EXECUTIVE FUNCTION AND SOCIAL COGNITION IN TYPICALLY DEVELOPING ADOLESCENTS

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Executive Function and Social Cognition in Typically Developing Adolescents

by

Darlene Walker

A dissertation submitted to the Faculty of Graduate Studies of York University in partial fulfillment of the requirements for the degree of

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Abstract

Purpose: Appropriate development of social skills is important for academic and career success. However, little research has focused on the impact of higher level cognitive function, referred to in this study as executive function, on social ability. Adolescence may be a sensitive period of reorganization in brain areas such as the frontal lobe, which can have significant effects on social development. The purpose of this dissertation is to investigate the relationship of social cognition and executive function across adolescent development. **Method:** Ninety-one males divided into three groups (10 to 12 year olds, 13 to 15 year olds and 16 to 18 year olds) participated in this research (mean age = 14.23, SD = 2.44). Participants completed measures of executive function (concept formation, verbal fluency, cognitive flexibility, inhibition, visual-spatial processing, planning and organization) and social cognition (perspective taking, social problem-solving, and social norm violations). Parents also completed questionnaires measuring general behaviour and executive function. **Results:** In study one, performance on visual executive function tasks was found to plateau in mid-adolescence, while verbal executive function tasks continued to develop at a linear rate throughout adolescence. Scores on working memory and complex attention tasks plateau in early to mid-adolescence, with an increase in performance in late adolescence. No differences between groups were observed on parent measures. In study two, a principal components analysis revealed six executive function components thought to represent inhibition/flexibility of thinking, concept formation/reasoning, working memory, verbal fluency, visual-spatial processing and attention/planning. A regression was used to look at whether these components were associated with performance on social cognition tasks. Tasks that involve encoding and interpretation of another's behaviour were associated with concept formation/reasoning and visual processing components. The ability to generate alternative social responses was associated with word generation and attention/planning components. **Conclusion:** This study found that concept formation, planning, attention and word generation are related to an adolescent's ability to engage in appropriate social cognition. Strategies targeting specific skills underlying, or related to, social cognition may enhance current social teaching methods, and allow for these skills to be incorporated more easily in a child's social database.

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Appropriate development of social skills is important for academic and career success. Social skills have been defined as the verbal and nonverbal behaviours employed when interacting at an interpersonal level with other people, which are goal-directed, interrelated, appropriate to the situation, identifiable units of learned behaviour under control of the individual (Hargie, Sanders & Dickson, 1987; Michelson, et al., 1983). Others have noted that social interaction requires motor skills, language, perceptual skills and often higher level cognitive skills (Merrell & Gimpel, 1998). However, little research has focused on the impact of higher level cognitive function, referred to in this study as executive function, on social ability. The purpose of this dissertation was to investigate the relationship of social abilities, in particular the area of social cognition, and executive function across adolescent development.

Early social development has long been an area of interest in the field of psychology. The development of particular skills that enable children to interact with others more efficiently and appropriately, as well as the impact of external forces on the development of these skills have been of particular interest. Erickson's eight stages of psychosocial development (1950), Vygotsky's social development theory (1978), and Piaget's stages of cognitive development (1983) are a few examples of important early research in the area. As well, researchers have investigated the impact of the development of language on children's ability to understand another's perspective, especially in children with social difficulties, such as children with Autism Spectrum Disorders (Chen & Yuan, 2008; Loucas et al., 2008; Sowden et al., 2008; Volden et al., 2009). However, the investigation of social development in adolescence has had less attention. Steinberg (2005), in a review of the literature on cognitive and affective development in adolescence, said that "the development of adolescence may well create a situation in which one is starting an engine without yet having a skilled driver behind the wheel" (p. 70). Further investigation of the adolescent behind the wheel may yield insight into the social intricacies of this period, and the internal forces that make adolescence one of the more emotionally challenging stages in life.

During adolescence, children experience significant changes in their social world. Typically developing children strengthen their same sex-peer relationships, as well as develop new relationships with the opposite sex. Individual and environmental changes both likely affect their social functioning. In Piaget's (1983) model of development, early adolescents (ages 11 or 12) are still in the Concrete Operations stage, where they are learning to function beyond the family. They learn to make decisions independently, increase their perspective taking ability and learn to generate alternative solutions to problems. As they enter the Formal Operations stage after age 12 (Piaget, 1983), they become more systematic in problem-solving, increase their social awareness and moral reasoning, and develop more complex social relationships. The adolescent period may be thought of as the transition time between childhood and adulthood with respect to social development.

Research has shown that during adolescence, significant synaptogenesis and synaptic pruning happen in the prefrontal cortex, an area of the brain involved in social cognition and executive function (Blakemore & Choudhury, 2006; Steinberg, 2005). The frontal lobe exhibits a different developmental pattern during adolescence than the rest of the brain, indicating non-linear development of skills associated with frontal regions. The purpose of the current study was to explore these patterns from a neuropsychological perspective. Research in this area is sparse – exploring social and executive function development in adolescence will help to provide a basis for understanding abnormal adolescent social development.

Social Cognition

Definition of Social Cognition. "Social functioning" is a very broad and multifaceted concept that has been defined in many ways. Social functioning can encompass terms that are used interchangeably, such as social skills, social competence and social cognition. More recently, researchers have separated the concepts of social skills and social cognition to represent differing levels of conceptualization along the same continuum. Yager and Ehrmann (2006), in their article looking at the measurement of social functioning in people with schizophrenia, identify social skills as behaviours (verbal or non-verbal) that are used to engage in positive interpersonal interactions. They believe these skills lie along a continuum of their own, ranging from basic, "molecular" skills (e.g., eye contact) to more complex, "molar" skills (e.g., starting a conversation). Wallace and colleagues (1980) developed a 3-stage model of social skills that involves receiving and processing of information, and sending out a response using verbal and non-verbal behaviour. While social skills may be the more overt behaviour seen in a social interaction (both verbal and non-verbal), social cognition is thought to be the mental processes that underlie social interactions, processes that are thought to be specialized in problem-solving in the social domain. Amodio and Frith (2006) refer to social cognition as "self-perception, person perception, and making inferences about others' thoughts" (p. 268). Some researchers define social cognition as an information-processing sequence of steps, similar in design to the 3-step model of social skills proposed by Wallace et al. (1980), through which an individual progresses when responding to a social situation (Milch-Reich, Campbell, Pelham, Connelly & Geva, 1999). Social cognition, thus encompasses the activities occurring behind the scenes, the processing of incoming information, thoughts about goals of the interaction, and processing of possible responses to determine the best course of action in a social interaction.

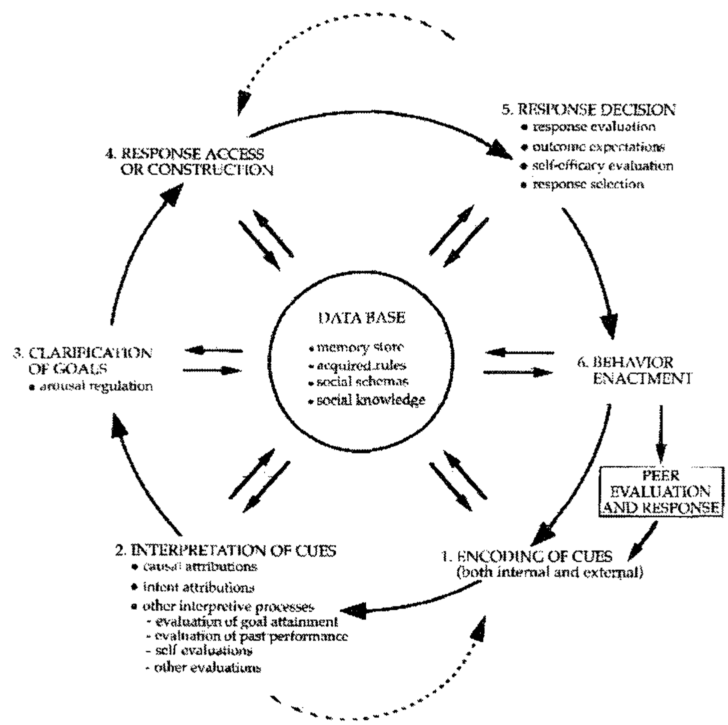
There are two 'definitions' of social cognition that are referred to in the literature (Brewer & Hewstone, 2004). First, social cognition is thought to refer to the mental representations that individuals hold of their social world, including their belief systems regarding the causes of events or the characteristics of people or groups, and their general knowledge of patterns and relationships in the social world. Secondly, and more important to this study, social cognition is thought to encompass social information processing, which follows the pathway of our encoding, interpretation, storage, retrieval and use of social information that we acquire through experience and learning. Past learning and experience directly affect how we respond to new social situations, and how we process and organize this learned social information will affect our ability to respond efficiently and appropriately.

In 1986, Dodge developed a linear model outlining the continuum from social skills to social cognition using information processing theory. Five steps were involved in the initial model. In the first step, sensation, perception and attention are focused on the social information presented to the child in order to encode this information. At step two, the child would interpret this information, by looking at previous social information stored in a child's social 'database' to construct an interpretation based on current social cues. During steps three and four, children again access their database for possible responses to the situation, and determine which response would be best. Finally, the child would enact a behavioural response. While this linear model provided a much-needed analysis of social interactions, and subsequently allowed researchers the ability to study components of the social interaction, its 'linearity' did not account for the ongoing, iterative and parallel processing of the social interaction. Therefore, in 1994, Crick and Dodge presented a more comprehensive information-processing model of social cognition.

In the Crick and Dodge (1994) model of social cognition (Figure 1), individuals come to a social situation with a database of information that they can use to evaluate and respond to the situation. In the case of peer interaction, children will first encode and interpret cues that are presented to them. They then clarify the goals related to the situation, access a possible list of responses or develop a new response, and determine which response is best to use in this situation. Children then exhibit the response. At this

Figure 1. Crick and Dodge Information-Processing Model of Social Cognition

Adapted from Crick & Dodge (1994).

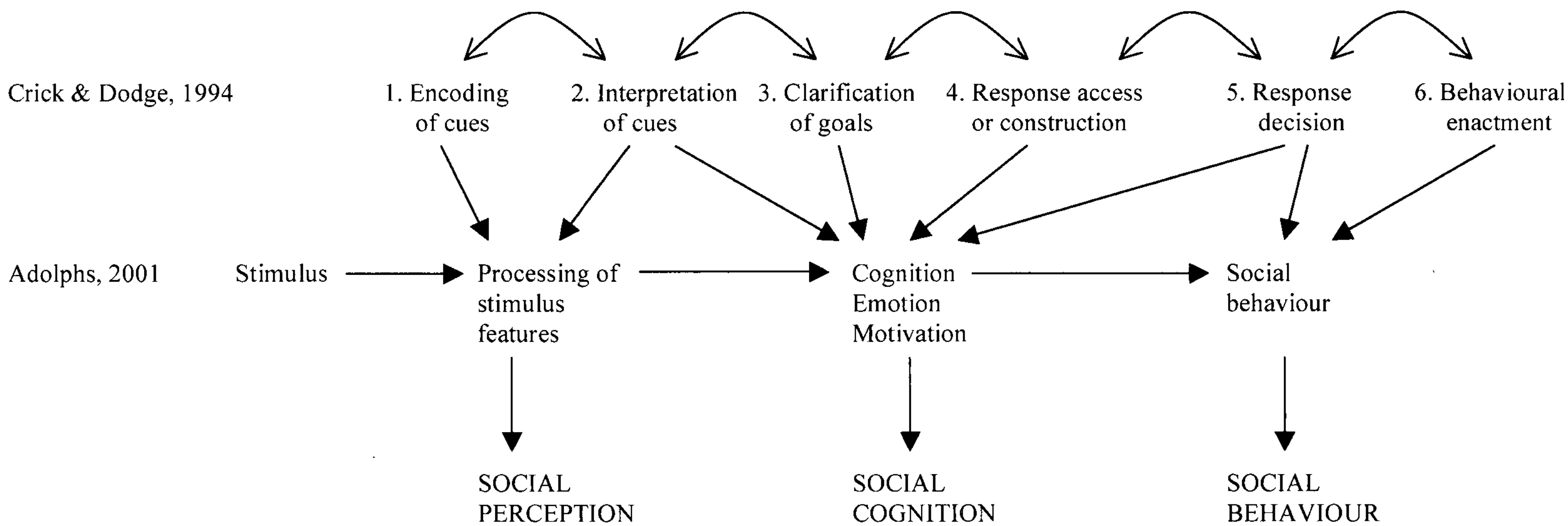


point, the peer will enact the same pattern and provide a response back, if necessary. Understanding the process of social cognition, or where children have difficulties in processing social information, may help develop remediation plans for those children with significant social problems.

This model provides a basic explanation of the process of social cognition, and fits well with other models. Adolphs (2001) identified three component processes of social interactions: social perception, social cognition and social behaviour. Social perception requires an individual to draw upon neural mechanisms involved in perceiving, recognizing and evaluating stimuli, which in combination provide the necessary information to construct a complex representation of the social environment. Social cognition is thought to guide the behaviour, interpreting the social perception that has developed, and determining and deciding on the best course of action. Social behaviour is the resulting decision, and the action produced. Social cognition in Adolph's (2001) model parallels the interpretation, clarification of goals, identification of alternative responses and decision-making stages in Crick and Dodge's (1994) model. Social perception would encompass the encoding phase and to some extent the interpretation phase. Social behaviour would parallel the response phase (see Figure 2).

Biological Bases of Social Cognition. Adolphs (1999), through a review of the literature, argued for the importance of the amygdala, temporal cortex, anterior cingulate cortex and orbitofrontal cortex in social cognition. Since that time, several research teams have investigated these and other brain structures to determine their involvement in

Figure 2. Linking Theoretical Models of Social Cognition



social cognition. Most research has involved neuroimaging and lesion studies with adults (Amodio & Frith, 2006; Van Overwalle, 2008), and single-cell and multidimensional recording in primates (Fujii, Hihara & Iriki, 2007a/b). Few studies have investigated the development of the social cognition "system." Arguments for a specific social cognition system come from three main areas of research – social impairments in humans with frontal lobe lesions, social impairment in individuals with autism and studies of social problem solving in adults and children using functional magnetic resonance imaging (fMRI).

Amodio and Frith (2006), through a review of normal adult literature involving neuroimaging methods such as fMRI, positron emission tomography (PET) and electroencephalography (EEG), sought to understand how the medial frontal cortex (MFC) is involved in social cognition. Social cognition in this study referred to "self-perception, person perception, and making inferences about others' thoughts" (p. 268). Three categories of tasks, involving the medial frontal cortex, were assessed. The first category was control and monitoring of actions, associated with the dorsal anterior cingulate cortex, and possibly the pre-supplementary motor area. The second category involved the monitoring of outcomes linked to punishment and reward, implicating the orbitofrontal cortex. The third category focused on social cognition, thought to be associated with the anterior cingulate cortex, the anterior frontal poles, and the region between these areas, known as the paracingulate cortex.

These authors first explored the functional divisions of the medial frontal cortex (MFC; Amodio & Frith, 2006). The caudal regions of the MFC incorporate motor areas involved in the movement of the hand, eye and mouth, this activity being directly related to behavioural response rates. The posterior rostral MFC may be involved in cognitive activities such as attention and error monitoring, while the anterior rostral MFC appears to be involved in emotional activities. Several studies have indicated that the posterior rostral MFC (specifically the posterior rostral anterior cingulate cortex) is involved in the continuous monitoring of actions to ensure consistency with situation and intention (as seen in the Stroop colour naming task), particularly in situations of conflict. Researchers have shown that the posterior rostral MFC is involved in the "representing and continuously updating the value of possible future action in order to regulate behavior" (Amodio & Frith, 2006, p. 271). The orbitofrontal cortex is involved in the monitoring of rewarding stimuli and responses (learning and gambling tasks). The lateral orbitofrontal cortex is thought to play a special role in inhibiting responses to previously rewarded stimuli.

Amodio and Frith (2006) believe that the difference between the posterior rostral MFC and the orbital MFC is that one guides behaviour through the value of possible actions (posterior rostral MFC) while the other guides behaviour by the value of possible outcomes (orbital MFC). The anterior region of the rostral MFC is situated between the posterior rostral MFC and the orbital MFC, having connections to both regions. This area thus has access to information about actions and outcomes, and is also involved in self-knowledge, person knowledge and mentalizing. Self-knowledge is the ability to separate the self from others and understand the preferences and attributes of oneself. Activation of this area has also been associated with recognition and monitoring of emotional states within oneself. Person knowledge is the perception and judgement of others, and increased activation of this area has been observed when a person judges someone else to be more similar to themselves. Researchers have found that activation of the anterior rostral MFC occurred also when a person was asked to think about the mental state of others. This is similar to mentalizing, the "ability to represent another person's psychological perspective" (Amodio & Frith, 2006, p. 273). Mentalizing can help us to predict the behaviour of others.

