV.
Table 2

Model 1 with aggregated sample (DV = Eyes Test)

<table>
<thead>
<tr>
<th></th>
<th>Entire Sample n = 177</th>
<th>Adults n = 67</th>
<th>Children n = 110</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>ADOS-SocCog</td>
<td>ADOS-SocCog</td>
<td>ADOS-SocCog</td>
</tr>
<tr>
<td>p-value</td>
<td>0.894</td>
<td>0.177</td>
<td>0.521</td>
</tr>
<tr>
<td>Δ R²</td>
<td>0.236</td>
<td>0.078</td>
<td>0.222</td>
</tr>
<tr>
<td></td>
<td>≤ 0.0001</td>
<td>0.006</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>0.286</td>
<td>0.169</td>
<td>0.278</td>
</tr>
</tbody>
</table>

Model 1 with Sample #1 (CPEA)—Cognitive flexibility. Using only the participants from Sample #1 (CPEA) (n = 63), the social cognition variable was entered at step 1, followed by the language variable, and then the cognitive flexibility variable (Twenty Questions). In this version of Model 1, neither the social cognition variables (p = 0.76, ADOS-SocCog; p = 0.882, ADI-SocCog) nor the cognitive flexibility measure (p = 0.876) were significant predictors of ToM. As occurred earlier, when social cognition and language were entered without cognitive flexibility, the language variable was significant (p = 0.003) and added 14.5% to the variance (adjusted R² = 0.112).

This version of model 1 was not run using a subgroup of adults because of the limited number of participants with a cognitive flexibility measure (n = 23; 10 participants required per IV entered into the model). When the model was run with only the children (n = 40), neither the social cognition variable (p = 0.654, ADOS-SocCog; p = 0.497, ADI-SocCog) nor the cognitive flexibility variable (p = 0.722) were significant predictors of ToM. However, the language variable had predictive power (p = 0.011), explaining an additional 15.5% (adjusted R² = 0.124) of the variance. Table 3 provides a summary of the results for model 1 with Sample #1 using the traditional tasks as the DV.
Table 3

Model 1 with Sample #1 (DV = Traditional ToM)

<table>
<thead>
<tr>
<th>IV</th>
<th>Entire Sample n = 63</th>
<th>Children n = 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.760</td>
<td>0.882</td>
</tr>
<tr>
<td>Δ R²</td>
<td>-0.033</td>
<td>0.112</td>
</tr>
</tbody>
</table>

Model 1 with Sample #2 (ACE)--Working memory (DV = traditional ToM).

Using only the participants from Sample #2 (ACE), the social cognition variable was entered at step 1, followed by the language variable, and then the working memory variable while using the traditional ToM measure as the DV. This version of model 1 was not run using the entire sample due to the fact that the children and adults were administered different working memory measures which did not allow this measure to be used as a consistent variable within the model.

Within the subgroup of adults (n = 61), neither the social cognition variables (p = 0.240, ADOS-SocCog; p = 0.859, ADI-SocCog) nor the working memory measures (p = 0.174, Digit Span Backwards; p = 0.473, Spatial Span Backwards) were significant predictors of ToM. However, the language variable was significant (p = 0.014) and added 14.6% (adjusted R² = 0.222) to the variance.

The working memory measure used for the subgroup of children was the CMS 9-16 Numbers Backwards. The CMS 5-8 Numbers Backwards was not utilized as an IV due to limited participants with scores (n = 21; at least 10 participants per IV required). Within the subgroup of children (n = 66), neither the social cognition variables (p = 0.307, ADOS-SocCog; p = 0.460, ADI-SocCog) nor the working memory measure (p = 0.638) were significant predictors of ToM. The language variable was significant (p ≤
0.0001) and added 23.3% (adjusted $R^2 = 0.270$) to the variance. Table 4 provides a summary of the results for model 1 with sample #1 using the traditional tasks as the DV.

**Table 4**

*Model 1 with Sample #2 (DV = Traditional ToM)*

<table>
<thead>
<tr>
<th>IV</th>
<th>Adults n = 61</th>
<th>Children n = 66</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.240</td>
<td>0.859</td>
</tr>
<tr>
<td>$\Delta R^2$</td>
<td>0.076</td>
<td>0.222</td>
</tr>
</tbody>
</table>

**Model 1 Sample #2 with different ToM measure (DV = Eyes test).** Using only the participants from Sample #2 (ACE), the social cognition variable was entered at step 1, followed by the language variable, and then the working memory variable while using ET as the DV. This version of model 1 was not run using the entire sample due to the fact that the children and adults were administered different working memory measures which did not allow this measure to be used as a consistent variable within the model. Within the subgroup of adults (n = 61), neither the social cognition variables ($p = 0.189$, ADOS-SocCog; $p = 0.638$, ADI-SocCog) nor the working memory measures ($p = 0.432$, Digit Span Backwards; $p = 0.714$, Spatial Span Backwards) were significant. The language variable was significant ($p = 0.025$) and added 6.5% (adjusted $R^2 = 0.119$) to the variance.

The working memory measure used for the subgroup of children was the CMS 9-16 Numbers Backwards. Again, the CMS 5-8 Numbers Backwards was not utilized as an IV due to limited participants with scores (n = 21; at least 10 participants per IV required). Therefore, the model was social cognition entered at step 1, language at step 2,
and working memory at step 3. Within the subgroup of children (n = 66), the social cognition variables demonstrated significance ($p = 0.03$, ADOS-SocCog; $p = 0.023$, ADI-SocCog) explaining 7% (adjusted $R^2 = 14.2$) of the variance. The language variable was significant ($p = 0.007$) and added 8.3% (adjusted $R^2 = 0.225$) to the variance. The working memory variable demonstrated no predictive power ($p = 0.584$) for ToM ability.