A study of 12 right-handed adult males investigated the areas of the brain that are involved in detecting social norm violations using functional MRI (Berthoz, Armony, Blair & Dolan, 2002). Participants viewed various stories with three different types of endings: a normal situation, an embarrassing situation or a situation where the person in the story violated a social norm (e.g., Kevin goes to the library looking for a book. He begins to take the books off the shelf and throws them over his shoulder until he finds the one he is looking for). These materials were presented in two ways: the story was either personal (i.e., about 'you') or the story was impersonal (the character had a name). Participants read the text silently while in the fMRI scanner, and clicked a response key when they had finished reading. They were asked to imagine what the person in the story felt if they were in the situation. Following scanning, participants rated the stories on how embarrassing, how inappropriate and how funny they thought the behaviour was. Brain activity associated with the violation of social norms showed increased activation in medial and superior prefrontal cortex (bilaterally), left middle and inferior cortex, left orbitofrontal cortex, anterior temporal poles (bilaterally), left temporal parietal junction, the cuneus and posterior fusiform gyrus and the brainstem. Embarrassing stories showed activation in the right medial and superior prefrontal cortex, left middle and inferior prefrontal cortex, left orbitofrontal cortex, anterior and middle temporal pole bilaterally, left temporal parietal junction and cuneus and fusiform gyrus. Significant overlap in brain activity is seen between social norm violations and embarrassing situations, including the left medial, middle and inferior prefrontal gyrus, superior frontal gyrus bilaterally, left orbitofrontal cortex, anterior and middle temporal pole bilaterally, left temporal parietal junction, cuneus, lingual and posterior fusiform gyri. There was, however, a greater MFC increase in activity related to violation of social norms than embarrassing situations, which the authors believe may reflect an increased computational load for intentional violations. Other studies have found this area to be involved in the understanding and representation of others' states of mind (Amodio & Frith, 2006). Faces and movement are thought to activate the temporal parietal region, an area often observed to be active during perspective taking tasks (Van Overwalle, 2008). Interestingly, an area also thought to be involved in the regulation and understanding of emotion, the amygdala, did not appear to be involved in the processing of intentional or unintentional social norm violations.

Levin and colleagues (2004) investigated the cognitive outcomes and psychosocial functioning of children with TBI frontal lobe lesions as compared to TBI nonfrontal lesions. Measures of cognitive functioning included declarative memory, expressive language and processing speed while psychosocial functioning was assessed using a semi-structured parent interview (The Vineland Adaptive Behavior Scales, comprised of Communication, Daily Living and Socialization subscales). Participants were 22 children with unilateral frontal lesions (11 left-sided and 11 right-sided), and 22 TBI patients without frontal lesions who were 5 to 15 years of age. Participants in each group were matched by lowest postresuscitation Glasgow Coma Scale score, age at injury (within one year) and age at test (within one year). Neuroradiologists measured the size of lesions seen on MRI scans between 3 months to 2 years post-injury. Although the authors expected to find differences based on previous research, no significant differences were observed between the left and right frontal groups in demographic characteristics, GCS scores, or parent interview scores for psychosocial functioning. Therefore, these groups were collapsed into one and compared to the nonfrontal TBI group. The frontal lesion group had significantly lower Daily Living and Socialization standard scores than the nonfrontal group, although the Communication subscale was not significantly different. Children with lower frontal lesion volumes had higher Socialization total raw scores, as evidenced by higher Interpersonal Relations and Coping Skills within this subscale. Frontal lesion volume was not significantly related to the Daily Living total raw scores. Comparison of 12 children with orbitofrontal, gyrus rectus, and/or inferior frontal gyrus lesions with children with middle and/or superior frontal gyri and/or white matter lesions revealed no significant differences in psychosocial functioning between groups. Location of the lesion did not seem to affect the overall parent ratings of psychosocial functioning. Significantly more children with frontal lesions were rated by their parents as exhibiting higher levels of maladaptive behaviour as compared to children with nonfrontal lesions. No significant cognitive differences were observed between the groups. Although this study did not look at the type of behaviour disturbance exhibited (e.g. verbal, supposedly left-sided disturbances versus emotional, right-sided disturbances), this study indicated that children with frontal injuries, regardless of side, exhibit more behavioural difficulties than children with injuries to other parts of the brain.

Van Overwalle (2008) completed a meta-analysis of the literature to investigate the location and function of brain regions that are thought to be involved in social cognition. This author looked at over 200 fMRI studies, and found that inferring temporary states such as the goals, desires or intentions of other people involves the temporal parietal junction, while interpreting more stable traits, interpersonal norms and scripts, involves activation of the medial prefrontal cortex. Van Overwalle (2008) found that the dorsal part of the medial prefrontal cortex is engaged when verbal trait information involves unfamiliar others, while the ventral medial prefrontal cortex is activated when this information involves familiar people, or the self. Visual information involved in social judgments is also thought to engage the temporal parietal junction.

Recent research has also focused on the mirror system, a system of neurons that fire both when specific actions are performed, as well as when those actions are performed by other animals or humans (Gallese, Keysers & Rizzolatti, 2004; Oberman, Pineda & Ramachandran, 2007; Rizzolatti, Fogassi & Gallese, 2001). This system is thought to involve the inferior frontal gyrus, as well as the inferior parietal lobe, superior temporal sulcus (STS) and parts of the limbic system. Most evidence, however, has been obtained through single-unit recording in primates. This system is thought to support imitation of physical movements in early childhood for the purpose of learning social verbal and nonverbal behaviours, but also helps us develop the underlying intentions, feelings and thoughts that accompany and motivate behaviour. The development of the underlying components may occur through connection with other brain areas, such as the prefrontal cortex, or the limbic system (i.e. the amygdala). Oberman and colleagues (2007) measured mu suppression as an index of mirror neuron activity in 20 college students who observed four scenes – visual white noise on a television; a non-interacting scene where three individuals threw a ball in the air to themselves; a social action scene where they were a spectator watching three individuals throw a ball to each other; and, a social action scene where the ball would sometimes be thrown towards the scene as if being thrown to the viewer to include them in the game. Results of this study indicate that increased mu wave suppression is observed as the degree of social interaction increases. According to the authors, this indicates that the motor system "is also sensitive to the degree of sociality, as evidenced by modulations in the degree of mu suppression between the three experimental conditions. This characteristic may provide a necessary link between simple action observation and more complex social skills, such as theory of mind, empathy and language" (p. 65). It might be useful to think of the mirror neuron system as a building block in the development of social understanding, as imitation is a significant component of child development.

The study of faces, including emotion, expression, perception and movement, is another area of focus in social cognition research. Researchers have investigated the abilities of typically developing individuals, using neuropsychological measures and neuroimaging. This research has shown that the perception of faces involves the fusiform gyrus (Haxby, Hoffman & Gobbini, 2000), while facial movement activates the STS (Allison, Puce & McCarthy, 2000). Emotional processing of facial expressions is thought to involve the amygdala (Kawashima et al., 1999; Morris et al., 1996). One important study found that individuals with bilateral amygdala damage found trustworthy and approachable those faces that individuals without such damage would find most untrustworthy (Morris et al., 1996). The amygdala is, however, thought to be a small part of a larger system of social cognition, with its strong connections to the prefrontal cortex.

Development of Social Cognition. While many studies have focused on the development of social skills in childhood, few researchers have investigated social cognition development. Frith (2008), in his review on social cognition, discussed the importance of the mirror system and imitation of others in the early development of skills important for social interaction. He states that we look to others to determine what is dangerous, scary, or interesting and nice, by viewing others' facial and body expressions. We first take cues from our mothers or caregivers, and around 14 months expand our learning environment to include familiarized strangers, while including unfamiliar people around 24 months of age. Pointing is another method of social interaction that helps to share information between two or more people – this skill can be observed in infants at 12 months of age (Frith, 2008). At around 18 months of age, the development of joint attention skills allows an infant to follow an adult's gaze, or look in the direction that they are pointing (Carpenter, Nagell & Tomasello, 1998). Pretend play also begins around this time (Leslie, 1987). As we get older, we learn to look for social cues that may help us attain a goal. An adult example given by Frith (2008) is looking for a drink at a reception, and following the direction of other people's movements in the room to determine where the drink table might be located. Early development of these abilities is key to the later development of mentalizing around the age of 4 or 5 (Amodio & Frith, 2006). Mentalizing, or the ability to take another person's perspective, is often tested at this age using a false-belief task. Children with autism tend to have significant difficult with these tasks (Baron-Cohen, 2001).

Although there is significant literature on early development of social abilities, little research has investigated development of social cognition in later childhood and adolescence. However, recent research has begun to support the idea that an important stage of social development occurs in adolescence. Blakemore (2008) highlighted that "compared with children, adolescents are more sociable, form more complex and hierarchical peer relationships and are more sensitive to acceptance and rejection by their peers" (p.269).

Puberty, Gender and Social Cognition. Research has shown that some social abilities may be affected by puberty. An early study by Carey, Diamond and Woods (1980) found that a cross-section of 160 girls showed a steady improvement in performance on a face recognition task between the ages of 6 and 10. After age 10, girls showed a plateau, or decline in performance on the same task. Sixteen year-old girls produced higher scores on this task, indicating that performance may begin to improve at this age. Another study of children and adolescents age 8 to 16 indicated that both males and females show a plateau in performance from ages 10 to 14, with a decline observed at age 12, and an increase at age 16 (Diamond, Carey & Back, 1983). Cognitive efficiency related to emotional material (a match-to-sample task using faces and emotion words) has also been shown to decline around the beginning of puberty (age 11 or 12) and recover in late adolescence/early adulthood, as seen in a study of 295 participants between the ages of 10 and 22 (McGivern et al., 2002). However, a differential effect was observed in this study for males and females between the ages of 15 and 17 – at this time, females exhibited longer reaction times than males, an effect that was not present in the 18 to 22 year olds. This means that during mid-adolescence, females were slower to process emotional material than males.

Although little evidence had been provided indicating performance changes on mentalizing tasks during adolescence, studies have shown that children and adolescents access brain regions in different ways as compared to adults when performing face recognition and mentalizing tasks (Monk et al., 2003; Pfeifer, Lieberman & Dapretto, 2007; Yurgelun-Todd, 2007). One study used functional MRI to examine the differences in brain activation of adolescents and adults when viewing different components of a face displaying fearful or neutral emotional expressions (Monk et al., 2003). Greater activation in the orbital frontal cortex was revealed across tasks in adults as compared to adolescents. When attending to a nonemotional component of the face, fearful faces activated the anterior cingulate cortex more in adolescents versus adults. When passively attending to fearful or neutral faces, fearful faces activated the anterior cingulate cortex, bilateral orbitofrontal cortex and right amygdala more in adolescents relative to adults. These results are thought to suggest that adults modulate brain activity based on attention demands, whereas adolescents modulate activity based on emotional components. It may be that adolescents are not as efficient at using their attentional system, and tend to rely on basal emotional components to guide their responses. In a recent study, a sample of 16 adolescents (nine males; seven females) viewed fearful and happy faces during fMRI (Yurgelun-Todd & Killgore, 2006). Age was found to be positively correlated with greater functional prefrontal cortex activation, such that age was correlated with bilateral prefrontal activation in females, but only right prefrontal activation in males. Thus, differences may exist in brain activation patterns for emotional stimuli between males and females. No significant activation patterns were seen in the amygdala.

Mentalizing has been shown to involve the prefrontal cortex and STS (Frith & Frith, 2006). With an increase in gray matter in the prefrontal cortex up to puberty, followed by a steady decline in adolescence and adulthood, a steady decline in STS gray matter, and an increase in both regions of white matter density (Gogtay et al., 2004; Sowell et al., 2003; Toga et al., 2006), it is hypothesized that changes in mentalizing ability might occur during this time as well. Blakemore and colleagues (2007) investigated the development of the neural network underlying mentalizing ability. Nineteen adolescents and 11 adults participated in this fMRI study. They were presented with scenarios that either pertained to intentions and consequential actions (intentional causality, e.g., would you move if you could not see the screen in a theatre?) or natural occurrences and consequential actions (physical causality, e.g. if a huge tree fell in the forest would it make a loud sound?). The participant had to choose whether this was likely or unlikely. Both groups showed more activation in the medial prefrontal cortex

(PFC), superior temporal sulcus/temporal parietal junction and temporal poles during intentional causality versus physical causality. The adolescents, however, showed greater activation of the medial PFC as compared to adults, while right STS activation was higher for intentional causality versus physical causality scenarios in the adult group only. The authors suggest a shift during adolescence from anterior to more posterior activation during mentalizing tasks. The speed at which decisions were made, and the actual responses made were similar for adolescents and adults. Therefore, differences in age groups seemed to be related to differential patterns of brain activity.

Kobayashi and colleagues (2007) used fMRI to study brain activity in 16 adults and 12 pre-pubertal children presented with verbal and nonverbal false-belief tasks. Both groups showed significant activation over baseline in the temporal parietal junction bilaterally and right inferior parietal lobule (IPL), regardless of modality presented. The IPL is thought to be a main component of the mirror neuron system, and has been shown to be involved in imitation tasks (Fogassi et al., 2005). Although the children and adults in the study had similar performance results on the task, age differences were observed in brain activation. Children showed greater activation in the right superior temporal gyrus, right temporal pole, cuneus and right ventromedial prefrontal cortex, while adults showed greater activation in the left amygdala. The right superior temporal gyrus has been implicated in early precursors to mentalizing, such as reading direction of eye gaze (Akiyama et al., 2006). The left amygdala has been shown to be involved in reading of emotional cues (Gallagher & Frith, 2004). As such, the authors hypothesize that the areas of increased activation in children as compared to adults may represent a developmental shift in understanding another's perspective, shifting from physical to emotional cues. Unfortunately, this study did not look at adolescents, where this shift may be occurring.

The development of social cognition begins from an early age. We start with encoding nonverbal cues, and learning through imitation of first our immediate caregivers, and then others in our environment. Social cognition involves activation of several brain areas, including the amygdala for emotional components, the superior temporal sulcus and the fusiform gyrus for facial recognition, and various regions of the medial frontal cortex, temporal lobe and anterior inferior parietal lobe to problem solve, make decisions and inhibit inappropriate responses. Many of the regions that have been implicated in social cognition maintain strong connections or overlap with brain areas involved in executive function. It would naturally follow that a significant relationship would exist between social cognition and executive function, such that deficits in executive function may lead to social difficulties.

Executive Function

Definition of Executive Function. Many researchers have provided definitions and theories about the executive system, executive control and executive function. While our first examination of the responsibilities of the frontal lobes goes back to the famous case of Phineas Gage, the original concept of executive control was first addressed by Luria in 1966. He proposed that the executive control system was in charge of formulating goals and plans, and developing goal-appropriate cognitive routines.

Research into the executive control system has since focused on the cognitive operations behind the formulation of goals and plans, as well as transitioning, or cognitive flexibility that allows someone to shift their cognitive set quickly when something unexpected happens (Goldberg & Bougakov, 2005). Miyake and colleagues (2000) have more recently divided executive control into three basic processes, including shifting or cognitive flexibility, monitoring incoming information to update old information with newer, more relevant information (which has been interpreted as working memory), and inhibiting automatic, prepotent responses. However, these researchers contend that these three basic processes may be further subdivided, and this list may not be exhaustive. Based on previous research, a model of executive function was proposed by Anderson (2002) that outlines four distinct domains: 1) attentional control, 2) information processing, 3) cognitive flexibility, and 4) goal setting. These distinct domains are conceptualized overall as a control system, where the individual domains are interactive and interconnected. Attentional control refers to the ability to inhibit responses and focus attention for a long period of time. This also involves the regulation and monitoring of actions so that goals are achieved. Information processing refers to the speed and efficiency with which output is produced, in addition to the quality of that output. Cognitive flexibility refers to shifting between sets, learning from mistakes to develop new, more effective strategies, divided attention and working memory. Goal setting is the ability to develop new ideas and concepts, to plan actions in advance and to approach tasks efficiently and effectively. All three components of Miyake et al.'s (2000) model are encompassed in the domains of attentional control (monitoring and inhibition) and cognitive flexibility (working memory), while two additional components exist in Anderson's (2002) model (information processing and goal setting). It is important to remember that different researchers are using different tasks to measure executive functions, making it difficult to determine which domains exist, and how they may be interrelated.

> Baron (2004) believes that executive function comprises "metacognitive capacities that allow an individual to perceive stimuli from his or her environment, respond adaptively, flexibly change direction, anticipate future goals, consider consequences, and respond in an integrated or common-sense way, utilizing all these capacities to serve a common purposive goal" (p.135).

Many clinicians and researchers today would agree with this definition, and see executive function as a supervisory system that oversees purposeful, goal-directed behaviours (Strauss, Sherman & Spreen, 2006), especially in novel or unfamiliar situations (Shallice, 1990). Executive functions are generally those skills that help individuals to organize, plan and be flexible in daily activities. They comprise less complex skills, such as attention and inhibition that are thought to develop early in childhood and are important for daily functioning, and more complex skills, such as working memory, decision-making, set-shifting and abstract problem-solving, which are required for more complex activities. Executive function allows us to select the information that we should attend to, modulate interpersonal and emotional behaviour, have continuity across time and place, and continually monitor, evaluate and adjust our thoughts and behaviours, providing us with insight and awareness of our effect on our environment (Johnstone & Stonnington, 2001). Many of these skills are necessary for adaptive social functioning. Individuals must pay attention to others in order to encode and interpret social information and inhibit inappropriate responses. More complex executive function skills may be necessary to engage in goal formation, response generation and problem-solving in social interactions.

Biological Bases of Executive Function. Although several definitions and theories exist regarding the concept of executive function, the common link to all is the areas of the brain thought to be involved. Executive function involves the frontal lobes and other cortical and subcortical regions, and is regarded as uniquely human. This region is particularly affected by traumatic brain injury because of the underlying jagged, uneven basal skull topography, or injuries to the middle cerebral artery which are more common than any other brain injury. Research has shown that executive functions are "synonymous with the functioning of the prefrontal cortex" (Koechlin & Summerfield, 2007, p. 229). However, many other brain regions have rich connections with the prefrontal cortex and frontal regions, and thus clinicians and researchers are wise not to use 'executive dysfunction' and 'frontal lobe dysfunction' interchangeably. People often present with deficits traditionally associated with the frontal lobes, even though the injury may not have been in the frontal region, because of these connections (Johnstone & Stonnington, 2001). Executive function is also dependent on the normal functioning of language, memory, perception, visuospatial processing and motor skills. Anderson et al. (2001) state that "although frontal regions may play a vital role in the mediation of [executive function], the integrity of the entire brain is necessary for efficient [executive function]" (p.386).

Injury to the brain in childhood has provided some clarity regarding the importance of the prefrontal brain regions in social development. Children and adults who experience head trauma, especially trauma involving the frontal cortex (Anderson et al., 1999), find social interactions significantly more challenging. When head trauma occurs early, as was the case with two young adults with a history of focal prefrontal injuries before 16 months of age, there is evidence of inadequate social behaviours, difficulty retrieving complex social information, and limited knowledge of moral rules and social conventions (Anderson et al., 1999). These behaviour difficulties were unresponsive to remediation. Studies have shown that prefrontal injury is related to poor planning and problem-solving, reduced capacity for abstract thought and slower processing speed (Anderson et al., 2001). The importance of these executive skills in adaptive social functioning requires further investigation.

Lesions to the ventromedial head of the caudate, an area that has connections to the orbitofrontal cortex, as well as to the globus pallidus, are associated with disinhibition (Lee & Chui, 2007). Inhibition of speech has been shown to involve the right inferior frontal cortex, which includes the pars opercularis and anterior insular cortex, and the pre-supplementary motor area. These areas were also involved with inhibition of a motor response (Xue, Aron & Poldrack, 2008).

Conflict processing (Stroop task) activity involves the anterior cingulate cortex, bilateral lateral prefrontal cortex, the anterior insula and the parietal lobe (Roberts &

Hall, 2008). Investigation of activation of the anterior cingulate cortex revealed dorsal anterior cingulate cortex activation during colour-word distractors (Mohanty et al., 2007). Inhibition of response during a stop signal task, which involved post-error slowing in reaction time, activated the ventrolateral prefrontal cortex (Li et al., 2008). This was referred to as the neural circuitry involved in error-associated behaviour modifications. Monitoring of behaviour involves the right lateral frontal area (Stuss, 2007; Stuss, Alexander et al., 2005). The anterior cingulate cortex has also been suggested as a monitoring centre, from which conflict signals are then transmitted to the dorsal lateral prefrontal cortex (Sohn et al., 2007).

Cognitive flexibility is the ability to abandon a previous response so that a new response can be generated. Rogers and colleagues (1998) have found that left frontal lobe lesions interfere with cognitive flexibility on a visual-motor task. Others have noted that individuals with focal lesions in the lateral prefrontal cortex exhibit difficulties with set-shifting, showing a significantly slowed performance and increased error rates (Yochim et al., 2007). In individuals with schizophrenia, left dorsolateral prefrontal gray matter volume predicted performance on the Wisconsin Card Sorting Test (Rüsch et al., 2007).

Working memory has been one of the most extensively studied areas of executive function (Baddeley, 1987, 1998, 2000). Working memory involves holding in mind and manipulating information to produce a response. The Central Executive of Baddeley's (1998) working memory model coordinates and controls attentional resources, similar to the Supervisory Attentional System in the Norman-Shallice information-processing model of attention (Norman & Shallice, 1986). The Central Executive supervises two slave systems called the phonological loop and the visuospatial sketch pad (Baddeley, 1998). The phonological loop has been proposed to manipulate linguistic information, and includes a phonological store and articulatory control process that is thought to recode written language into a phonological code for storage. The faster the articulatory control process can run, the more items will be maintained. The visuospatial sketch pad manipulates visual-spatial (or nonverbal) information in a similar way (Baddeley, 1998).

Research has shown the working memory system to involve distinct frontal networks, including Broca's area, the anterior cingulate cortex and dorsolateral prefrontal cortex (Smith & Jonides, 1999; Ungerleider, Courtney & Haxby, 1998). Courtney, Petit, Maisog, Ungerleider and Haxby (1998) using imaging techniques, found that working memory involving visual objects activated an inferior frontal region, while spatial working memory tasks activated a caudal portion of the superior frontal sulcus. Studies have also shown that Broca's area is necessary for the rehearsal component of verbal working memory (Smith, Jonides, Marshuetz & Koeppe, 1998).

Grafman (2007) describes planning as the formulation of an abstract sequence of processes or operations in order to achieve a goal. The plan, which is a representation of this sequence, can be stored internally in the mind, or externally, such as a route drawn on a map. Several areas of the brain are active during different phases of the planning process. Planning deficits are seen with frontal lobe lesions and subcortical disorders affecting the basal ganglia. Knowledge specifically related to a plan appears to be stored in the prefrontal cortex, while the execution of a plan involves motor processes of the basal ganglia and frontal lobes (Frank, Loughry & O'Reilly, 2001). It is interesting to note that individuals with prefrontal cortex lesions often have little difficulty with navigation of well-known routes, but show significant impairment when learning a new route, suggesting that automatic plans or scripts involve less activation of prefrontal areas (Karnath & Wallesch, 1992). Planning also involves the caudate head, as damage to this area has been shown to interfere with planning ability (Lee & Chui, 2007).

Baker and colleagues (1996) subtracted the activation of the brain as seen by fMRI during a hard Tower of London (ToL) task from an easy ToL task (based on the number of pieces and number of steps required) and found that activation remained in the right Brodmann's area 10 (rostral prefrontal cortex, or medial frontal gyrus), left Brodmann's area 9 (superior frontal gyrus, prefrontal association cortex) and the premotor cortex. Others have also found difficult ToL tasks to be related to more left prefrontal activation (Morris et al., 1993), especially structural analysis of the planning process (Grafman, 2007), while temporal and planning components may be associated with more right prefrontal activation (Grafman, 2007). Cazalis and colleagues (2006) found differences in brain activation profiles during a modified ToL task between participants considered 'high performers' on the task, and those considered 'standard' or 'low' performers, either with or without severe traumatic brain injury. Healthy high performers and high performers with brain injury exhibited a large left dorsolateral prefrontal cortex (DLPFC) activation and a small anterior cingulate cortex (ACC) activation. Healthy standard performers exhibited a lower left DLPFC activation and higher ACC activation than traumatic brain injury high performers, but were not significantly different than the healthy high performers. Although a limitation of this study is the small sample size (as is the case for much fMRI research), it provides evidence for involvement of the DLPFC and ACC in planning.

Organization is the ability to efficiently put objects, words or other items in a particular order or group, to arrange items in a certain way. Quite often, organization is a skill that is involved in the process of planning. Read (1981) found that individuals with temporal lobe lesions have significant difficulty placing words or pictures into categories.

Reasoning is "the attempt to reach secure conclusion from prior beliefs, observations or suppositions" (Monti et al., 2007, p. 1005). Although research thus far has shown inconsistent results, speculation about the areas involved in deductive reasoning include left frontal (BA 6, 47) and parietal (BA 7, 40) cortices, thought to maintain the formal structure of arguments, while the left rostral and bilateral medial prefrontal cortex perform deductive operations (Monti et al., 2007). Other research using fMRI have found the left caudate head, left and right rostrolateral prefrontal cortex, right ventrolateral prefrontal cortex, right orbital gyrus, posterior right DLPFC, right inferior/middle temporal gyrus, and bilateral parietal cortex to be involved (Melrose, Poulin & Stern, 2007). Research indicates that the caudate head interacts with these frontal and parietal areas during reasoning tasks, including rule deduction, rule application and cognitive sequencing.

Development of Executive Function. Research has begun to indicate that social cognition does not develop at a steady rate throughout life. Similarly, research of executive functions has shown similar patterns. While some abilities develop early in life, others do not. Several researchers have investigated the early development of executive function, but few have focused on their development in adolescence. Anderson (2002) is one of the few researchers who has investigated the development of executive function from early childhood through to late adolescence. He has examined these skills in terms of the four domains outlined in his model of executive function, and in terms of gender differences. In his work, and review of the literature, Anderson (2002) has found that attentional control processes (monitoring and inhibition of behaviour) develop mostly in infancy and early childhood, and are relatively established by middle childhood. Information processing (processing speed and fluency), cognitive flexibility (switching, working memory, divided attention) and goal setting (planning, organization) are relatively developed by the age of 12, but are not fully developed until mid-adolescence or early adulthood. Anderson (2002) notes that research has indicated a developmental regression in these domains that may be associated with a transitional period in early adolescence (possibly between the ages of 11 and 13). It seems that development of attentional control may be paramount for further development of executive function abilities (Anderson, 2002; Garon, Bryson & Smith, 2008).

Infant research has shown that basic executive skills begin developing at an early age (Garon et al., 2008). Children's ability to hold information in mind over a delay increases from 6 months to 11 years, in both capacity and length of time (Gathercole, 1998). However, manipulation of a representation in mind, such as an invisible displacement task, does not appear to emerge until 24 months of age (Corrigan, 1981). Inhibition is thought to emerge in the first year of life, and continue to increase in early life (Kochanska, 2002). Carlson (2005) found that 50 % of 24-month-olds were able to suppress gratification (eating a treat) for 20 seconds, 85 % of 3 year-olds were able to suppress gratification for one minute, and 72% of four year olds were able to not eat the treat for five minutes. Increased performance in other, more difficult inhibition tasks, such as Stroop-like tasks and Simon Says tasks, are also seen in children age 3 to 5 (Carlson, 2005). This research suggests that from infancy to age 5, children improve in their ability to hold and manipulate online information, and inhibit responses, both in terms of inhibiting inappropriate responses, and in delaying gratification.

Brocki and Bohlin (2004) investigated the development of executive function in children age 6 to 13. Using a cross-sectional design, they used measures that, following factor analysis, resulted in three dimensions: disinhibition, speed/arousal and working memory/fluency. Children participating in the study were divided into four age groups: 6.0 to 7.5, 7.6 to 9.5, 9.6 to 11.5 and 11.6 to 13.0. On the disinhibition dimension, differences were observed between the 7.6 to 9.5 age group and the 9.6 to 11.5 age group, such that the older group performed better. No differences were observed between the two younger groups, nor between the two older groups. As such, a developmental "shift" was thought to occur somewhere between 7.6 and 11.5 years of age. No differences were observed with respect to gender. On the speed/arousal dimension, the youngest age group was found to perform at a slower rate than all other groups, with no other significant differences. Overall, girls also performed at a slower rate than boys, regardless of age. On the working memory/fluency domain, a significant effect for age was found. The youngest age group's performance was worse than the second youngest group, and the oldest age group's performance was better than the second oldest age group. No other significant differences were observed. As such, the authors reported that improvement was observed in working memory performance at two time points: one around the age of 8, and a second around the age of 12. As these researchers collected data on children age 13 and under, it cannot be determined whether there are any changes in developmental course in later years.

In a study of executive function in children aged 11 to 18, Anderson and colleagues (2001) identified some variability in development across age and gender. On a forward digit span task, children age 11 to 14 performed significantly worse than children age 15. No age differences were noted for a digit backwards task, although a gender difference indicated that girls age 11 achieved lower scores than comparably aged males, but all other ages of girls achieved higher scores. On a more complex test of selective attention, working memory and cognitive flexibility, similar results were noted, with an increase in performance around 14 to 15 years of age. Speed on this task was noted to be slower for younger girls, where a similar gender shift was noted with girls performing the task faster than boys around age 13. A gradual increase in performance was noted on a measure of planning from age 11 to age 15+.

Crone et al. (2006) investigated working memory, looking at both maintenance and manipulation of information, in individuals between the ages of 8 and 25. Participants in the study were divided into three age groups: 8 to 12 years old, 13 to 17 years old and 18 to 25 years old. Results demonstrated that children in the youngest age group made more errors when maintaining and manipulating information in working memory than adolescents or adults. The youngest participants also had significantly more difficulty with manipulation than maintenance tasks, as compared to adolescents and adults. Activation of the right dorsolateral prefrontal cortex and left and right superior parietal cortex also differed between age groups, such that children failed to engage these areas more strongly for manipulation than maintenance tasks during a delay period, unlike adolescents and adults. Activation profiles for the left DLPFC did not differ between groups. This study grouped together early and late adolescents, thus not allowing for comparison of early and late adolescents on working memory performance and fMRI activation patterns.

Research thus far on executive function in adolescence has shown linear improvement with age on some executive function tasks, but not others (Blakemore & Choudhury, 2006). However, these studies often use few tasks, or have few participants. More research is required in this area to enable a better understanding of executive function development in adolescence.

Social Cognition and Executive Function

Blakemore and Choudhury's (2006) review of the literature investigates the development of the prefrontal area and theorizes about the impact of puberty on executive function and social cognition. Synaptic proliferation occurs in most of the brain in early postnatal development. At this time, synaptic density far exceeds levels in adulthood, synaptic pruning occurs, and new synaptic connections are formed. As development continues, myelination increases the speed of transfer of neural information, and pruning of unnecessary synapses results in adult levels of synaptic density. These connections are strengthened through myelination, which continues well into adolescence. However, a different pattern occurs in the prefrontal area. Studies in both monkeys and humans have shown an increase in synapses in childhood and early puberty. Once puberty has begun, a plateau phase occurs, followed by synaptic pruning and reorganization and strengthening of prefrontal synaptic connections. This synaptic pruning is thought to result in more efficient transfer of information within the prefrontal area and to other regions of the brain. Research has shown that while white matter development appears to be linear in nature through childhood, adolescence and early adulthood, changes in gray matter may not be linear in some regions of the brain. Researchers have found pre-pubertal increases in volume of frontal gray matter (around age 12 for males and age 11 for females), followed by a reduction post-adolescence. A similar pattern has been observed in the parietal area, while a peak in temporal lobe gray matter volume occurred much later, at around 17 years. Changes in the brain, especially the frontal lobe, continue to occur well into young adulthood. Reductions in gray matter are often accompanied by increases in white matter volume. While studies have investigated structural changes in the frontal areas of the brain during adolescence, few have focused on the changes in executive function and social cognition abilities. Studies that have investigated the development of executive functions in adolescence using various executive function measures have found linear improvement on some tasks (for example, selective attention, working memory and problem-solving) but not others (for example, organization and planning, use of strategies and matching face-to-word tasks), although these results are not consistent. Researchers investigating social cognition before, during and after puberty have shown the development of social perspective taking to follow a non-linear pattern of development. This, again, is thought to be related to synaptic proliferation and reorganization in the prefrontal area. As mentioned previously, facial recognition task performance has also been found to decline around the age of puberty, with participants exhibiting a 10 % drop in performance between the ages of 10 and 12, with recovery of task performance from age 14 to 16 (Carey, Diamond & Woods, 1980).

Functional MRI (fMRI) has helped to identify the areas activated in the brain during executive function tasks. fMRI has also been helpful in looking at developmental patterns of activation. During an inhibition task, the anterior cingulate, orbitofrontal cortex and inferior and middle frontal gyri were activated in both children and adults, although a higher activation of the prefrontal region was noted in children, specifically in the DLPFC and the anterior cingulate (Casey et al., 1997). Adults exhibited more activation in the ventral PFC. The best performance on the task was seen in participants with the most orbitofrontal activation and the least DLPFC activation. During a word generation task, children performed significantly worse on the task and exhibited greater activation in the left inferior frontal cortex and the DLPFC as compared to adults. These researchers feel that greater activation seen in children may occur to compensate for less efficient connectivity between neurons.

Social cognition involves the amygdala, STS, fusiform gyrus, inferior parietal lobe and the medial frontal cortex. Executive function activates the anterior cingulate cortex, caudate, regions of the temporal and parietal lobes, and the lateral frontal cortex.