Table 5 provides a summary of the results for model 1 with sample #2 using the Eyes test as the DV.

**Table 5**

*Model 1 with Sample #2 (DV = Eyes Test)*

<table>
<thead>
<tr>
<th>IV</th>
<th>Adults</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 61</td>
<td>n = 66</td>
</tr>
<tr>
<td>ADOS-SocCog</td>
<td>0.189</td>
<td>0.03</td>
</tr>
<tr>
<td>ADI-SocCog</td>
<td>0.638</td>
<td>0.023</td>
</tr>
<tr>
<td>VIQ</td>
<td>0.025</td>
<td>0.007</td>
</tr>
<tr>
<td>WM Digit Span</td>
<td>0.432</td>
<td>0.142</td>
</tr>
<tr>
<td>WM Spatial Span</td>
<td>0.714</td>
<td>0.225</td>
</tr>
<tr>
<td>ADOS-SocCog</td>
<td>0.03</td>
<td>0.192</td>
</tr>
<tr>
<td>ADI-SocCog</td>
<td>0.023</td>
<td>0.007</td>
</tr>
<tr>
<td>VIQ</td>
<td>0.097</td>
<td>0.225</td>
</tr>
<tr>
<td>CMS</td>
<td>0.584</td>
<td>0.216</td>
</tr>
</tbody>
</table>

**Model 1 conclusion.** In the hypothesis for model 1, it was predicted that social cognition would explain most of the variance or have the most impact on ToM skills. Social cognition was revealed to be a significant factor only for the subgroup of children derived from the aggregated sample (DV = traditional ToM) and for the children in Sample #2 (DV = Eyes test) when entered with a model that included language and working memory. In both cases, social cognition only accounted for a relatively small percent of the variance (5.8% and 7%, respectively). Although social cognition abilities may be more of a predictor for ToM in children than adults, it is not a primary factor. No executive functioning measures were revealed to be significant predictors of ToM ability in ASD for either the children or adults.
Based on the results obtained for model 1, language, which was entered into the model following social cognition, demonstrated the highest predictive power for ToM ability. It revealed to be a significant IV in every version of model 1 that was run, across the three different samples used (i.e. aggregated sample, sample #1, and sample #2), and across all groups of participants (i.e. entire sample, adult subgroup, children subgroup). In addition to exhibiting predictive power for outcomes on both ToM measures used as DVs, it also added additional explanation for the variances within each version of model 1 that was run. This suggests that language has a substantial impact on ToM ability within the ASD population for both adults and children with this disorder.

Model 2—Language as the Main Predictor of ToM

Hypothesis 2: Theory of Mind performance is related to measures of language in children and adults with high-functioning autism.

In this model, the hypothesis was that language would make a unique contribution to ToM performance with social cognition explaining significant additional variance. The language measure was entered at step 1 with the social cognition measure at step 2, followed by a cognitive flexibility (Sample #1) or working memory (Sample #2) score at step 3. With respect to hypothesis 2, the expectation was that all of the measures would be significant, with the greatest predictive power, or highest r-square, coming from the first set of language variables, the next highest coming from the social cognition measures, and finally, an additional increment coming from the executive functioning variables.

Model 2 with aggregated sample (DV = traditional ToM). Using the combined sample (272 participants) with the traditional ToM measure as the DV, the language variable was entered at step 1 with social cognition entered at step 2. No executive
function variable was added in this version of the model as no common measures were available for the aggregated sample. For this version of Model 2, the language variable was significant ($p \leq .0001$) and predicted 15.3% of the variance (adjusted $R^2 = 0.164$). The social cognition variable demonstrated no predictive power for ToM ability ($p = 0.397$).

When Model 2 was run for the subgroup of adult participants ($n = 106$), language was again significant ($p \leq .0001$) and predicted 17.5% of the variance (adjusted $R^2 = 0.173$). The social cognition variable demonstrated no predictive power for ToM ability ($p = 0.940$).

When Model 2 was run for the subgroup of child participants ($n = 166$), language was significant ($p \leq .0001$) and predicted 25.6% of the variance (adjusted $R^2 = 0.265$). The social cognition variable was also a significant predictor of ToM ($p = 0.047$); however, the additional variance predicted above that predicted by language was only 1.4% (adjusted $R^2 = 0.279$). Table 6 provides a summary of results for model 2 with the aggregated sample using the traditional tasks as the DV.

**Table 6**

*Model 2 with aggregated sample (DV = Traditional ToM)*

<table>
<thead>
<tr>
<th>IV</th>
<th>Entire Sample $n = 272$</th>
<th>Adults $n = 106$</th>
<th>Children $n = 166$</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>≤ 0.0001</td>
<td>≤ 0.0001</td>
<td>≤ 0.0001</td>
</tr>
<tr>
<td>ADOS-SocCog</td>
<td>0.397</td>
<td>0.940</td>
<td>0.047</td>
</tr>
<tr>
<td>VIQ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>△ $R^2$</td>
<td>0.164</td>
<td>0.173</td>
<td>0.265</td>
</tr>
</tbody>
</table>

**Model 2 aggregated sample, with different ToM measure (DV = Eyes test).**

Model 2 was then re-run using the combined sample ($n = 177$) with the Eyes test as the DV, entering language at step 1 and social cognition at step 2. For this version of Model 2, the language variable was significant ($p \leq .0001$) and predicted 6% (adjusted $R^2 =$
0.290) of the variance. The social cognition variable demonstrated no predictive power for ToM ability (p = 0.894).

When this version of Model 2 was run using the subgroup of adults (n = 67), language was significant (p = 0.006) and predicted 17% of the variance (adjusted R² = 0.158). The social cognition variable demonstrated no predictive power (p = 0.177).