Strong connections exist among these regions, indicating that a relationship would exist between the stages of social cognition and executive function. The purpose of this study was to further investigate how they are related. However, researchers have questioned the involvement of emotion in the development of social cognition (Lemerise & Arsenio, 2000). The amygdala, thought to be involved in the regulation of emotion, has shown activation in some social cognition tasks involving emotion (Monk et al, 2003) while other studies involving emotion showed more activation in the prefrontal cortex (Yurgelun-Todd & Killgore, 2006). Emotions such as happiness, sadness or anger are a part of social interactions and the underlying thoughts that help guide social problem-solving and decision making. Our ability to regulate our emotions may be related to our self-control (executive function) and our success in social interactions.

Emotion, Social Cognition and Executive Function

Executive function refers to "cognitive operations that help maintain behavioral adaptation to context and maintain a goal set" (Martel et al., 2007, p. 543). Executive functions are, as such, related to deliberate self-regulation, a concept that Martel and colleagues termed resiliency. Resilience is the ability of a person to cope with and 'bounce back' from experiences of adversity or stress, such that they are able to make decisions, solve problems and relate to others in a positive and productive way (Goldstein & Brooks, 2005). Resiliency involves emotion regulation and effortful control. The brain areas thought to be involved in resiliency include the anterior attention system, which is composed of the anterior cingulate gyrus and the prefrontal cortex, with projections to the basal ganglia and thalamus. Significant overlap with areas involved in executive functions (dorsolateral and orbital prefrontal cortex, anterior cingulate gyrus, and associated subcortical structures including the thalamus and basal ganglia) exists. 498 children participated in research by Martel et al (2007), investigating resiliency, regulation and executive function in a high-risk sample (362 male, 136 female). They followed a community sample of families with high alcohol use disorder, substance use disorder or other psychopathology, as well as families without these difficulties. Fetal alcohol syndrome was an exclusionary factor. Five waves of data were available for the children, taken between the ages of 3 and 18 years. Outcome measures and executive function measures were obtained between 12 and 18 years of age. This study used the Child Behavior Checklist (CBCL; Achenbach, 2001) social competence scale to measure social ability, and various executive function tests to measure behavioural inhibition, alertness, activation, effort, fluency, interference control, monitoring response conflict, suppressing competing responses, planning and manipulation of complex information in working memory. Resiliency and reactive control (non-deliberate, more reactive or impulsive responding) were measured using the California Child Q-Set (CCQ) common language version (Caspi et al., 1992), looking at specific items related to resiliency and reactive control. Response inhibition and naming speed were significantly positively correlated with resiliency. The results indicated that resiliency was significantly related to executive function, while reactive control was not. These results may indicate that conscious control is required for resiliency, where reaction control is not; thus, resiliency may be related to executive function in that conscious, deliberate control of actions and behaviours is required. Final results indicated that only good interference control and resiliency were contributors to variance in social competence. These effects were small and only marginally improved model fit, probably due to stability of social competence between childhood and adolescence. There may also be an effect of limited reporting of social competence, as only one measure, completed by a caregiver, was used to measure this construct. These researchers also found that executive function weakness was related to the development of problem behaviours, as measured by the internalizing and externalizing scales of the CBCL.

Adolescent years involve a great deal of change in brain areas associated with response inhibition, risk and reward assessment, and emotion regulation (Steinberg, 2005). This activity is "not limited to the early adolescent period, nor is it invariably linked to processes of pubertal maturation" (p. 69). However, puberty may heighten emotional arousal, sensation-seeking and reward orientation (again, related to inhibition and arousal). Adolescent development proceeds non-linearly with the goal of more conscious behaviour and abilities, more self-regulation and more self-direction with the development of complex cognitive processes (Steinberg, 2005). While the prefrontal cortex is the area specifically under development during adolescence, this area is also developing new connections and strengthening those connections already formed with other areas of the brain. As well, the increase in myelination results in increased rapid connectivity between neurons. Pruning of unnecessary synapses also occurs, reducing congestion and increasing efficiency of brain connections. While the development of executive function in middle childhood and early adolescence has been studied to some extent, less research has focused on late adolescence. It appears that some brain changes in structure and function may be linked to neuroendocrine changes during puberty, but others occur later, and it would be helpful to separate the former from the latter.

Study Purpose

Adolescence may be a sensitive period of reorganization in brain areas such as the frontal lobe, which can have significant effects on social development. It is important to understand the development of social cognition and its relationship to complex executive functioning in adolescents in order to then identify mechanisms of dysfunction. Much of the research focusing on executive function development has focused on early to middle childhood or adulthood, with little research available on adolescence. Being a time of significant transition – physically, emotionally and cognitively – it is important to investigate changes that may be occurring in higher level functioning during adolescence. In addition, little research has investigated the development of social cognition – those cognitive skills underlying social interaction. In adolescence, successfully navigating the social world is paramount, and typically developing children find this challenging, let alone those with dysfunctional social skills. Three specific questions come to mind when reviewing previous research: 1) How do executive function and social cognition develop in late childhood to early adulthood, 2) Do similar executive function dimensions exist in adolescence as shown in previous research of younger children and adults, and 3) Do these executive function components predict social cognition? While researchers have investigated the impact of executive dysfunction on social skills following traumatic brain injury (Godfrey & Shum, 2000), few have investigated this relationship in typically developing children, especially adolescents. These questions were examined in the current study in two separate analyses. Within each study, more specific hypotheses are identified. A brief explanation is provided here. The first analysis investigated social cognition and executive function across ages, using a cross-sectional design, looking at children from 10 to 18 years of age. The purpose of the second study was to examine the dimensions of executive function, whether executive function dimensions predict social cognition, and whether emotional coping strategies used by children and adolescents are related to performance on social cognition tasks.

General Method

Participants

Ninety-nine typically developing children and adolescents between the ages of 10 and 18 (Mean age = 14.23, SD = 2.44) were recruited through Crescent School, a private boys' school in Toronto, Ontario; online advertisements on www.craigslist.com and www.kijiji.com; Introductory Psychology classes at York University; and, public places around the Greater Toronto Area (e.g., flyers distributed at malls, parking lots). Exclusion criteria for this group were an IQ below 70, severe language impairment, any evidence of a seizure disorder or brain injury, a learning disability and behavioural or emotional disorders. Four participants previously diagnosed with Attention-Deficit/Hyperactivity Disorder were included in this study as no significant differences were noted between their scores and other participants with respect to IQ, executive function and social cognition measures. Eight participants were excluded from this study for the following reasons: seven were excluded from the study because they were female – a low number of female participants volunteered for the study, and as such the remaining participants were male; one participant was excluded because he informed the examiner of a traumatic experience the day before, which was significantly affecting his task performance.

Measures

Demographic Questionnaire. A structured case history form was given to parents/caregivers for each child participating in the study to collect demographic information regarding each child. This included such information as early developmental history (age at which participant reached developmental milestones), and diagnoses that would be relevant to inclusion or exclusion criteria, such as a diagnosis of Autism Spectrum Disorder or learning disabilities, any psychiatric history, such as a history of anxiety or depression, and general functioning at school. In addition, several questions asked about immediate and extended family history, including medical and psychiatric history. While these questions were not used for the purpose of analysis in this study, they were used to screen participants for exclusion criteria, and compile information regarding general demographics of the participants. This form can be found in Appendix A, and was based on the case history forms that might be used for a clinical assessment.

Clinical Assessment of Behavior: Parent Extended Rating Form (CAB-PX; Bracken & Keith, 2004). The CAB-PX is a 170-item behaviour rating form for children and adolescents age 2 to 18. The responses are provided on a 5-point likert scale, ranging from 'Always or Very Frequently' to 'Never'. It provides three clinical scales (Internalizing Behaviours, Externalizing Behaviours and Critical Behaviours) investigating childrens' and adolescents' adjustment difficulties, 10 clinical subclusters (Anxiety, Depression, Anger, Aggression, Bullying, Conduct Problems, Attention-Deficit/Hyperactivity, Autistic Spectrum Behaviours, Learning Disability and Mental Retardation), and 3 adaptive scales (Social Skills, Competence and Adaptive Behaviours). Internal consistency for the CAB-PX is α=.95 for the Internalizing Behaviours scale, α=.97 for Externalizing Behaviours scale and α=.91 for Critical Behaviours Scale. The adaptive scales and clinical subclusters range from .91 to .97, evidence of very good reliability. The CAB-PX individual clinical scale reliabilities were generally greater than .90 when gender and age were taken into account – only males and females in the 2 to 6 year age group obtained reliabilities less than .90. The CAB-PX also shows evidence of good content, construct and concurrent validity.

*Behavioural Rating Inventory of Executive Function (BRIEF; Gioia, et al., 2000).*The BRIEF is used to evaluate executive functions in children age 5 to 18 years. The BRIEF questionnaire, completed by parents, consists of 86 items in eight nonoverlapping clinical scales (Inhibit, Shift (with Behavioral Shift and Cognitive Shift subscales), Emotional Control, Monitor, Working Memory, Plan/Organize, Organization of Materials, and Task Completion), and two validity scales (Inconsistency and

Negativity), that form Behavioural Regulation and Meta-cognition Indices. A Global Executive Composite is also calculated. Reliability is quite good, with high internal consistency (alphas = .80-.98) and good test-retest reliability (*r*s = .82). Convergent validity has been established with other measures of inattention, impulsivity, and learning skills. Divergent validity was demonstrated against measures of emotional and behavioral functioning.

Wechsler Abbreviated Intelligence Scale (WASI; Wechsler, 1999). The WASI is a shortened yet reliable measure of the Wechsler Intelligence Scales, yielding a similar output of Verbal, Performance and Full-Scale IQ scores. The Vocabulary and Similarities subtests yield the Verbal IQ score, while Block Design and Matrix Reasoning provide the Performance IQ score. The scale measures verbal knowledge, understanding of the relationship between objects or concepts, visuospatial and analytical reasoning skills.

The Vocabulary subtest of the WASI consists of 42 items that require the examinee to indicate knowledge of the object or concept. The first 4 items consist of pictures that the examinee must name. Item 5-42 are orally and visually presented words that the examinee must define orally. The Similarities subtest consists of four picture items and 22 verbal items. The first 4 items consist of 3 similar pictures on the top half of a page, and 4 items presented on the bottom of the page. Examinees must choose the correct item that is most similar to the items on the top of the page. The verbal items consist of two orally presented words requiring the examinee to explain the similarity between the two objects or concepts presented. The correlation of the Vocabulary subtest to the Vocabulary subtest of the Wechsler Intelligence Scale for Children – Third Edition (WISC-III) is .72. The Similarities subtest also has a low correlation of .69 with its WISC-III counterpart.

The Block Design subtest consists of 13 visually demonstrated or printed templates of geometric patterns that the examinee replicates with the use of blocks within a certain period of time. All blocks are the same, and must be manipulated to form the pattern specified. The Matrix Reasoning subtest consists of 35 incomplete patterns. The examinee must choose one of five possible responses to complete the pattern. Correlation of the Block Design subtest with the WISC-III Block Design task is .74.

Reliability of the tasks of the WASI for the children's sample based on internal consistency coefficients, range from .86 to .93 for Vocabulary, from .81 to .91 for Similarities, from .84 to .93 for Block Design and from .86 to .96 for Matrix Reasoning. The average reliability coefficients range from .87 to .92 for the children's sample. Reliability coefficients for the VIQ and PIQ subscales range from .92 to .95, while the Full Scale IQ ranges from .95 to .97.

Delis-Kaplan Executive Function System (D-KEFS) subtests – Tower, Colour-Word and Verbal Fluency and Sorting Test (Delis, Kaplan & Kramer, 2001). The D-KEFS is a standard assessment of higher-level cognitive functioning for individuals age 8 to 89. The entire test is designed to measure flexibility of thinking, inhibition, problem-solving, impulse control, concept formation, abstract thinking and creativity in both verbal and spatial domains. The subtests chosen for this study assess inhibition of interference (Colour-Word), planning and problem-solving ability (Tower), concept formation and reasoning ability (Sorting Test), and generation of verbal responses within a set rule (Verbal Fluency). Split-half reliability estimates are good for Color-Word (.62 to .86) and Verbal Fluency – Letter Fluency Condition (.68 to .90) while moderate to good for the Sorting subtest (.70 to .79) and Tower subtest (.50 to .80). These values are not high, but are comparable to other neuropsychological tests currently in use (Delis, et al., 2004; Homack, Lee & Riccio, 2005). Studies have shown the D-KEFS to be sensitive to executive function deficits in a wide variety of clinical groups (Delis et al., 2004).

Rey Complex Figure Test (Meyers & Meyers, 1995). The RCFT is a neuropsychological measure of visuospatial construction ability and visual memory. It consists of four test conditions: copy, immediate recall, delayed recall and recognition. Participants look at a complex drawing and initially try to copy it. The drawing is removed from sight once the individual is finished, and they complete a short verbal task. They are then asked to draw the figure from memory. Then, after a 30 minute delay, they are asked to draw the same figure again. Once this is complete, they are provided with a booklet that has many parts of the drawing along with parts that were not in the drawing. They are asked to circle those parts that they think were in the original drawing. Scores are based on location, organization and accuracy. The copy subtest is also a useful measure of planning and organizing ability. Interrater reliability coefficients ranged from .93 to .99 for total raw scores, with a median of .94. Test-retest correlations of the Immediate Recall, Delayed Recall and Recognition total correct were .76, .89 and .97 respectively. Correlation with the Weschler Adult Intelligence Scale – Revised, revealed that the RCFT is a measure of visuoconstructional ability and visuospatial memory, and is useful in discriminating both diagnostic groups and left and right hemispheric damage.

Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948). The WCST is a test used to assess perseveration and abstract thinking, which is sensitive to frontal lobe dysfunction. The participant is required to match cards with figures of various shapes, colours and sizes to one of four template cards according to rules determined by the examiner. Participants are told whether they are correct or incorrect, and the rules consistently change once the participant has completed a set. This test is designed for individuals age 6.5 to 89, and measures several areas of frontal lobe function: strategic planning, organized searching, using environmental feedback to shift a cognitive set, directing behaviour towards a goal and inhibition of impulsive responding. A computerized research version of the test was used. This version is the same presentation as the original card version, but with the cards viewed on the computer screen, and the computer instructing the participant whether they are right or wrong, rather than the experimenter. Test-retest reliability scores have been shown to be low to moderate (.25 to .60; Bowden, et al., 1998), and validity results have been variable, including strong correlations with Wechsler Adult Intelligence Scale – Revised scores (Heinrichs, 1990) as well as factor analysis indicating the measurement of one ability with large observed error terms (Bowden, et al., 1998).

Mind in Eyes Task (Baron-Cohen et al., 2001). The child and adolescent version of the Eyes Task involved participants looking at 28 pictures of male and female faces, showing only the eye area. The pictures were presented on paper. The participant was asked to choose one of four alternative words or phrases that best describe what the person in the picture is thinking or feeling. This test measures the ability of participants to understand emotional facial expression. This is an experimental task and does not currently have reliability statistics available. However, it has been shown to discriminate children with Autism Spectrum Disorders (ASD) from typically developing children (Baron-Cohen et al., 2001).

Mind in Voice Task - Revised (Golan, Baron-Cohen, Hill & Rutherford, 2006). Twenty-five segments of speech recorded on the computer from dramatic audio books were presented to participants. Each segment was either a sentence or phrase. Participants looked at a computer screen with four adjectives to describe the speaker's mental state or emotion. Prior to starting the task, participants were given a definition sheet explaining the meaning of all of the emotion words included in the task. All words were at or below a Grade five level. Participants listen to the two-second segment, and then choose the word they think best describes the voice. The next segment begins 500 milliseconds after an answer is chosen. Task scores range from 0 to 25. This task requires the extraction of mental state when hearing only a voice. This is an experimental task and does not currently have reliability statistics available. However, it has been shown to discriminate adults with ASD from normal adults (Golan et al., 2006).

Wechsler Intelligence Scale for Children – Fourth Edition: Digit Span subtest (WISC-IV; Wechsler, 2003). The WISC-IV is an intelligence test battery for use with children ages 6 to 16. The subtest used for this study, Digit Span, is a measure of verbal working memory. Participants were presented with various combinations of numbers from 1 to 9 of increasing length. In the Digits Forward component of the subtest, children were asked to repeat back the numbers they heard in the same order they heard them. They received a score for the number of sequences they complete correctly. In the Digits Backward component, children first listened to the sequence of numbers, and then repeated them back to the examiner, but in the reverse order. This section was scored in the same way. The reliability split-half coefficient of the Digit Span subtest is good (r_{xx}=.87), while test-retest reliability is also good (corrected r=.83). Overall, the WISC-IV has been found to discriminate various clinical groups, evidence of adequate validity. While some participants were over the age of 18, this test was used with all participants to ensure consistency. Only raw scores were analyzed.

Children's Interpersonal Problem Solving Task (ChIPS; Shure & Spivack, 1985). This is an experimental task used to measure the ability of an individual to generate alternative responses to a hypothetical social situation. It can be used for children ages eight and up. For example, "Johnny wants Peter to be his friend. What can Johnny do so Peter will be his friend?" The child is presented with three different scenarios similar to this one, and asked to think all of the different ways the child in the story could solve his or her problem. Probes are implemented to elicit as many potential solutions as the participant can produce. For example, if a child gave a general response such as "Get to know him better" for the above situation, the examiner would say, "How could he do that?" The examiner would try to elicit 10 verbalizations. The number of individual relevant alternative responses were scored. These responses also fit into different categories, resulting in a score for the number of relevant categories provided. Irrelevant responses are also scored.