When this version Model 2 was run using the subgroup of children (n = 110), language demonstrated significant predictive power (p = 0.003) and predicted 5.3% (adjusted R² = 0.282) of the variance. The social cognition variable demonstrated no predictive power (p = 0.521). Table 7 provides a summary of results for model 2 with the aggregated sample using the Eyes Test as the DV.

**Table 7**

**Model 2 with aggregated sample (DV = Eyes Test)**

<table>
<thead>
<tr>
<th></th>
<th>Entire Sample n = 177</th>
<th>Adults n = 67</th>
<th>Children n = 110</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>VIQ</td>
<td>ADOS-SocCog</td>
<td>VIQ</td>
</tr>
<tr>
<td>p-value</td>
<td>≤ 0.0001</td>
<td>0.894</td>
<td>0.006</td>
</tr>
<tr>
<td>( \Delta R^2 )</td>
<td>0.290</td>
<td>0.286</td>
<td>0.158</td>
</tr>
</tbody>
</table>

**Model 2 with Sample #1 (CPEA)—Cognitive flexibility.** Model 2 was then re-run with only participants from Sample #1 (n = 63), which allowed the cognitive flexibility variable (Twenty Questions) to be entered into the model at step 3 (DV = traditional ToM). The language variable demonstrated significance (p = 0.003) predicting 14% (adjusted R² = 0.139) of the variance. The social cognition variable did not demonstrate significance (p = 0.760, ADOS-SocCog; p = 0.882, ADI-SocCog). The cognitive flexibility variable did not exhibit predictive power (p = 0.876) for ToM ability.
Model 2 was not run with the subgroup of adult participants with the cognitive flexibility measure entered at step 3 because the sample size (n = 23) was too small (minimum number of cases needed per IV is 10). When Model 2 was run with the subgroup of child participants (n = 40), the language variable demonstrated significance ($p = 0.011$) predicting 14.9% (adjusted $R^2 = 0.158$) of the variance. The social cognition variable did not add predictive power ($p = 0.654$, ADOS-SocCog; $p = 0.497$, ADI-SocCog) to ToM ability. The cognitive flexibility variable (Twenty Questions) did not reveal significance ($p = 0.722$) for ToM ability. Table 8 provides a summary of results for model 1 with sample #1 using the traditional tasks as the DV.

**Table 8**

*Model 2 with Sample #1 (DV = Traditional ToM)*

<table>
<thead>
<tr>
<th></th>
<th>Entire Sample</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n = 63$</td>
<td>$n = 40$</td>
</tr>
<tr>
<td><strong>IV</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIQ</td>
<td>0.003</td>
<td>0.011</td>
</tr>
<tr>
<td>ADOS SocCog</td>
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<td>ADI SocCog</td>
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<td>0.497</td>
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<td>CF</td>
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<td>0.722</td>
</tr>
<tr>
<td><strong>R^2</strong></td>
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</tr>
<tr>
<td>$\Delta$ $R^2$</td>
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<td>0.158</td>
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<td></td>
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<td>0.158</td>
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</tbody>
</table>

**Model 2 with Sample #2 (ACE)—Working Memory (DV = traditional ToM).**

Model 2 was then re-run using only the participants in Sample #2, which allowed the working memory measure to be entered at step 3 (DV = traditional ToM). This version of model 2 was not run within the entire sample due to the fact that the children and adults were administered different working memory measures which did not allow this measure to be used as a consistent variable within the model. Within the subgroup of adults (n = 61), the language variable was found to be significant ($p = 0.014$), predicting 30% (adjusted $R^2 = 0.228$) of the variance. Neither the social cognition variable ($p = 0.240$, ADOS-SocCog; $p = 0.859$, ADI-SocCog) nor the working memory measure ($p = 0.174$, ADOS-SocCog)
Digit Span Backwards; \( p = 0.473 \), Spatial Span Backwards) appeared as a significant predictor of the ToM measure.

This version of model 2 with working memory measures (CMS 9-16) entered at step 3 was then run with the subgroup of children (\( n = 66 \)). The language variable demonstrated significance (\( p \leq .0001 \)) and predicted 27.2\% (adjusted \( R^2 = 0.269 \)) of the variance. Neither the social cognition variable (\( p = 0.307 \), ADOS-SocCog; \( p = 0.460 \), ADI-SocCog) nor the working memory measure (\( p = 0.638 \)) exhibited predictive power for the ToM measure. Table 9 provides a summary of the results for model 2 with sample #2 using the traditional tasks as the DV.

**Table 9**

*Model 2 with Sample #2 (DV = Traditional ToM)*

<table>
<thead>
<tr>
<th></th>
<th>Adults</th>
<th></th>
<th>Children</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( n = 61 )</td>
<td></td>
<td>( n = 66 )</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.014</td>
<td>0.240</td>
<td>0.859</td>
<td>0.174</td>
</tr>
<tr>
<td>( \Delta R^2 )</td>
<td>0.228</td>
<td>0.222</td>
<td>0.246</td>
<td>0.269</td>
</tr>
</tbody>
</table>

**Model 2, Sample #2, with different ToM measure (DV = Eyes test)**. Model 2 (with language at step 1, social cognition at step 2, and working memory at step 3) was then re-run with a subgroup of participants (\( n = 156 \)) using the Eyes test as the DV. Within the subgroup of adults (\( n = 61 \)), language demonstrated significance (\( p = 0.025 \)) and predicted 12.8\% (adjusted \( R^2 = 0.112 \)) of the variance. Neither the social cognition measure (\( p = 0.189 \), ADOS-SocCog; \( p = 0.638 \), ADI-SocCog) nor the working memory measure (\( p = 0.432 \), WMS Digit Span; \( p = 0.714 \), WMS Spatial Span) added predictive power to the ToM measure.
This version of model 2 was re-run using the subgroup of children (n = 66) from Sample #2. Language was found to be significant \((p = 0.007)\) and predicted 7.4% (adjusted \(R^2 = 0.146\)) of the variance. Social cognition also exhibited predictive power \((p = 0.03, \text{ADOS-SocCog}; p = 0.023, \text{ADI-SocCog})\) and predicted an additional 7.9% (adjusted \(R^2 = 0.225\)) of the variance. Working memory measures (CMS 9-16) were not a significant variable \((p = 0.584)\) within the model. Table 10 provides a summary of results for model 2 with sample #2 using the Eyes Test as the DV.

**Table 10**

*Model 2 with Sample #2 \((DV = \text{Eyes Test})\)*

<table>
<thead>
<tr>
<th>IV</th>
<th>Adults n = 61</th>
<th>Children n = 66</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.025</td>
<td>0.189</td>
</tr>
<tr>
<td>(\Delta R^2)</td>
<td>0.112</td>
<td>0.119</td>
</tr>
</tbody>
</table>

**Model 2 conclusion.** Based on the results obtained for model 2, language, which was entered into the model at step 1, demonstrated the highest predictive power for ToM ability and uniquely explained 15.3% of the variance when adults and children were considered together in a model with social cognition as the additional IV. Language was revealed to be a significant IV in every version of model 2 that was run, across the three different samples used (i.e. aggregated sample, sample #1, and sample #2), and across all groups of participants (i.e. entire sample, adult subgroup, children subgroup). In addition, language exhibited predictive power for outcomes on both ToM measures used as DVs; however, it uniquely explained the most variance for the traditional ToM measures. Language was the highest predictor of ToM in the language-social cognition
model that only included data from the children with the traditional ToM measure (25.6%).

As discussed above, language also added additional explanation for the variances within each version of model 1 that was run. Therefore, whether language was entered first or second into the model, it continued to be a significant predictor of ToM. This provides further evidence that language has a substantial impact on ToM ability within the ASD population for both adults and children with this disorder.

As seen in Model 1, for Model 2, social cognition was revealed to be a significant factor only for the subgroup of children derived from the aggregated sample (DV = traditional ToM) and for the children in Sample #2 (DV = Eyes test) when entered with a model that included language and working memory. Therefore, whether the social cognition measures were entered at step 1 or step 2, they added to the variance and exhibited predictive power for ToM for children. However, social cognition uniquely explained 1.4% and 7.9% of the variance, respectively, suggesting that it alone was not a strong predictor. The consistency of results across the two models, suggests that children may rely more heavily on social cognition or that children require the use of more social cognitive resources when completing ToM tasks when compared to the adult population. No executive functioning measures were revealed to be significant predictors of ToM ability in ASD in Model 2 for either the aggregated group or the adult or child subgroups.

**Model 3—Executive Function as the Main Predictor of ToM**

*Hypothesis 3: Theory of Mind performance is related to measures of working memory and cognitive flexibility in children and adults with high-functioning autism.*
In this model, it was hypothesized that executive functioning (i.e. working memory and cognitive flexibility) would make a unique contribution to ToM performance with language explaining significant additional variance. The working memory measures (Sample #2) or cognitive flexibility measures (Sample #1) were added at step 1 with the language measure at step 2, followed by the social cognition measure at step 3. With respect to hypothesis 3, the expectation was that all of the measures would be significant, with the greatest predictive power, or highest r-square, coming from the first set of executive functioning variables, the next highest coming from the language variables, and finally, an additional increment coming from the social cognitive measures. It should be noted that no model with the aggregation of the two samples was run for Model 3 because there were no common cognitive flexibility or working memory measures available across both samples.

**Model 3 with Sample #1 (CPEA)—Cognitive flexibility.** Using the participants from Sample #1 (n = 63), the cognitive flexibility variable (*Twenty Questions*) was entered at step 1, with the language variable at step 2, and the social cognition variables at step 3. The cognitive flexibility variable demonstrated no predictive power for the ToM measure ($p = 0.876$). The language measure was significant ($p = 0.003$), explaining an additional 13.5% of the variance (adjusted $R^2 = 0.125$). The social cognition variable was not significant ($p = 0.760$, ADOS-SocCog; $p = 0.882$, ADI-SocCog).

This version of model 3 was not run for a subgroup of adults due to limited cognitive flexibility measures within the adult subgroup (n = 23; at least 10 participants needed for each IV entered into the model). Within the subgroup of children (n = 40), cognitive flexibility did not add predictive power to the ToM measure ($p = 0.722$).
language variable demonstrated significance \((p = 0.011)\), explaining an additional 15.3\% of the variance \((\text{adjusted } R^2 = 0.136)\). The social cognition variable did not exhibit predictive power \((p = 0.654, \text{ADOS-SocCog}; p = 0.487, \text{ADI-SocCog})\). Table 11 provides a summary of the results for model 3 with sample #1 using the traditional tasks as the DV.