The adult version of this measure has been used in recent research assessing the effects of early brain injury on social problem-solving in adults (Anderson, et al., 1999). Little normative data exist for children and existing data are significantly outdated. Therefore, analysis in this study looked at the raw number of relevant responses, relevant categories and irrelevant responses, rather than comparing current scores to existing norms.

Social Norms Violation Task (Berthoz et al., 2002). The original task comprised 120 scenarios that included 60 personal references (where they are the protagonist in the story) and 60 impersonal references (where the protagonist is a character other than themselves). These stories were thought to have three general types of endings: (a) a description of a normal situation; (b) description of an embarrassing situation for the story protagonist (an unintentional violation of social norms); or (c) description of a situation where the story protagonist's behaviour violates social norms (an intentional violation). An example of an embarrassing situation would be as follows, "Gail walks into her boss's office, sits down and says hello to her boss. She starts planning a conference with her boss when her false teeth fall out and land in the middle of her boss's desk." Further qualitative investigation of the original questionnaire identified four types of scenarios: (1) not embarrassing and socially appropriate; (2) not embarrassing and socially inappropriate; (3) embarrassing and socially appropriate; and, (4) embarrassing and socially inappropriate. Due to time constraints, as well as significant repetition in the original measure (many of the same scenarios were used, with different protagonists), five scenarios were randomly chosen for each of the four scenario types, resulting in a total of 20 scenarios. The participants were asked to rate each story on the following: (i) how embarrassing the situation was for the protagonist; (ii) how appropriate the protagonist's behaviour was; and, (iii) how funny they thought the story was. Participants rated these questions on a 7-point likert scale, where 1 was 'not at all embarrassed', 'appropriate' and 'not at all funny' and 7 was 'very embarrassed', 'very inappropriate' and 'very funny'. This was an experimental task and does not have reliability statistics available although the authors reportedly have validity data of the original measure from two previous unpublished experiments. However, research has shown this task increases brain activity in several frontal and prefrontal regions (Berthoz et al., 2002).

Pubertal Development Scale (Petersen, Crockett, Richards & Boxer, 1988). This questionnaire assesses pubertal changes in secondary sexual characteristics, including growth spurts, changes in skin, and body hair in males and females; breast growth and menarche in females; and facial hair and voice changes in males. Participants rated each of five questions on a 4-point scale ranging from 'has not yet started' to 'seems completed'. An overall pubertal stage was calculated. The five stages include pre-pubertal, early pubertal, mid-pubertal, late pubertal and post-pubertal. Reliability alpha coefficients are good (.68 to .83) and the scale has been shown to correlate well with objective measures of pubertal status. Care should be taken to use this scale as a perceived index of pubertal status, as one study found that 26 percent of females were classified as one stage later on the PDS than on other scales, while 32 percent of males were classified as one stage earlier (Bond et al., 2006).

Cognitive Emotion Regulation Questionnaire (CERQ – Child Version; Garnefski, Rieffe, Jellesma, Terwogt & Kraaij, 2007; CERQ – Adult Version; Garnefski, Kraaij & Spinhoven, 2001). The CERQ child and adult versions both have 36 items that make up nine subscales: *self-blame* refers to the thought of blaming yourself for something that has happened; *other-blame* refers to the thought of blaming someone else for something that has happened; *rumination* refers to thinking about your thoughts and feelings related to an event over and over again; *putting into perspective* refers to reducing the importance of an event to a more realistic level; *positive reappraisal* refers to thinking of an event in a positive way to promote personal growth; *catastrophizing* refers to thinking about only the negative components of a negative event; *positive refocusing* refers to thinking about something positive instead of the actual event; *acceptance* refers to thoughts of resigning yourself to what happened; and *planning* refers to thinking about what you can do to resolve or handle a negative event. Participants were asked to rate each statement on a scale of 1 '(almost) never' to 5 '(almost) always' as to what they generally think when they experience a negative or unpleasant event. The child version of the questionnaire is for participants aged 9 to 11, and is very similar to the adult version, except that statements are in more simple terms. The child version show good internal consistencies for the most part, with alpha coefficients ranging between .67 and .79, except for the acceptance subscale, which was .62. Several subscales of the child version (self-blame, acceptance, rumination, positive refocusing, catastrophizing and other-blame) were correlated with measures of depression, worry and fearfulness, providing some evidence for criterion-related validity. The child version has not been tested for other forms of validity and reliability. The adult version has Cronbach's alpha reliabilities for the various subscales above .75, and in most cases above .80. The CERQ adult version has also shown good discriminative properties and good construct validity, correlating with measures of coping, personality, self-esteem and self-efficacy. Test-retest reliability of the subscales (after a five month period) ranged between .41 and .59, suggesting that emotional regulation strategies are not as stable as personality traits.

Test of Everyday Attention for Children – Score and Score DT subtests (TEACh; Manly, et al., 1999). The TEACh is a test of various types of attention in children ages 6 to 16. The Score subtest is a measure of sustained attention. Children listen to an audiocassette recording of a repeated sound. They must count the number of times that this sound is heard, without using fingers or saying numbers aloud, and then tell the examiner the total number at the end of each trial. Score DT is a measure of sustained-divided attention. Children again count the number of sounds heard, while at the same time listen to a reporter making a newscast in which the child must listen for the name of an animal. At the end of each trial, the child tells the examiner the number of sounds heard and the name of the animal. Test-retest reliability was found to be moderate to good (Pearson's correlation coefficient ranging from .64 to .92) with adequate convergent validity (significant r=.28 and r=.40 on the Score! and Score DT subtests when correlated with a test of inhibition) and discriminant validity (nonsignificant r = .14 for both subtests as compared to overall IQ scores; Manly, et al., 2001). Although this test is used for children for children aged 6 to 16, it was used for all participants, and only raw scores were analyzed.

Procedure

Participants were asked to attend a 3 ½-hour session at York University in Toronto, Ontario, or at Crescent School if they were a student of that school. Parents and children completing the assessment at York University attended an initial orientation session on the day of testing, to discuss the testing procedure, to provide informed consent (parents; Appendix B) and assent (children; Appendix C), and to ensure that children and their families had an opportunity to ask questions. Parents were then asked to leave the testing area and provided with various questionnaires to fill out while their child was being assessed. Children who completed the assessment at Crescent School were introduced to the study during several assembly presentations, as well as small presentations in their classrooms. If interested, children were provided with an introductory letter and/or consent form to take home to their parents (Appendix B). Once parents signed the consent form, the examiner contacted them via telephone to discuss the study further and answer any questions they had. Appointments were then booked for their child at their convenience. Parent questionnaires were mailed home to the parents to complete and return to the school or mail back to the examiner in the envelope provided. Assent was obtained from the child and questions were answered prior to starting the assessment. The testing session lasted approximately 3 to 3 ½ hours in total, including breaks as necessary. The order of tests was varied depending on the length of each session, and children often participated in two 1 ½-hour sessions, rather than one 3-hour session. See Table 1 for a list of tests administered to each participant and their proposed connection to the Crick & Dodge (1994) model. A demographic questionnaire was given to all parents to be completed, as presented in Appendix D. Further questionnaires completed by parents included:

1. Clinical Assessment of Behavior (CAB)
2. Behavioral Rating Inventory of Executive Function (BRIEF)

Once the participants completed the testing session, they were debriefed (Appendix D), the tests were scored and all participants received a basic research report by mail outlining their results and any recommendations, if applicable, within four months following the testing session. Participants and their parents were immediately given the opportunity to ask questions about the research project, and were given a summary of the overall results of the study upon completion, if requested. All participants were given a token of appreciation (for example, a movie coupon and a community service certificate) and snacks for participating in the study. All parents were provided with free parking and money to cover travel expenses, as necessary.

General Results

Demographics

Sixty-one parent questionnaires were returned, providing more in-depth demographic information for two-thirds of the participants. Of the 61 questionnaires returned, 54 participants had no formal diagnosis, 5 had a diagnosis of ADHD and 2 had been tested and confirmed as gifted/talented. Ten of the participants were an only child, while 34 had one sibling, 12 had two siblings and 5 had three or more siblings.

Table 1. Measures Administered to Participants

Name	Concept(s) Measured	Proposed Crick & Dodge Stage
Intelligence		
WASI	Brief measure of intelligence	
Executive Function		
D-KEFS: Tower	Planning, problem solving	Interpretation, Response Generation
D-KEFS: Colour-Word	Inhibition of interference, cognitive flexibility	Encoding, Interpretation, Response Generation
D-KEFS: Sorting	Concept formation, reasoning	Interpretation
D-KEFS: Verbal Fluency	Word Generation	Response Generation
RCFT Copy	Visual spatial processing, planning, Organizing	Interpretation
RCFT Immediate Recall	Visual spatial memory	Interpretation
WCST	Cognitive flexibility, abstract thinking	Response Generation

WISC-IV: Digit Span Forward	Short-term memory	Response Generation
WISC-IV: Digit Span Backward	Working memory	Response Generation
TEACh: Score	Sustained attention	Encoding
TEACh: Score DT!	Divided attention	Encoding
Social Cognition		
Mind in Eyes*	Mentalizing, perspective taking (visual)	Encoding, Interpretation
Mind in Voice*	Mentalizing, perspective taking (auditory)	Encoding, Interpretation
ChIPS*	Social problem-solving	Response Generation
Social Norms Violation Task*	Perspective taking, social reasoning	Interpretation
CERQ	Emotion regulation and coping	

* These measures are experimental. Therefore, the concepts they are purported to measure have not yet been validated through statistical analysis.

Information about birth order revealed that 38 were the first born (this included only children), 16 the second-born, 5 the third-born and 2 were the fourth born children of the family. Most of the children were from intact families (N=55), while two were from divorced families, two from separated families and two from single parent families where the mother was the primary caregiver. Further information broken down by age groups can be seen in Table 2. It should be noted that the mean IQ for participants is one standard deviation above the norm. As such, most participants were high functioning, a common occurrence in typically developing research volunteers.

A non-statistical comparison of overall IQ between typically developing children, children diagnosed with ADHD and gifted children revealed no large differences between means on all measures. Table 3, 4 and 5 provide correlations between measures of executive function and social cognition used in the current study. These correlations indicate that few high correlations exist between social cognition and executive function measures, and those that are high are mainly scores from the same or similar tasks.

General Analysis

Screening of data for violation of underlying assumptions was performed prior to analysis. Frequency descriptives, histograms and regression were used to identify univariate and multivariate outliers. Only univariate outliers were identified (z-scores > 3.29). A transformation was not deemed appropriate, as only 1 to 2 scores were found to be outliers on 10 different variables. Prior to changing the scores, the data were screened for multivariate outliers. No multivariate outliers were detected (using stepwise regression on SPSS). As such, scores found to be univariate outliers were changed to be

Table 2. Participant Demographics

Age Group	10 to 12	13 to 15	16 to 18
N (total)	25	36	30
N (questionnaires complete)	19	27	15
Diagnoses (Frequencies)			
None	18	22	14
Gifted	1	0	1
ADHD	0	5	0
Birth Order (Frequencies)			
Only child	4	3	3
First born	7	16	5
Second born	6	5	5
Third or more born	2	3	2
Siblings (Frequencies)			
One	10	16	8
Two or more	5	8	4
Parent Marital Status (Frequencies)			
Married	16	26	13
Separated/Divorced	1	1	2
Single	2	0	0

Family History (Frequencies)			
No diagnoses	9	17	7
ADHD	2	1	1
Learning Disability	1	0	0
Language Difficulties	1	1	0
Mental Health Issues	4	3	3
Gifted/Talented	2	0	1
Multiple	0	5	3
WASI Standard Scores (Means, Standard Deviations)			
Verbal IQ	119.08(12.54)	116.40(12.97)	111.07(7.72)
Performance IQ	112.44(13.35)	112.44(9.86)	110.62(11.25)
Full Scale IQ	118.00(11.11)	116.15(10.29)	112.31(9.06)

Table 3. Correlations of Variables – Executive Function

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.0	.53**	.45**	-.64**	-.52**	-.57**	-.45**	.29**	.33**	.22*	.30**	.35**	-.31**	-.26*
2		1.0	.60**	-.38**	-.33**	-.38**	-.23*	.20	.30**	.19	.36**	.32**	-.23*	-.19
3			1.0	-.42**	-.28**	-.21*	-.22*	.27*	.25*	.08	.13	.25*	-.16	-.10
4				1.0	.71**	.73*	.67*	-.15	-.26*	-.15-	.27*	-.34*	.24*	.21*
5					1.0	.64**	.69**	-.22*	-.21*	-.15	-.30**	-.22*	.28**	.29**
6						1.0	.64**	-.17	-.32**	-.32**	-.32**	-.32**	.29*	.26*
7							1.0	-.18	-.22*	-.19	-.24*	-.22*	.41**	.37**
8								1.0	.58**	.14	.27*	.29**	-.31**	-.30**
9									1.0	.23*	.38**	.47**	-.37**	-.34**
10										1.0	.14	.07	-.13	-.05

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
11											1.0	.47**	-.10	-.07
12												1.0	-.15	-.14
13													1.0	.95**
14														1.0

Variable Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	-.27*	-.32**	.25*	.35**	.39**	.36**	-.17	-.12	-.21	-.19	-.27*	-.28*	-.18	-.23
2	-.19	-.25*	.01	.14	.30**	.18	-.11	-.03	-.02	-.19	-.13	-.16	-.21	-.17
3	-.11	-.19	.15	.15	.22*	.08	-.09	.11	.03	-.20	-.16	-.14	-.25	-.12
4	.21*	.24*	-.25*	-.28**	-.29**	-.35**	.19	-.03	.13	.22	.29*	.29*	.22	.18
5	.29**	.25*	-.24*	-.29**	-.24*	-.20	.19	-.11	.03	.02	.17	.21	.11	.10
6	.26*	.30**	-.25*	-.32**	-.39**	-.33**	.25	.02	.13	.19	.21	.25	.23	.19
7	.37**	.41**	-.32**	-.35**	-.22*	-.24*	-.02	-.09	-.05	-.04	.19	.12	.12	.00
8	-.30**	-.30**	.17	.02	.27*	.11	-.10	-.14	-.07	-.06	-.04	-.09	-.07	-.06
9	-.34**	-.38**	.08	-.07	.29**	.16	-.30*	-.15	-.16	-.13	-.15	-.30*	-.19	-.25
10	-.05	-.18	.07	.01	.24*	.15	.02	-.12	-.13	-.01	-.03	.01	.02	-.09
11	-.07	-.16	.16	.20	.29**	.17	-.40**	-.21	-.19	-.15	-.12	-.16	-.03	-.19
12	.02	.01	.02	.18	.20	.15	-.23	.00	-.04	-.22	-.05	-.15	-.12	-.26*
13	.95**	.97**	-.09	-.17	-.29**	-.34**	.02	.17	.11	-.02	.08	.12	.05	.06

Variable Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
14	.99**	.85**	.-.05	-.17	-.24*	-.35**	.02	.13	.08	-.01	.08	.11	.11	.06
15	1.0	.85**	-.05	-.16	-.24*	-.37**	.03	.12	.07	-.01	.09	.10	.11	.07
16		1.0	-.12	-.16	-.30**	-.29**	.02	.19	.13	-.02	.07	.12	.08	.06
17			1.0	.55**	.17	.19	-.27*	.08	-.03	-.13	-.20	-.05	.03	-.14
18				1.0	.28**	.30**	-.23	-.04	-.11	-.30*	-.12	-.19	-.11	-.34*
19					1.0	.49**	-.10	-.02	.08	-.04	-.03	-.13	-.12	-.15
20						1.0	-.12	-.12	-.04	-.15	-.21	-.22	-.09	-.30*
21							1.0	.42**	.66**	.60**	.65**	.60**	.32**	.69**
22								1.0	.78**	.54**	.45**	.50**	.43**	.55**
23									1.0	.62**	.60**	.59**	.40**	.66**
24										1.0	.77**	.81**	.54**	.80**
25											1.0	.84**	.53**	.69**
26														

Variable Number	15	16	17	18	19	20	21	22	23	24	25	26	27	28
27													1.0	.63**
28														1.0

1= Verbal Fluency Letter; 2=Verbal Fluency Category; 3=Verbal Fluency Category Switching; 4=Colour-Word Word Naming; 5=Colour-Word Word Reading; 6=Colour-Word Inhibition; 7=Colour-Word Inhibition/Switching; 8=Sorting Confirmed Correct Sorts; 9=Sorting Recognition Description; 10=Tower; 11=RCFT Copy; 12=RCFT Immediate Recall; 13=WCST Total Errors; 14=WCST Perseverative Responses; 15=WCST Perseverative Errors; 16=WCST Nonperseverative Errors; 17=Longest Digit Span Forward; 18=Longest Digit Span Backward; 19=Score! 20=Score!DT; 21=BRIEF Inhibition; 22=BRIEF Shifting; 23=BRIEF Emotional Control; 24=BRIEF Initiate; 25=BRIEF Working Memory; 26=BRIEF Plan/Organize; 27=BRIEF Organization of Materials; 28=BRIEF Monitor Behaviour.