**Table 11**

*Model 3 with Sample #1 \((DV = \text{Traditional ToM})\)*

<table>
<thead>
<tr>
<th>IV</th>
<th>Entire Sample (n = 63)</th>
<th>Children (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>p-value</strong></td>
<td>0.876</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>(\Delta R^2)</strong></td>
<td>-0.010</td>
<td>0.125</td>
</tr>
</tbody>
</table>

**Model 3 with Sample #2 \((ACE)\)—Working memory \((DV = \text{traditional ToM})\).** Using the participants from Sample #2, the working memory variable(s) was entered at step 1, with the language variable at step 2, and the social cognition variables at step 3 using the traditional ToM measure as the DV. This version of model 3 was not run within the entire sample due to the fact that the children and adults were administered different working memory measures which did not allow this measure to be used as a consistent variable within the model. Within the subgroup of adults \(n = 61\), neither the working memory variables \((p = 0.174, \text{Digit Span Backwards}; p = 0.473, \text{Spatial Span Backwards})\) nor the social cognition variables \((p = 0.240, \text{ADOS-SocCog}; p = 859, \text{ADI-SocCog})\) demonstrated predictive power for the ToM measure. The language measure was significant \((p = 0.014)\), explaining an additional 12.2\% of the variance \((\text{adjusted } R^2 = 0.253)\).
This version of model 3 with working memory measures (CMS 9-16) entered at step 3 was then run with the subgroup of children (n = 66). Neither working memory ($p = 0.638$) nor social cognition ($p = 0.307$, ADOS-SocCog; $p = 0.460$, ADI-SocCog) demonstrated significance within this model. The language variable was significant ($p \leq 0.0001$), predicting an additional 27.6% of the variance (adjusted $R^2 = 0.260$). Table 12 provides a summary of results for model 3 with sample #2 using the traditional tasks as the DV.

**Table 12**

*Model 3 with Sample #2 (DV = Traditional ToM)*

<table>
<thead>
<tr>
<th>IV</th>
<th>Adults n = 61</th>
<th>Children n = 66</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM Digit Span</td>
<td>0.174</td>
<td>0.638</td>
</tr>
<tr>
<td>WM Spatial Span</td>
<td>0.473</td>
<td>≤ 0.0001</td>
</tr>
<tr>
<td>VIQ</td>
<td>0.014</td>
<td>0.307</td>
</tr>
<tr>
<td>ADOS SocCog</td>
<td>0.240</td>
<td>0.460</td>
</tr>
<tr>
<td>ADI SocCog</td>
<td>0.859</td>
<td></td>
</tr>
<tr>
<td>CMS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADOS SocCog</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADI SocCog</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Model 3 Sample #2 with different ToM measure (DV = Eyes test).** Using the participants from Sample #2, the working memory variable(s) was entered at step 1, with the language variable at step 2, and the social cognition variables at step 3 using the Eyes test as the DV. This version of model 3 was not run within the entire sample due to the fact that the children and adults were administered different working memory measures which did not allow this measure to be used as a consistent variable within the model. Within the subgroup of adults (n = 61), neither the working memory variables ($p = 0.432$, Digit Span Backwards; $p = 0.714$, Spatial Span Backwards) nor the social cognition variables ($p = 0.189$, ADOS-SocCog; $p = 0.638$, ADI-SocCog) were significant.
predictors for the ToM measure. The language measure was significant \( p = 0.025 \), explaining an additional 12.3% of the variance (adjusted \( R^2 = 0.098 \)).

This version of model 3 with working memory measures (CMS 9-16) entered at step 3 was then run with the subgroup of children \( (n = 66) \). Working memory \( (p = 0.584) \) did not appear to be a significant predictor of ToM ability. The language variable was significant \( (p = 0.007) \), predicting an additional 7.9% of the variance (adjusted \( R^2 = 0.136 \)). The social cognition variables \( (p = 0.03, ADOS-SocCog; p = 0.023, ADI-SocCog) \) demonstrated significance within this model and predicted an additional 8% of the variance (adjusted \( R^2 = 0.216 \)). Table 13 provides a summary of results for model 3 with sample #2 using the Eyes Test as the DV.

Table 13

*Model 3 with Sample #2 (DV = Eyes Test)*

<table>
<thead>
<tr>
<th>IV</th>
<th>Adults ( n = 61 )</th>
<th>Children ( n = 66 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM</td>
<td>WM</td>
<td></td>
</tr>
<tr>
<td>Digit Span</td>
<td>Spatial Span</td>
<td></td>
</tr>
<tr>
<td>WM</td>
<td>VIQ</td>
<td>ADOS SocCog</td>
</tr>
<tr>
<td>Digit Span</td>
<td></td>
<td>ADI SocCog</td>
</tr>
<tr>
<td>p-value</td>
<td>0.432</td>
<td>0.714</td>
</tr>
<tr>
<td>ADOS SocCog</td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td>ADI SocCog</td>
<td>0.189</td>
<td>0.638</td>
</tr>
<tr>
<td>CMS</td>
<td>0.584</td>
<td>0.007</td>
</tr>
<tr>
<td>VIQ</td>
<td>0.007</td>
<td>0.136</td>
</tr>
<tr>
<td>ADOS SocCog</td>
<td>0.03</td>
<td>0.023</td>
</tr>
<tr>
<td>ADI SocCog</td>
<td>0.023</td>
<td></td>
</tr>
<tr>
<td>( \Delta R^2 )</td>
<td>-0.033</td>
<td>0.098</td>
</tr>
</tbody>
</table>

**Model 3 conclusion.** No executive functioning measures were revealed to be significant predictors of ToM ability in HFA. Once again, language, which was entered into the model at step 2, demonstrated the highest predictive power for ToM ability and uniquely explained additional variance. These findings are consistent with model 1 and model 2, which also showed language to have significant predictive power for ToM ability. Therefore, whether language was entered first or second into the model, or whether it was entered following the social cognition measure or the executive function measures, language consistently emerged as a significant predictor of ToM ability in the current study.
functioning measure, it continued to demonstrate significance and to account for the variance of the ToM measures. This provides further evidence that language skills have a substantial impact on ToM ability within the ASD population for both adults and children with this disorder.

Social cognition, entered into the model at step 3, again exhibited significance only with a subgroup of children from Sample #2 when using the Eyes test as the DV. This was the same sample of children in which social cognition demonstrated predictive power for ToM within models 1 and 2. Therefore, whether social cognition was entered at step 1, step 2, or step 3, it was found to be a significant predictor when using the Eyes test as the DV for the children with ASD. This provides supplementary evidence that children may rely more heavily on social cognition or that children require the use of more social cognitive resources when completing ToM tasks when compared to the adult population.