* $p<.05$; ** $p<.01$

Table 4. Correlations of Variables – Social Cognition

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.0	.29**	-.05	-.04	.01	.16	.06	-.12	-.02	.09	-.26*	-.05	.33**
2		1.0	:22*	.21	.18	.05	.06	-.18	.03	-.04	-.09	-.07	-.14
3			1.0	.95**	.33**	-.06	.05	-.18	-.30**	-.22*	-.07	-.16	-.02
4				1.0	.29**	-.08	.05	-.19	-.28*	-.17	-.00	-.15	.02
5					1.0	.14	.06	.03	-.27*	-.03	.03	.04	-.10
6						1.0	.39**	.44**	.01	.30**	.20	.37**	.05
7							1.0	.21	.07	-.04	.20	.03	.10
8								1.0	.12	.35**	.39**	.61**	.29**
9									1.0	.22*	.16	.20	.26*
10										1.0	.31**	.53**	.36**
11											1.0	.30**	.74**

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13
12											1.0	.24*	

1=Mind in Voice; 2=Mind in Eyes; 3=ChIPS Alternative Responses; 4=ChIPS Alternative Categories; 5=ChIPS Inappropriate Responses; 6=Not Embarrassing, Social Appropriate – Embarrassing; 7=Not Embarrassing, Socially Appropriate – Appropriateness; 8= Not Embarrassing, Social Inppropriate – Embarrassing; 9= Not Embarrassing, Social Appropriate – Appropriateness; 10= Embarrassing, Social Appropriate – Embarrassing; 11= Embarrassing, Socially Appropriate – Appropriateness; 12= Embarrassing, Social Inppropriate – Embarrassing; 13= Embarrassing, Social Appropriate – Appropriateness

*$p<.05$; **$p<.01$

Table 5. Correlations of Variables – Social Cognition and Executive Function

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13
VFLetter	.17	.14	.35**	.37**	.02	.15	-.14	-.12	-.22*	-.23*	-.19	-.17	-.19
VFCategory	.06	-.02	.36**	.37**	.05	.19	.03	-.12	-.14	-.23*	-.03	-.08	-.08
VFCategory Switch	.19	.13	.27**	.23*	.12	.20	.08	.01	-.09	-.15	.04	<.01	-.08
CWColour Naming	-.27*	-.24*	-.19	-.22*	-.02	-.06	.10	.13	.21*	.22*	.09	.05	.09
CWWord Reading	-.27*	-.24*	-.19	-.22*	-.02	-.06	.10	.08	.15	.22*	.08	.05	.05
CW Inhibit	-.12	-.14	-.14	-.22*	.07	-.08	.06	.06	.17	.31**	.18	.19	.13
CW Inhibit/Switch	-.22*	-.14	-.16	-.19	.03	-.06	.16	.10	.16	.26*	.11	.10	.18
Sort Conf. Correct	.29**	.03	.04	.01	.12	<.01	-.14	-.24*	-.20	-.22*	-.06	-.23*	-.24*
Sort Recognition	.27*	.21	.25*	.23*	.17	-.01	-.10	-.19	-.18	-.26*	-.07	-.28**	-.09
Tower	.22*	-.02	.15	.16	-.06	<.01	-.14	.01	-.19	-.19	.03	-.20	-.13
RCFT Copy	.35**	.21*	.15	.14	-.03	<.01	-.03	-.20	-.14	-.23*	-.01	-.28**	-.05

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13
RCFT Immediate	.34**	.10	.19	.16	.05	-.08	-.11	-.18	-.22*	-.40**	-.13	-.38**	-.28**
WCST Total Error	-.12	.06	-.04	-.04	-.04	.03	.04	<.01	.04	.09	.06	.13	.03
WCST P. Response	-.11	.04	-.01	.01	-.06	.07	.06	-.03	.07	.10	.07	.12	.09
WCST P. Error	-.12	.04	-.01	<.01	-.05	.07	.05	-.02	.06	.09	.05	.11	.09
WCST NP. Error	-.11	.07	-.07	-.07	-.02	<.01	.02	.03	.02	.08	.007	.14	-.02
Digit Span Forward	.10	.20	.16	.18	-.09	-.07	.01	-.18	-.02	-.04	-.04	.03	-.10
Digit Span Backward	.03	-.03	.06	.04	-.16	.06	.08	.03	-.03	-.06	-.17	.02	-.14
Score!	.20	.05	.16	.17	-.04	.01	.02	<.01	.01	-.05	.06	-.05	.12
Score!DT Animals	.03	<.01	.09	.10	.08	-.01	.08	-.14	.13	.04	-.07	.04	-.02
Score!DT Count	.21*	.10	.12	.18	-.08	-.05	-.13	-.05	<.01	.02	.04	.06	.01
BRIEF Inhibit	-.10	-.18	-.16	-.19	-.04	-.16	-.09	-.02	.01	-.09	.03	.02	-.10
BRIEF Shift	-.02	-.13	-.01	-.03	.04	-.11	.04	-.16	-.01	-.20	.25	-.01	.08

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13
BRIEF E.Control	-.02	-.12	-.07	-.11	.03	-.15	.01	-.16	-.01	-.19	.19	-.02	.04
BRIEF Initiate	.02	-.02	-.12	-.15	.07	-.17	-.18	.02	-.09	-.12	-.03	-.09	-.05
BRIEF WM	-.06	-.15	-.20	-.24	-.09	-.24	-.15	.02	-.04	-.07	-.03	-.03	-.04
BRIEF Plan/Organize	-.05	-.11	-.19	-.21	-.05	-.14	-.10	.05	.06	-.04	.05	.07	-.02
BRIEF Org. Materials	-.07	-.20	-.24	-.23	-.13	-.03	-.03	-.11	.08	-.10	.07	<.01	.14
BRIEF Monitor	-.04	-.12	-.20	-.24	.06	-.08	-.04	-.03	.03	-.10	.05	.01	.03

1=Mind in Voice; 2=Mind in Eyes; 3=ChIPS Alternative Responses; 4=ChIPS Alternative Categories; 5=ChIPS Inappropriate Responses; 6=Not Embarrassing, Social Appropriate – Embarrassing; 7=Not Embarrassing, Socially Appropriate – Appropriateness; 8= Not Embarrassing, Social Inppropriate – Embarrassing; 9= Not Embarrassing, Social Appropriate – Appropriateness; 10= Embarrassing, Social Appropriate – Embarrassing; 11= Embarrassing, Socially Appropriate – Appropriateness; 12= Embarrassing, Social Inppropriate – Embarrassing; 13= Embarrassing, Social Appropriate – Appropriateness; *$p<.05$; **$p<.01$

INTERNAL ERROR - FALSE

POSITION : 0x10f54b1c (284511004)

SYSTEM : H6FW/xl_image

LINE : 482

VERSION : QPDL 1.26 05-06-2004

Table 6. Means and Standard Deviations for Age Groups on Measures of Social Cognition and Executive Function

Test	10 to 12	13 to 15	16 to 18
EXECUTIVE FUNCTION TASKS			
Verbal Fluency			
Letter**	30.52 (6.53)	37.89 (7.79)	41.66 (6.56)
Category**	35.88 (8.12)	44.66 (8.55)	44.66 (8.11)
Category Switching*	12.16 (2.87)	14.34 (2.35)	14.21 (2.44)
Total Set Loss Errors	.36 (1.04)	.17 (.45)	.14 (.35)
Total Repetition Errors	.60 (1.29)	.60 (1.14)	.62 (1.18)
Colour-Word			
Inhibition**	59.92 (14.70)	51.58 (12.08)	44.33 (7.32)
Inhibition Total Errors	2.84 (2.10)	2.75 (2.13)	1.60 (1.50)
Inhibition/Switching**	70.48 (15.68)	58.78 (10.26)	50.20 (9.63)
Inhib/Switch Total Errors**	3.80 (2.02)	2.44 (1.75)	1.53 (1.28)

Sorting			
Confirmed Correct Sorts	9.72 (1.28)	10.86 (1.82)	10.90 (1.79)
Free Sorting Description*	35.36 (5.45)	39.89 (7.35)	40.80 (7.03)
Recognition Description*	39.16 (8.84)	44.89 (6.63)	44.17 (6.55)
Tower			
Achievement*	16.64 (2.08)	18.11 (2.77)	19.17 (3.01)
Time-Per-Move	3.00 (.98)	2.49 (.59)	2.92 (1.02)
Rule Violation	.80 (1.08)	.63 (.94)	.37 (.56)
RCFT			
Copy*	30.50 (5.44)	33.43 (1.72)	34.12 (1.65)
Time to Copy	260.32 (73.00)	243.66 (112.71)	245.79 (124.15)
Immediate Recall*	19.34 (6.28)	23.76 (4.57)	23.33 (5.76)
WCST			
Trials Administered*	98.20 (22.83)	87.14 (20.12)	81.38 (11.79)
Total Correct	73.56 (11.77)	70.03(9.52)	68.90 (7.08)
Errors Total*	24.64 (18.77)	17.11 (14.23)	12.48 (5.39)

Perseverative Responses	11.52 (9.28)	8.80 (7.77)	6.38 (3.18)
Perseverative Errors	10.72 (8.04)	8.46 (6.93)	6.14 (2.68)
Nonperseverative Errors*	13.92 (11.44)	8.66 (7.75)	6.24 (3.56)
Categories Completed	5.28 (1.28)	5.60 (1.12)	5.97 (.19)
Trials to Complete 1st Category	17.64 (10.77)	13.29 (5.89)	12.38 (2.88)
Failure to Maintain Set	.92 (1.38)	.63 (.97)	.61 (1.02)
Digit Span			
Forward	9.56 (1.89)	10.57 (2.66)	11.45 (2.54)
Longest Digit Span Forward*	6.20 (.91)	6.77 (1.40)	7.41 (1.18)
Backward Digit Span	8.48 (1.90)	8.97 (2.99)	10.46 (2.53)
Longest Digit Span Backward*	5.00 (1.58)	5.00 (1.63)	6.32 (2.13)
TeaCh			
Score!	8.96 (1.43)	9.26 (1.15)	9.68 (.55)
Score! DT Animals	10.00 (.00)	9.94 (.24)	9.93(.26)
Score! DT Count*	8.60 (1.80)	8.60 (1.42)	9.57 (.63)

SOCIAL COGNITION TASKS:			
Mind in Voice**	12.92 (2.83)	15.57 (2.52)	15.86 (2.28)
Mind in Eyes	19.44 (2.76)	20.60 (2.84)	21.31 (2.47)
ChIPS			
Alternative Responses	13.00 (4.73)	15.40 (4.62)	15.46 (4.48)
Alternative Categories	11.76 (3.79)	13.34 (3.84)	14.14 (3.91)
Inappropriate Responses	.64 (.91)	.90 (1.41)	.39 (.57)
Social Norm Violation Task			
Not Emb/Soc Approp – Embarrass	1.72 (.57)	1.73 (.76)	1.46 (.55)
Not Emb/Soc Approp – Appropriate	1.53 (.54)	1.72 (1.00)	1.90 (1.25)
Not Emb/Soc Approp – Funny	1.25 (.35)	1.37 (.76)	1.16 (.36)
Not Emb/Soc Inapprop – Embarrass	3.98 (1.70)	3.23 (1.19)	2.80 (1.54)
Not Emb/Soc Inapprop – Appropriate	6.15 (.59)	5.78 (.74)	5.86 (.65)
Not Emb/Soc Inapprop – Funny	2.36 (1.15)	2.44 (.99)	2.39 (1.03)
Emb/Soc Approp – Embarrass	5.98 (.85)	5.61 (.74)	5.67 (.74)
Emb/Soc Approp – Appropriate*	3.99 (1.07)	3.01 (1.07)	3.23 (1.07)

Emb/Soc Approp – Funny	3.03 (1.60)	3.19 (1.33)	3.77 (1.26)
Emb/Soc Inapprop – Embarrass	5.90 (.78)	5.59 (.81)	5.46 (.80)
Emb/Soc Inapprop – Appropriate*	5.41 (.72)	4.85 (.69)	5.03 (.68)
Emb/Soc Inapprop – Funny	3.48 (1.31)	3.54 (1.19)	4.23 (1.06)
CERQ			
Self-Blame	2.60 (.78)	2.71 (.63)	2.63 (.69)
Acceptance	3.23 (.79)	3.20 (.74)	3.21 (.82)
Rumination	2.89 (.82)	2.49 (.72)	2.85 (.79)
Positive Refocusing	2.53 (.96)	2.54 (1.05)	2.62 (.86)
Planning	3.22 (.76)	3.25 (.80)	3.56 (.77)
Positive Reappraisal	2.92 (.71)	3.24 (.97)	3.47 (.79)
Put in Perspective	2.85 (.78)	3.24 (.92)	3.28 (.78)
Catastrophizing	2.33 (.95)	1.99 (.62)	1.97 (.68)
Blaming Others	2.18 (.72)	2.18 (.64)	2.31 (.63)

PARENT QUESTIONNAIRES:			
CAB			
Internalizing	56.33 (19.41)	51.89 (16.60)	46.57 (17.66)
Externalizing	44.67 (16.93)	44.81 (12.42)	42.00 (18.37)
Critical Behaviours	32.67 (4.27)	32.07 (2.32)	36.60 (7.60)
Social Skills	52.50 (18.24)	53.11 (12.39)	49.00 (18.66)
Competence	57.78 (17.44)	54.30 (13.31)	50.60 (14.14)
Adaptive Behaviours	36.39 (11.19)	32.70 (5.10)	31.40 (6.39)
BRIEF			
Inhibit	13.28 (3.04)	13.12 (4.21)	11.92 (3.52)
Shifting	11.56 (3.90)	10.92 (2.50)	10.43 (2.85)
Emotional Control	15.11 (5.54)	14.62 (4.49)	12.93 (4.57)
Initiate	12.11 (3.45)	11.88 (2.94)	11.86 (3.39)
Working Memory	15.22 (4.48)	14.04 (4.53)	13.29 (4.01)
Plan/Organize	18.78 (5.45)	18.27 (4.91)	18.50 (5.83)
Organize Materials	11.33 (4.63)	10.65 (2.50)	10.36 (3.10)

Monitor	13.39 (3.38)	13.76 (3.03)	12.07 (4.70)
Behaviour Rating	39.94 (11.19)	38.65 (9.38)	35.29 (10.34)
Metacognition	70.83 (19.36)	68.62 (15.16)	66.07 (19.32)
General Executive Composite	110.78 (28.94)	107.27 (21.86)	101.36 (28.64)

* $p<.01$, ** $p<.001$, [a] $p<.05$

Fluency, $F(2, 86) = 6.32$, $p<.01$, were found to be significant. On the Letter Fluency subtest, the 10 to 12 year old group generated significantly fewer words than the 13 to 15 year old group, who generated fewer words than the 16 to 18 year old group. On the Category Fluency and Category Switching Fluency subtests, the 10 to 12 year old group generated fewer words than both the 13 to 15 year old group, and the 16 to 18 year old group, while the latter two groups did not differ.

Colour-Word Inhibition, $F(2, 88) = 12.31$, $p<.001$, and Colour-Word Inhibition/Switching, $F(2, 88) = 20.14$, $p<.001$, raw scores were found to be significantly different. All three groups were significantly different from each other, such that 16 to 18 year olds performed better than 13 to 15 year olds, who in turn performed better than 10 to 12 year olds. A significant difference was also observed on the total number of errors made on the Colour-Word Inhibition/Switching subtest, $F(2, 88) = 12.27$, $p<.001$. Again, all three groups differed from each other, such that 10 to 12 year olds made more errors than 13 to 15 year olds, who made more errors than 16 to 18 year olds.

On the Sorting Test, significant differences were observed on the Free Sorting Description raw score, $F(2, 87) = 4.97$, $p<.01$, and Sort Recognition Description raw score, $F(2, 87) = 5.03$, $p<.01$. On both tasks, the 10 to 12 year old group performed lower than the 13 to 15 and 16 to 18 year old groups, while no difference was observed between the latter two groups.

On the Tower Test, a significant difference was observed only for overall performance, $F(2, 87) = 6.05$, $p<.01$, while a linear trend was observed for the time-per-move ratio, $F(2, 87) = 3.19$, $p=.046$, as was a stronger cubic trend, $F(1, 87)=4.77$, $p=.014$.

The 10 to 12 year old group had a lower overall performance than the 13 to 15 and 16 to 18 year old groups, while no difference was observed between the latter two groups. No other cubic trends were observed.