**Discussion**

The theory of mind (ToM) deficit in autism spectrum disorder (ASD) has been proposed to arise from an impairment in social cognition, to be related to the language problems that are characteristic of ASD, or to be related to a more general cognitive impairment in executive function, specifically in cognitive flexibility and/or working memory. The purpose of this study was to further explore the relationship of performance on measures of social cognition, language, cognitive flexibility, and working memory to the ToM deficit in high-functioning children and adults with ASD. Participants included two large samples of individuals with a diagnosis of ASD ranging in age from 5 to 55 years. A hierarchical multiple regression analysis was used to assess the ability of social
cognition, language, cognitive flexibility, and working memory variables to predict measures of ToM. Three different models, related to the hypothesized relationships between these variables, were used to determine whether the independent variables were significantly related to the dependent variable of ToM and whether the independent variable uniquely added any predictive power to the model. In addition, the three models were run again using a second ToM measure, the Eyes test, which was not thought to be as heavily dependent on language abilities as the traditional measures of ToM.

The model in which language was entered first had the highest predictive power for both the traditional ToM measures and ToM as measured by the Eyes test. Language also added significant predictive value in the other models in which social cognition and the measures of cognitive flexibility and working memory were entered first. Overall, language was the independent variable most highly predictive of ToM abilities.

Further evidence for the critical impact of language skills on ToM is apparent in the fact that the language measure was a significant predictor across two different measures of ToM--traditional ToM tasks (i.e., Sally-Anne, Peter-Jane, & John-Mary) and the Eyes test. It could be assumed that language skills would play a larger role during completion of the traditional tasks than in the latter. In the traditional tasks, the examinee must comprehend an orally presented story and then respond verbally to questions about the story. The Eyes test has a lesser language demand, only requiring the examinee to choose 1 word out of 4 textually presented stimuli to describe an individual’s feeling within a photo. The difference in language demand between the two measures is possibly reflected in the difference in the amount of variance explained by language for each of the variables, with language usually predicting the most variance for the traditional ToM
measures. Language appears to be imperative to comprehend that others possess feelings and ideas of their own and to be able to describe or express this understanding.

A problem in the development of both language comprehension and expression is a classic diagnostic criterion for ASD (APA, 2000), and a wide range in the severity of these language deficits is observed across the ASD population. This language impairment may contribute to problems with social interaction not only by limiting the means by which individuals with ASD can communicate but also by being a significant factor in the difficulty these individuals have with perceiving and understanding the thoughts, ideas, desires, feelings, and beliefs of others. Problems with language may be an essential underlying factor driving the impairments in ToM ability, resulting in a lack of appropriate social interaction, a hallmark characteristic of ASD. At minimum, the observed strength of the relationship between the language measures and the ToM measures in the current study would suggest a shared underlying factor that affects the performance of individuals with ASD in both areas.

The need for language to attribute thoughts to others is consistent with the observation that language is necessary to formulate one’s own thoughts. According to the Cognitive Complexity and Control Theory – Revised (CCC-r) (Frye, Zelaro, & Burack, 1998), individuals with typical development have the ability to shift between various perspectives within the brain. It is theorized that these perspectives are formed linguistically via silent self-directed speech (Farrant et al., 2012), requiring language to both formulate and comprehend this knowledge. Without language skills, no words/concepts to describe others’ thoughts are available, leaving open the question as to how this process would otherwise occur. In typical development, this ability to think
silently about concepts and the perceptions of others is a skill which develops early in childhood, concurrent with the development of language skills (Leslie, 1987). The ability to conceive of and project the thoughts and intentions of others is an implicit and essential process requiring little thought or effort on the part of “normal” communicators as they use it to engage in socially appropriate interactions.

The connection between language ability and ToM in children with ASD found in the current study is consistent with earlier work in this area. For example, a direct and substantial correlation between an individual’s verbal ability and verbal mental age (VMA) and ToM ability was also reported in a study with young children with and without ASD (Happé, 1995). The tasks used in that study to measure ToM included two false belief tasks; the Sally-Ann task, as used in the current study, and the Smarties task. One of the most interesting findings of the Happé study was the identification of a possible “threshold” with regards to verbal ability and ToM. She found that all typically developing subjects with a VMA below 2.10 failed the ToM tasks, while all of those with a VMA above 6.9 passed. However, in the children with ASD, those with a VMA below 5.6 failed the tasks, while those with a VMA above 11.7 passed all the ToM tasks. These results suggest that the children with ASD required a higher verbal ability when compared to typically developing individuals to complete ToM tasks and raise the question as to why this would occur.

Is a higher VMA required because a higher level of language is needed to compensate for deficits in social reasoning or is a problem with language somehow interfering with development of social reasoning? In other words, language may be related to ToM in ASD because language is being used to “bootstrap” or compensate for
the lack of the automatic or implicit process of ToM, or language may be related to ToM in ASD because the language processing demands are consuming cognitive resources that are needed for ToM processing, resulting in a lag in the development of this skill until language skills reach a critical point, freeing up cognitive resources. We will now review several recent functional magnetic resonance imaging (fMRI) studies with individuals with ASD for evidence related to the relationship between linguistic and ToM processing.