On the Rey Complex Figure Test, significant differences were observed for both the copy trial, $F(2, 86) = 9.55$, $p<.001$, and immediate recall trial, $F(2, 86) = 5.38$, $p<.01$, raw scores. The 10 to 12 year old group had a lower performance on both trials than the 13 to 15 and 16 to 18 year old groups, while no difference was observed between the latter two groups. No cubic trends were observed for this data.

Significant differences were observed on the Wisconsin Card Sorting Test on the number of trials administered, $F(2, 86) = 5.54$, $p<.01$, the number of overall errors made, $F(2, 86) = 5.34$, $p<.01$, and the number of nonperseverative errors made, $F(2, 86) = 6.36$, $p<.01$. More trials were administered for the 10 to 12 year old group than the 13 to 15 or 16 to 18 year old groups, while no difference was seen between the latter two groups. The same pattern was observed for both overall errors and nonperseverative errors, where the 10 to 12 year old group made more errors than both the 13 to 15 year olds and the 16 to 18 year olds, while no difference was seen between the latter two groups. No cubic trend was observed for these variables.

On measures of working memory, using the Digit Span subtest from the WISC, significant differences were observed on both the longest digit span forward, $F(2, 86) = 6.84$, $p<.01$, and longest digit span backward, $F(2, 86) = 5.21$, $p<.01$. The 16 to 18 year old group was able to recall more forward and backward digits than both the 10 to 12 year old group and the 13 to 15 year old group, while no difference was observed between the latter two groups (Figures 17 and 18). No significant cubic trend was observed.

On measures of attention, a significant difference was observed on the number of counts correct on the Score! DT test, $F(2, 85) = 4.89$, $p=.01$. The 16 to 18 year old group performed better on this task than both the 10 to 12 year old group and the 13 to 15 year old group, while no difference was observed between the latter two groups. Again, no significant cubic trend was observed for these variables.

Executive function skills appear to develop at different rates throughout childhood, adolescence, and likely early adulthood. Some skills continue developing in a linear fashion throughout adolescence. These skills include verbal fluency, inhibition, verbal flexibility of thinking. All of the tasks used to measure these concepts involved a significant verbal component. It is likely that as children get older, they become more adept in these verbal executive function areas, and correspondingly develop more refined ways to engage in social interactions. It is important that these skills continue to develop. Schaie (2005), through the Seattle Longitudinal Study, has found that people continue to develop their vocabulary and language skills well into their sixties. This continuous development of language likely has an impact on performance of executive function tasks that involve language ability. Although using different tasks, Anderson et al. (2001) found similar linear increases in performance on verbal fluency and cognitive flexibility tasks involving a verbal component when studying children ages 11 to 17.

Many executive function skills appear to continue developing until mid-adolescence, at which point they level off. It may be that these skills complete the majority of their development at this time, and that while further refining of executive function skills occurs in to adulthood, it occurs at a much slower rate. The skills that were observed to plateau in mid-adolescence were those associated with tasks measuring visual planning and organization, abstract visual processing and memory, and nonverbal flexibility of thinking. Category fluency and category switching fluency were also found to plateau in mid- to late adolescence, and this may be because of a similar visual conceptualization with respect to providing responses that fit a certain category, rather than a certain letter. All of these executive function skills involve visual-spatial processing of information to some extent, and it may be that executive function skills that involve language continue to develop through adolescence and early adulthood, while those less influenced by language plateau earlier. Previous research using a similar task of planning and organization, found little improvement over adolescence, suggesting the skills required may have formed earlier in childhood (Shallice, 1982). In humans, sensory and motor tracts of the brain begin to myelinate first, spreading from the spinal cord to the medulla, pons, midbrain, diencephalon and telencephalon (Spreen, Risser and Edgell, 1995). While unmyelinated nerve cells are capable of transmitting signals, myelination makes the signal transfer more efficient and effective. This bottom to top, back to front development of the brain may underlie the trends observed in the current study, indicating earlier developmental trends of visual versus verbal skills.

Finally, verbal working memory and auditory divided attention were found to plateau in early to mid-adolescence, at which point development in these areas again increases. Previous research on verbal working memory in children ages 4 to 11 has found a linear increase in performance up to age 10, with a plateau from ages 10 to 11 (Alloway, Gathercole & Pickering, 2006). A sentence working memory task yielded similar results in a study of 189 children, indicating a plateau around the age of 12, and an increase in performance again seen around the age of 15 (Walker, 2004). Research looking at ages 4 to 15 has found a plateau in some verbal working memory measures around age 14, but not others (Gathercole et al., 2004). The question comes to mind as to how a plateau of these skills could affect social development. Strong working memory skills and a more focused attention when interacting with others could result in better retention of information that can be stored in the 'database' of social responses and make 'online' review of social information easier, more accurate and more efficient.

Social Cognition. A significant difference was observed between groups on the Mind in Voice task, $F(2, 86) = 10.92$, $p<.001$, while only a trend was observed on the Mind in Eyes task, $F(2, 86) = 3.26$, $p=.043$. The 10 to 12 year old group had a lower performance on the Mind in Voice task than the 13 to 15 and 16 to 18 year old groups, while no difference was observed between the latter two groups. On the Mind in Eyes task, a trend was observed such that the 10 to 12 year old group performed worse than the 16 to 18 year old group, but no other differences were observed. No significant cubic trend was observed.

On the ChIPS, no significant differences were observed between groups. On a measure of social norm violations, a linear difference was observed on the rating of appropriateness of behaviour of a person in an embarrassing, socially appropriate scenario, $F(2, 83) = 7.53$, $p<.01$, while a non-significant cubic trend was observed, F(1, 83)=7.47, p=.012. The 10 to 12 year old group indicated that the person's behaviour in the story was more inappropriate than both the 13 to 15 and 16 to 18 year old groups, while no significant difference was observed between the latter two groups. A significant linear difference was also observed when rating the appropriateness of behaviour in an embarrassing, socially inappropriate scenario, F(2, 83) = 4.52, p=.01, with a non-significant cubic trend also observed, F(1, 83)=2.80, p=.018. The 10 to 12 year old group rated the behaviour as more inappropriate than the 13 to 15 year olds, while no other differences were observed. It appears that younger children may have more difficulty determining what is embarrassing behaviour as compared to inappropriate behaviour. A linear trend was observed on the rating of embarrassment felt by a person in a nonembarrassing, social inappropriate scenario, F(2, 83) = 4.29, p=.017, such that the 10 to 12 year olds rated the person as more embarrassed by the scenario than the 16 to 18 year olds. No other differences were observed. On measures of emotional control, and all parent questionnaires, no significant differences were observed, nor were any linear or cubic trends observed.

Although studies of facial recognition (Carey et al., 1980) and match-to-sample tasks involving pictures of faces and emotion words (McGivern et al., 2002) have revealed a dip in performance in early adolescence (ages 10 to 12) followed by a recovery and increase in performance in mid- to late adolescence, few studies were found looking at the pattern of perspective taking development in typically-developing adolescents. Choudhury, Blakemore & Charman (2006) found that the efficiency of perspective taking (or how quickly a person can make a decision about what another person's perspective might be) increased across adolescence. Synaptic reorganization, pruning, and increased myelination in frontal and parietal cortices may account for the increased efficiency observed at this time. Young adolescents have also been found to make more high-risk decisions than older adolescents and adults (Eshel et al., 2007), although they do appreciate that others may make less risky decisions (Crone et al., 2008). These patterns have been correlated with differential brain activation patterns in adolescents versus adults (Eshel et al., 2007). It appears that the ability to take another's perspective continues to develop in adolescence.

The results of this study suggest that many executive skills associated with language continue to develop throughout adolescence at a linear rate. However, nonverbal executive abilities appear to plateau in mid-adolescence, and while they may continue to develop through to adulthood, they may do so at a much slower rate. Interestingly, verbal working memory and auditory divided attention, as observed in this study, begin to improve in later adolescence, as compared to early and mid-adolescence. It may be that these skills do not begin to fully develop until mid- to late adolescence, or this may be another growth spurt at which time working memory and divided attention further develop. Regardless, working memory and attention are thought to be important for encoding and interpretation of information that leads to the development of the 'database' necessary for social problem-solving and engaging in appropriate social interactions. Difficulties with working memory and attention may affect the development of the database, such that encoding of inappropriate information, or inadequate interpretation of social information may result in an inefficient database. Although a similar plateau was not observed in the Mind in Voice, Mind in Eyes and Social Norm Violation tasks, pre- and early adolescents performed worse on these tasks than mid- to late adolescents, suggesting that these skills are continuing to develop. A plateau in early to mid-adolescence of working memory and divided attention could significantly affect the ability for adolescents to navigate their ever-changing social world. Recent research has indicated that individuals with difficulties with working memory exhibit social deficits (Gokcen et al., 2009; Hommel et al., 2009).

Although no cubic trends were observed in this data to indicate a period of stagnation in early to mid-adolescence, this may be due to a number of reasons. First, only three age groups were compared – one in pre- to early adolescence, one in mid-adolescence and one in late adolescence. Extending the age of participants from 8 to 20 years of age may help better capture early and late growth in the domains assessed. Second, it may be that performance on tasks does not plateau, but rather growth is slowed during this time, which could not be observed from this data. Third, the sample size is quite small, making it necessary to split the data into groups. Looking at the data across individual ages may provide more accurate results.

No differences were observed between groups on parent or self report measures. It should be noted that only high-functioning males volunteered to participate in this study (many from a private school setting), and only 67 percent of parent questionnaire packages were returned.

Executive function skills develop at different rates throughout adolescence, either in a linear or non-linear fashion. These different trajectories may affect the development of social cognition in different ways. It is important to further understand the relationship of executive function and social cognition so that we can better understand how the development of executive function might affect social development. With little research to date looking at the relationship of executive function and social cognition, experiment two will begin to examine this relationship in adolescence.

Study Two: The Relationship of Social Cognition and Executive Function

Goals and Hypotheses

The model of social information-processing developed by Crick and Dodge (1994) outlines a pathway that individuals follow when involved in a social interaction. First, individuals encode internal (for example, attributions or feelings from the social exchange) and external (for example, situational cues, analysis of the event), verbal and nonverbal cues. The next step is to interpret those cues. The third component is to clarify the goals of both the individual and possibly the person they are interacting with. The fourth step is response access and construction – the individual must list possible responses they have used in the past, and/or make up new possible responses. Next, the individual must decide what response to use, and enact that response. Specific social tasks were used in the current study to try to imitate some of these steps in social information processing. These social tasks are thought to be related to specific executive function tasks, due to similarity in the processes necessary to complete the social task. The following exploratory hypotheses were proposed:

1. It was hypothesized that two social tasks involving encoding of the social situation (Mind in Eyes Task, Mind in Voice task) will be related to executive function tasks measuring attention, working memory, visual spatial performance and memory, and inhibition.
2. Interpretation of the social situation (Social Norms Violation Task) are related to inhibition, planning, problem-solving and working memory.
3. Response access and construction (ChIPs response generation) are related to executive function tasks measuring working memory, planning/organizing, strategic thinking, inhibition and word generation.

A principal component analysis was used in study two to determine the number of executive function components in the data. Looking at measures that were used (although significant overlap exists between these tasks with respect to the skills they are measuring), as well as reviewing previous theoretical models of executive function and the measures used to support these models (Anderson, 2002; Miyake et al., 2000), exploratory hypotheses predicted that five executive function components would be found, representing working memory/attention, planning/organizing/problem-solving, inhibition of inappropriate behaviour, flexibility of thinking, and word generation. Social cognition measures were not investigated through principal component analysis, as these measures are experimental in nature. It was thought that looking at each one individually at this point would be more appropriate. Multiple regressions were performed to look at what executive function components were associated with performance in the social cognition tasks.

An exploration of the relationship between measures of social cognition and emotion was also done. Correlations were performed between each of the social cognition measures, and the Cognitive Emotion Regulation Scale.

Results and Discussion

A principal components extraction with varimax rotation was performed. SPSS factor analysis was used, and the 18 raw scores derived from various executive function tasks were entered in to the analysis. The main purpose of this principal component analysis was to determine the number of components that represent those executive functions measured, and to reduce the number of scores available for multiple regression analysis to a more reasonable number. Six components were derived with an Eigenvalue greater than one (see Table 4). All variables loaded on to a component, as seen in Table 5, and were often a combination of several individual scores from different tests, as would be expected. It should be noted that components are listed in order of variability accounted for, such that more variability accounted for is higher on the list. The first component combined the overall errors, perseverative responses, perseverative errors and nonperseverative errors made on the WCST. Although these variables were already highly related, they were combined using the principal components method to derive a single variable for comparison to social cognition tasks. This component represents inhibition and flexibility of thinking (Grant & Berg, 1948). The second component represents concept formation/reasoning, and includes the free sorting description score,

Table 7. Component Eigenvalues and Variance

Factor Number	Eigenvalue	% of Variance
1	6.14	32.30
2	2.55	13.44
3	2.09	10.98
4	1.39	7.30
5	1.14	5.98
6	1.06	5.58

Table 8. Principal Component Analysis of Executive Function Tasks (Beta Weights Reported)

Test	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
WCST Pers. Responses	**.968**	-.115	-.058	-.034	-.053	-.054
WCST Pers. Errors	**.965**	-.121	-.060	-.037	-.044	-.064
WCST Total Errors	**.964**	-.142	-.068	-.100	-.034	-.117
WCST Nonpers. Errors	**.897**	-.156	-.068	-.143	-.022	-.151
Sorting Free Sort Descr.	-.135	**.944**	.057	.067	.158	.075
Sorting Confirmed Correct	-.177	**.910**	.077	.096	.110	.066
Sorting Recognition	-.257	**.620**	-.130	.131	.427	.193
Digit Span Forward	.033	.218	**.852**	.021	-.084	.063
Digit Span Backward	-.107	-.116	**.819**	.091	.148	.074
CW Inhibition/Switch	.369	.033	**.470**	-.154	-.275	-.260

VF Category/Switch	-.043	.223	.117	**.885**	-.014	-.009
VF Category	-.126	-.018	-.041	**.812**	.288	.188
VF Letter	-.187	.060	.330	**.555**	.291	.341
RCFT Immediate Recall	-.062	.189	.031	.178	**.811**	-.044
RCFT Copy	.034	.208	.122	.084	**.745**	.164
Tower Achievement	.049	.113	-.105	.096	-.113	**.785**
Score!	-.164	.184	.184	.129	.167	**.636**
Score! DT	-.313	-.033	.262	-.024	.159	**.527**
CW Inhibition	.199	.065	-.350	-.241	-.404	**.502**

Please Note: Raw scores were used.

the number of correct sorts, and the recognition description score of the Sorting subtest of the D-KEFS. The third component represents working memory, and includes the number of digits recalled forward and backward, as well as the raw score from the Colour-Word Inhibition/Switching subtest of the D-KEFS. Colour-Word Inhibition/Switching may have loaded on this factor because the participant would need to hold in memory the different rules of the task in order to complete it more quickly and efficiently. The fourth component includes the Verbal Fluency subtests, and is represents word and category generation. The fifth component is represents visual-spatial processing, including the raw scores of the copy and immediate recall trials of the RCFT. The sixth component represents attention and planning, combining the total score from Score!DT and the Score! Subtests of the TeaCh, as well as the Tower and the Colour-Word Inhibition subtest raw scores from the D-KEFS. The Tower subtest may have loaded on this factor because of the high attention requirement to keep track of previous moves made in order to plan appropriately future moves. In addition, Colour-Word Inhibition may have loaded on this factor due to the attention required to ensure the correct response is provided (saying the colour versus reading the word).

Component scores were saved in SPSS for use in multiple regression analyses. Each social cognition task was entered into the regression with all six executive function component scores, using the ENTER command in SPSS linear regression, to determine whether any of the components would be uniquely associated with performance on the social tasks. As principal component analysis reduced the impact of multicollinearity of variables, no evidence of multicollinearity was found.

On the Mind in Voice task, a significant result was found. Performance on the Mind in Voice task was associated with the second (concept formation/reasoning; standardized $\beta = .31$) and the fifth (visual spatial processing; standardized $\beta = .27$) components, $F(6, 80) = 3.44$, $p<.05$. However, $r^2=.21$, which represents a low to moderate effect size, such that 21% of the variability was accounted for by these components. On the Mind in Eyes task, no components were found to be associated with performance.

Assessment of the Social Norm Violation task revealed that ratings of embarrassment on non-embarrassing or embarrassing, socially appropriate or inappropriate scenarios, as well as rating of appropriateness on non-embarrassing, socially appropriate or inappropriate scenarios were not associated with the executive function components. However, ratings of appropriateness on embarrassing, socially appropriate, $F(6, 83) = 2.79$, $p<.05$, and ratings of appropriateness on embarrassing, socially inappropriate, $F(6, 84)=2.52$, $p<.05$, scenarios were associated with the fifth (visual spatial processing; standardized $\beta = -.33$ and $-.34$, respectively) component. This factor was found to account for 18% and 16% of the variability seen, respectively, indicating a low effect size.