**Language as necessary for expression of ToM**

An essential function of the human brain is to make sense of the world, including the actions of the other people around us, and the ability to translate experiences and impressions into language appears to play a central role in this sense-making process (Gazzaniga, 2000). Language allows our brain to generate ideas and create thoughts within our mind. Even when a task does not explicitly require the use of language, individuals with typical development appear to do so; however, this may not be as true of individuals with ASD as indicated by the results of a recent study with children with ASD. Carter, Williams, Minshew, & Lehman (2012) used fMRI to examine the neurofunctional mechanisms underlying behaviors of children with ASD when making social judgments. The children with ASD performed similarly to the children with typical development in terms of accuracy of their responses when distinguishing which of two pictorial vignettes depicted socially inappropriate behavior (a social reasoning condition) or which of two pictorial vignettes showed children who were outside (a physical decision condition). However, differences were observed in the patterns of brain activation during these tasks. The children with typical development had a stronger distinctive response during the social scenarios with increased activation in brain areas
related specifically to language and social reasoning (i.e. medial prefrontal cortex, left superior temporal lobe, bilateral inferior frontal gyrus at the pars triangularis, and the left inferior frontal gyrus/Broca’s area). The children with ASD used primarily right inferior frontal gyrus and bilateral posterior superior temporal sulcus, areas associated with social reasoning. Based on the behavioral performance and brain activation pattern of the ASD group, a reduced subset of language and social areas of the brain was sufficient to accurately complete these simple tasks; however, the children with typical development appeared to be automatically encoding social reasoning/knowledge into language. The children with ASD did not appear to automatically encode their social understanding into language, a result consistent with reports of behavioral studies that children with ASD can recognize socially inappropriate behavior but have difficulty explaining why the behavior is inappropriate (Nah & Poon, 2010; Grant, Boucher, Riggs, & Grayson, 2005). Therefore, the results of this study suggest that the social reasoning of the children with ASD was adequate but was occurring with a lack of automatic encoding into language, suggesting an underlying impairment in linguistic processing which could interfere with the verbal expression of the ToM knowledge.

The results from another fMRI study with children with ASD, suggests that the underlying problem is a failure to automatically engage ToM processing unless it is explicitly elicited in a task (Wang, Lee, Sigman, & Dapretto, 2006). In this fMRI study, children with and without ASD listened to short scenarios that were delivered with prosody that was manipulated to convey either a sincere or an ironic/sarcastic intent, with the latter condition expected to activate ToM regions in the brain. These investigators reported the children with ASD had greater activation in the right inferior frontal gyrus
and the bilateral temporal regions, a network associated with ToM processing. This result was interpreted as reflecting more effortful processing from the children with ASD to interpret the meaning of the ironic/sarcastic utterances. The investigators suggested that ToM processing was affected in ASD but could be engaged with increased effort. An additional finding from this study was interpreted as supporting a compensatory relationship between language and ToM processing in ASD—the children with higher Verbal IQs were the ones most likely to have a greater activation in the right IFG and bilateral temporal areas. The investigators suggested that these children were using their “verbal reasoning skills in place of an ‘instinct’ for interpreting the communicative intent of others” (p. 941). It is also plausible that these individuals with increased brain activation who also demonstrated increased language abilities may have learned more to compensate by using the RH to help increase language skills when the task required more language demands due to the limited language resources within the LH.

**Language as a competitor for processing resources**

Problems with linguistic processing and a related inefficiency in ToM were reported in another fMRI study with adults with ASD (Mason, Williams, Kana, Minshew, & Just, 2008). In that study, adults with and without ASD read short discourse segments which required physical, emotional, or intentional inferences, with the use of a right hemisphere ToM network expected, especially in the third condition. In all three conditions, the participants with ASD displayed increased activation of the right hemisphere, specifically the right temporo-parietal junction (a prime region in the ToM processing network) when compared to the controls with typical development. However, even though the adults with ASD had brain activity above threshold in this region, they
had a decrement in behavioral performance, particularly in the third condition. This pattern of activation suggested that the ToM brain region was being used for more generalized linguistic processing and was not contributing to social reasoning per se.

The theory behind the findings of Mason and colleagues (2008) is that the demand of the task assigned is more difficult in the ASD population and requires a processing load that the language-dominant left hemisphere cannot handle. Thus, these extreme processing demands consume the resources of the language areas in the left hemisphere of the brain, and require a spill-over to the right hemisphere to make sense of a task (Just, Carpenter, Keller, Eddy, & Thulborn, 1996; Just, Carpenter, & Varma, 1999; Prat et al., 2011). The left temporal lobe is responsible for language skills, specifically language comprehension; therefore, when this brain region can no longer increase processing in response to increase cognitive demands, the demand “spills-over” to the right temporal lobe.

Prat, Mason, & Just (2011) provided evidence for the “spill-over” theory of language processing, using fMRI to examine neural differences during the reading of moderately and distantly related sentences by adults with typical development. The authors found decreased activation of the right hemisphere (RH) when the participant demonstrated increased language skill. Activation of the RH homologue of Broca’s area (left IFG) and the individual’s vocabulary size were negatively correlated, indicating that the RH required less activation if the participant demonstrated an increased semantic repertoire. Additionally, increased activation of the RH homologue of Wernicke’s area (left PSTG) was apparent in individuals who were characterized as less skilled readers. The authors did not find any positive correlations between vocabulary size and RH
activation. Finally, the authors found reliable negative correlations between vocabulary size and activation of the Wernicke’s area when attempting to comprehend passages which were considered less coherent, in that they did not include clause connectives, indicating that the individuals with lower semantic skills required increased activation of this area. These passages without the clause connectives, which provide an explicit cue for the inference to be made, would put an increased demand on the language system because rather than providing the language which would connect the clauses to make sense of the stimuli, the language system is required to reason and fill in the missing words and meanings in order to make sense of the task. The authors state that these results show that less-skilled readers exhibited less-efficient neural processing when reading, requiring more resources. They also observed increased activation of the RH homologues of LH language regions (Broca’s area and Wernicke’s area) used by the less-skilled readers, and the authors theorize that this is due to limited neural resources within these language areas. Therefore, according to this “spill-over” hypothesis, the RH is likely to be activated in certain situations due to greater amount of processing that the LH cannot handle. The authors also state that role of RH in language may in fact be a result of the resource-drive allocation function.

Based on the “spill-over” model in which other regions of the brain are recruited secondary to processing overload, it can be hypothesized that individuals with ASD are recruiting different areas of the brain to compensate for impaired language abilities. Based on the results of Mason and colleagues (2008), the resources used for additional language processing may be those that could have been used for ToM or social reasoning instead. If the language areas of the ASD brain do exhibit this processing threshold
resulting in the “spill-over,” then the ASD population would experience an inefficiency in ToM and an increased difficulty encoding social situations into language. This could serve as one of the reasons as to why language skills are so highly correlated with ToM ability in HFA.

Social cognition and ToM

With regards to the relationship between social cognition and ToM, social cognition was not the most correlated independent variable. The social cognitive measures appeared to be a more significant predictor of ToM in the subgroups of children than the subgroups of adults; although, it should be noted that the amount of variance uniquely predicted by social cognition was generally small. However, this result suggests that, whereas, performance on the ToM tasks by the adults with ASD is primarily related to their language abilities rather than social cognition, the ToM tasks may be more related to more generalized social cognitive abilities in the children. The traditional ToM tasks were developed for use with children with typical development, and ToM has been considered to be highly related to the development of social cognition in that population. Perhaps the findings for the children indicate that there is a link between ToM and social cognition for the children with ASD also but that, over time, language becomes a more important variable for individuals in this population. The children in the current sample were 5 years of age and older, whereas the traditional ToM measures have been used most often with preschool-aged children. Therefore, the age of the children in the current study may have made it more difficult to observe the connection between social cognition and ToM.
Contribution of problems with language development

There is the notion that humans are born with specific innate skills which allow us to easily tune into, learn from, and engage in our environment (Frith, 2001). Frith describes this as an innate “start-up kit” (p. 970) which allows us to develop the ability to mentalize about others thoughts, perceptions, etc. through fast learning, and the perceptions of faces, voices, and movements of humans around us. These inherent skills allow our ToM ability to fully develop via exposure to socially influential stimuli throughout our environment. However, it is now generally accepted that ASD is a neurodevelopmental disorder (Frith, 2001) and that such inherent and neurological preferences such as specific attention for human faces, voices, and movements are most likely lacking across the ASD population. Klin (1991) found that preschool children with ASD did not show a preference for human speech over non-speech stimuli as would typically developing children. Hobson (1993) found that older children with ASD do not show a preference for facial expressions over salient objects presented as stimuli. Lastly, Schultz et al., (2000) studied brain activation patterns in adults with ASD and demonstrated that they did not distinguish between objects and human faces as normally developing adults did, indicating that even in adulthood, individuals with ASD still do not acquire these skills that typically developing individuals use from birth in order to develop a better understanding of the social environment around them.

Some research indicates that maternal linguistic input is one of the factors contributing to the child’s understanding that the mother has her own thoughts and perceptions. Farrant et al. (2012) found maternal linguistic input to be correlated with ToM skills. However, for this linguistic input to have a meaningful impact on the child, it
is assumed the child would need a preference for human voice as a pre-requisite in order to attend to it. For example, a child with ASD who might focus on the sound of rain or a wind chime over the voice of his/her mother would not benefit as a typically developing child would from the consistent mentalistic language provided from the mother. Although joint attention and attention to the mother’s voice and facial expressions are essential, language skills are also vital for the understanding and application of the mother’s linguistic input. Individuals with ASD may have difficulty comprehending or attaching meaning to the mother’s language and therefore cannot use this input to create states of mind and apply these states to agents within the environment.

Limitations

Limitations for this study included a lack of ability to directly select the assessments used to measure social cognition, language, working memory, and cognitive flexibility. These assessments had previously been administered and therefore appropriate measures for each independent variable had to be derived from the data that had already been collected. There was some limited sampling of behavior using the traditional ToM tasks/false belief tasks given that only three items were administered; however the Eyes Test included more sizeable behavioral samples and served to replicate or verify the results with a task requiring less language ability. Executive functioning measures were not entered into the models for the aggregated sample because these measures were not consistent between Sample #1 and Sample #2. Therefore only social cognition and language were able to be measured as predictors for ToM ability within this larger aggregated sample. The cognitive flexibility measure (Twenty Questions) was not a direct measure of perspective taking, the specific cognitive flexibility skill that has been argued
to be related to ToM; this may have contributed to the lack of significance for this variable. Lastly, a strict definition of working memory was used; only specific subtests which required manipulation of information following verbal input were included. This difference in the measure of working memory may have contributed to findings that were inconsistent with previous research about the relationship between ToM and working memory.

**Conclusion**

This study provides evidence for the strong relationship between language skills and ToM ability in adults and children with ASD. General social cognition skills were less related to ToM abilities than language was, suggesting that individuals with ASD either depend on language to compensate for the lack of the development of ToM or cognitive resources needed for ToM processing are being devoted to language processing instead. Surprisingly, no relationship was seen between measures of cognitive flexibility and working memory and ToM. Although, these cognitive processes are thought to be essential for perspective taking and holding information on-line (in order to be able to think about the thoughts of others), no relationship with ToM was revealed in the current large sample of children and adults with ASD. Even though, the results of this study cannot determine what the nature of the relationship is between linguistic and ToM processing, they do provide support for current intervention efforts that use language skills to compensate for the lack of inherent ToM processing in individuals with ASD. Whether language is being used to compensate for a lack of automatic ToM processing or using cognitive resources needed for ToM, increased language skills appear to be the most promising route to increased ToM ability in ASD.
References