On the ChIPS, the number of alternate responses given was found to be associated with the fourth component $F(6, 80) = 2.41$, $p<.05$, which is thought to represent word generation (standardized $\beta = .33$). Again, $r^2=.15$, which represents a low effect size, such that 15% of the variability is accounted for by this component. The number of alternate categories of responses was associated with the fourth component, representing word generation (standardized $\beta = .31$), and the sixth component, representing attention and planning (standardized $\beta = .20$), $F(6, 80) = 2.65$, $p<.05$, accounting for 17% of the variability, a low to moderate effect size. The number of inappropriate responses made on the ChIPS was not found to be associated with the components. These findings highlight the importance of word generation and attention and planning in the generation of alternative responses to social situations.

Correlations between social cognition measures and a self-report assessing emotional coping yielded few significant results. The Mind in Voice task was found to be significantly negatively correlated with the Catastrophizing subscale on the CERQ, $r(88) = -.301$, $p<.01$. As such, children who performed better on the Mind in Voice task engaged in less catastrophizing of events, or thinking more of the negative when something bad happens. Finally, a significant correlation was observed between the rating on the Social Norms Violation task on embarrassing scenarios, and the Positive Reappraisal subscale, $r(86) = -.280$, $p<.01$. As such, participants who rated individuals in the scenarios as experiencing more embarrassment engaged in less positive reappraisal of negative situations.

In summary, tasks that involve encoding and interpretation of another's behaviour were predicted by concept formation/reasoning and visual processing factors. These are surprising results, as it was expected that working memory would play a significant role in the first two steps of Crick & Dodge's (1994) social information processing model. However, significant overlap exists between the measures of executive function used in this study, and concept formation/reasoning and visual processing account for a small portion of the variability seen on these tasks. In addition, the ability to generate alternative responses was predicted by word generation and attention/planning factors. While these results were not surprising, they again account for little of the variability seen on these tasks. Low to moderate effect sizes observed throughout may indicate that: 1) other skills are contributing to social cognition abilities that were not measured by executive function tasks used in this study; 2) little variability was observed on social cognition tasks, such as the Mind in Eyes task, and therefore no predictive relationship could be observed; or 3) the sample size was not sufficiently large enough to find significant effects in some of the regression analyses.

The correlations observed between social cognition tasks and the emotional coping questionnaire may provide further insight into the relationship between encoding/interpretation of information and social cognition. Individuals who find encoding and interpretation of social information difficult may engage in more negative emotional coping, such as catastrophic thinking. When children have difficulty encoding social information, they may focus on the negative aspects first. Previous research has shown that individuals are more likely to remember emotional narratives (Laney et al., 2004) and negative or taboo words (Schmidt & Saari, 2007) than neutral information. Catastrophic thinking may lead children to believe the worst, and avoid social contact, thus further limiting their ability to develop appropriate social skills.

General Discussion

The current research presents several interesting findings. The results indicated that executive function and social cognition skills develop at different rates. Tasks that showed development of skills at a more linear rate included measures of verbal fluency, verbal inhibition and verbal flexibility of thinking. Given that children begin to use language around 12 months of age, spending the majority of their time responding to nonverbal cues before language use (e.g., facial recognition, facial expression and intonation of voice – see review by Feinman et al., 1992), and that we live in a world where language is required in some form, it is appropriate that language skills continue to develop throughout adolescence and adulthood (Schaie, 2005). Research has found similar developmental trends in verbal executive function development as that seen in the current research (Anderson et al., 2001). The findings across research studies thus highlight that executive functions dependent on language skills continue to develop over time.

Tasks that measure more nonverbal skills, such as visual planning and organizing, visual concept formation/reasoning, abstract visual processing and nonverbal cognitive flexibility continue to develop in early adolescence, and begin to plateau in mid- to late adolescence. While these skills may continue to develop into adulthood, it may be at a slower rate. Research indicates that the brain develops from bottom to top and back to front, and thus supports the development of visual skills (i.e., those that depend on the posterior areas of the brain such as the occipital and parietal cortices) earlier in childhood than verbal skills (which depend on function of anterior parts of the brain, particularly the frontal lobes) (Shallice, 1982; Spreen, Risser & Edgell, 1995).

Previous research has indicated that white matter increases at a linear rate throughout the brain from early childhood through late adolescence, but that gray matter volume peaks at different times in different regions in the brain, and in many areas, begins to decline in mid- to late adolescence (Giedd et al., 1999). Frontal and parietal gray matter volumes peaked at around 10 to 11 years of age for females and 11 or 12 years of age for males, which correlates well with the beginning of puberty for both genders. Therefore, studying males and females separately is important, especially at this age, as gray matter development may affect performance on tasks that involve these areas of the brain, such as executive function and social cognition tasks. Although there is not yet full agreement in the literature as to the trajectories of male and female brain development, an age-related increase of left inferior frontal gyrus white matter has been shown in developing males, while no significant increase in any frontal regions was observed in females (Blanton et al., 2004). It is important to take in to consideration gender differences in brain development, as this may affect cognitive development as well. Although many studies did not look at gender differences, several have found significant differences between male and female adolescents on both executive function tasks (Anderson et al., 2001; Brocki & Bohlin, 2004) and social cognition tasks (McGivern et al., 2002; Yurgelun-Todd & Killgore, 2006). Therefore, it is quite possible that these results are specific to male adolescent development.

A plateau was observed in working memory and divided attention in early to mid-adolescence. On first glance, these results appear to be in contradiction to Brocki and Bohlin's (2004) research, reporting a working memory growth spurt around the age of 12 – however, these researchers did not investigate the pattern of development past the age of 13. While a growth spurt may occur around age 12, a plateau seems to occur after this stage, resulting in a stasis in development until late adolescence. Anderson (2002) noted that research has shown a developmental regression that may be associated with a transitional period in early adolescence, between the ages of 11 and 13. This transition period coincides with the time of peak gray matter volume in the frontal and parietal cortex, identified by Giedd and colleagues (1999). Anderson (2002) hypothesized that while the attentional control systems develop early in infancy, divided attention may develop at a later stage. In the current research, working memory and divided attention skills appear to plateau around the time that synaptic growth, reorganization and pruning is taking place in the frontal and parietal regions. Working memory and divided attention may either resume development, or increase in efficiency, in mid- to late adolescence.

The importance of executive function skills to the development of social cognition are further identified in the second study. Principal components analysis of the executive function measures resulted in six components, significantly more than those identified in previous studies by Miyake and colleagues (2000) and Anderson (2002). However, it should be noted that both research teams stated that more factors may exist, and that none are mutually exclusive. The same conclusion has been reached in the current study – although six components were identified, they are highly related and not all-encompassing. Differences seen in the various models likely relate to the different number and type of tasks used. The high inter-relatedness of factors found in research on executive function and in the current study invoke the question of whether separate executive function skills truly exist, or whether these tasks can be looked at as higher order verbal and visual tasks that require executive control. However, a method to separate an executive control mechanism from other, lower-order cognitive skills, has not yet been reported. Therefore, regardless of the answer to this question, interesting relationships were observed between executive function and social cognition. The six components identified in this study were thought to represent cognitive flexibility/inhibition, concept formation/reasoning, working memory, word generation, visual-spatial processing and attention/planning. Cognitive flexibility/inhibition and attentional control were common factors between previous models of executive function (Anderson, 2002; Miyake et al., 2000) and the current research, but unlike the current model, these factors encompassed working memory in previous research.

Twenty-one percent of the variability in the Mind in Voice task was associated with the concept formation/reasoning and visual-spatial processing components. It may be that when a participant listened to the voice, they would visualize the facial expression associated to determine what emotion the speaker was feeling. The participant was also considering several terms to choose from that were not typical emotion words (e.g., melancholy versus sad), and may have had to consider the concept or category in which that emotion fit. Being a new measure of perspective taking, few studies have investigated the validity of this task, but it is interesting to hypothesize about the skills necessary for adequate performance on this measure. Visual processing also accounted for 16 to 18% of the variability on ratings of appropriateness of behaviour during embarrassing, socially appropriate or inappropriate scenarios. Children may be thinking about previous similar scenarios or concepts they have stored in their social database, and may be trying to use deductive reasoning with what concepts they have available to them, to distinguish between inappropriate versus embarrassing situations, a skill that was observed to be more challenging for 10 to 12 year olds participating in this study. Research has shown significant overlap in brain areas activated while thinking about inappropriate versus embarrassing behaviour (Berthoz et al., 2002). These include medial prefrontal cortex, and areas within the left hemisphere, including orbitofrontal, temporal and parietal cortices. Reasoning tasks activate left frontal and parietal cortices (Melrose et al., 2007; Monti et al., 2007), and bilateral medial PFC. Adolescence is a time during which further development of these brain areas occurs. At that time, teens are learning skills of deductive reasoning and logic, and further refining their ability to recognize more complex emotions. They are increasing their social awareness, and learning to make decisions independently. The formation of concepts and categories will help to make their database of social information more efficient and effective.

This study indicated that word generation and attention and planning abilities are associated with alternative response generation skills. It should be noted that these abilities account for a low to moderate amount of the variability, indicating that other factors play a role. However, working memory was not found to be a predictor of response generation. Previous authors have hypothesized about the importance of working memory and attention in adequate social performance, especially in the process of building an 'online' database of social responses (Crick & Dodge, 1994; Lemerise & Arsenio, 2000). A plateau in working memory and divided attention in early to mid-adolescence will surely have an impact on an adolescent's ability to problem solve in a social context. The increase in synapses observed in the frontal cortex and parietal areas in early adolescence may, in fact, interfere with development of these skills (Blakemore & Choudhury, 2006). The current research findings indicate that no significant differences were found between the age groups with respect to generation of alternative responses. It may be that within a laboratory setting, where time is not a factor, and participants are given the freedom to generate all the possible responses they can think of without regard for the reaction to those responses, working memory is less of a factor. Attention to what responses have already been produced, and word generation abilities may take priority.

While researchers have hypothesized that emotion plays a significant role in social information processing (Lemerise & Arsenio, 2000), the current study found few significant correlations between a measure of emotional coping and social tasks. Children who engaged in more catastrophic thinking performed worse on the Mind in Voice task. This may indicate that children who have difficulty identifying emotions in the voice may have more negative thoughts, and may more often resort to negative interpretations in a social interaction. In addition, on the Social Norms violation task, children who rated the scenarios as more embarrassing engaged in less positive reappraisal of negative situations. It is possible that children who are more sensitive to embarrassment may have difficulty seeing the positive when presented with a negative situation. Children who have difficulty interpreting social situations may engage in more negative or catastrophic thinking. Research has shown that participants are more likely to remember negative or taboo emotional information than neutral information (Laney et al., 2004; Schmidt & Saani, 2007). Thus, focusing on, encoding, and interpreting negative information early in life may result in negative interpretation of other's cues. Collaborative problem-solving methods advise that when working with children with behavioural problems, telling them that they are not in trouble before engaging in problem-solving significantly reduces the likelihood of a negative behavioural response (Greene & Ablon, 2006). It may be that they are anticipating the worst.

Limitations and Future Directions. Comparable to many research studies dependent on volunteers, the average IQ of participants in this study was approximately one standard deviation above the norm. This can affect the data and make results less applicable to the general population, and may also affect executive function. However, considering the plateau in development of working memory and divided attention observed in high functioning children, it can be hypothesized that children with average cognitive functioning would function at the same level or lower in comparison. Therefore, these results may represent the best level of social and executive functioning possible in adolescence.

This study did not investigate the effectiveness of the alternative responses provided on the ChIPS. Although not significant, it should be noted that children aged 13 to 15 produced more inappropriate responses than the other age groups. It would be important to look at not just the quantity, but the quality of responses provided, which may yield a measure of more versus less effective problem-solving. In addition, a multiple choice system might be used to determine what type of response children at different ages would choose, and whether this would change across ages. The ChIPS also provides a measure of social problem-solving that is not naturalistic, which may affect the factors that would predict this measure. Watching participants in a more natural setting, such as observation of social problem-solving with peers, may yield a more reliable, although possibly more subjective measure. It would also be important for future research to investigate the quality of these responses, especially given the challenge that younger children in this study found distinguishing embarrassing from socially inappropriate situations. These changes would provide further information regarding social problem-solving across ages.

This research was a cross-sectional examination of executive function and social cognition. As such, we can draw some potential conclusions about developmental changes in adolescence. However, a longitudinal design would likely provide more conclusive evidence of the developmental trajectory through adolescence. In addition, while we are able to look at neuropsychological measures of executive function and social cognition, these provide only limited evidence of developmental changes in adolescence. Neuropsychological measures, in conjunction with neuroimaging such as fMRI, should be used in future research to investigate not only the observable cognitive changes, but those changes which are happening within the brain. Studies have begun to show these changes; for example, the different brain activation patterns of children and adults when performing an inhibition task (Casey et al., 1997).

This study looked at children aged 10 to 18. Future research may encompass a larger age group, to include more pre-adolescents and post-adolescents. This would be important to further understand the developmental trajectory. Many studies have investigated younger children or adults (Kobayashi et al., 2007), but little research has focused on adolescents. Keeping the age range as wide as possible would help us better understand the developmental trajectories of these skills. Kobayashi and colleagues (2007) reported differential brain activation during verbal and nonverbal mentalizing tasks in pre-pubertal children and adults. It would be important to study adolescents to determine whether this change in activation occurs in a linear or non-linear fashion.

Only males were included in this study because of gender differences observed in previous research in executive function and social cognition. Many previous studies did not look at gender differences, grouping together samples of males and females. It was thought that having a large sample of males would provide a better assessment of the relationship of executive function and social cognition. Research has shown that these skills develop at slightly different rates in males and females (Anderson et al., 2001; Carey et al., 1980; Diamond et al., 1983; McGivern et al., 2002; Yurgelun-Todd & Killgore, 2006) and that on some tasks, males may perform differently than females (Anderson et al., 2001). While the present research investigated males, future research should also examine female participants, and a comparison across gender should be performed.

The child version of the Mind in Eyes task was used in this study, which resulted in little variability in scores, both between participants and age groups. Given the high level of functioning of the participants in this study, a ceiling effect may have been observed on this task. Future studies might use an adolescent version of this task, to ensure that it is sufficiently challenging to the study participants.

A principal components analysis was used in this study to look at unique variance within executive function, where tasks often overlap in the concepts that they measure. This exploratory method allows us to look for distinct components. As such, for the purpose of this study, it allowed us to look at specific associations between these components and the social cognition tasks. However, these distinct components accounted for low to moderate amounts of variance across social cognition tasks, indicating that there are other concepts that may account for variance in performance. Future research with a larger sample may look at whether a predictive relationship can be established between executive function and social cognition, through looking at common and unique variance, and possibly other areas of functioning, such as language development.

To further analyze the relationship between social cognition and emotion, future researchers may look at the responses chosen on the Mind in Voice and Mind in Eyes task, to determine whether children who engage in more catastrophic thinking choose more negative emotion words. This would help us to better understand whether children who engage in catastrophic thinking encode and interpret non-negative facial expressions or vocal intonation as negative. Helping these children to better interpret these cues may help them to better understand their environment.

Crick and Dodge (1994) and Adolphs' (2001) models of social cognition are thought to require executive function abilities, such as working memory, attention, concept formation and visual processing for adequate social performance. The current research highlights the development of these skills, where visual executive skills may develop earlier than verbal executive skills. However, working memory and divided attention skills plateau in early adolescence, a time at which significant synaptic reorganization is thought to occur (Blakemore & Choudhury, 2006). While skills such as concept formation, reasoning and visual-spatial processing are thought to be important for encoding and interpreting cues in social interactions, attention, planning and word generation may be involved in the later stages of response generation and planning. Emotional coping may play a role in the ability of children and adolescents to engage in efficient encoding and interpretation of social cues, using these various skills to build their database of social information, so that they might be successful in their social world. These are important areas for future research and potential areas of training or rehabilitation for children with social difficulties. Researchers should further investigate the possibility of deficits in these areas in children with known social deficits, such as children with Autism Spectrum Disorders (Howlin, 2003; Szatmari et al., 2003; Walker et al., 2004) and Fetal Alcohol Spectrum Disorders (Jirikowic, Kartin & Olson, 2008; Peadon et al., 2009).

This study contributes to the scientific literature on social cognition and executive function by investigating the developmental trajectories of these skills across adolescence, and how these skills may relate to and interact with each other. It has provided some evidence that brain changes observed in early adolescence may have an effect on cognitive functioning, which in turn may affect the adolescent's ability to function in the more independent environments of middle and high school. Academically, this is where adolescents begin to choose classes, moving to different classrooms and adapting to different teaching styles throughout the day, as well as navigating the academic system in order to plan for their futures. Not only does school become more complex, but social interactions increase in complexity as well. Peer interactions are an important factor in adolescent development, where long-term friendships strengthen and romantic relationships emerge. Typically developing adolescent males may naturally experience a plateau in early adolescence in working memory and divided attention, skills that are necessary to help them function within their social and academic settings. This plateau indicates that early adolescent males may require continued assistance navigating their world, even though the inclination of the parent is to increase their child's independence at this stage in life.

Although a relationship between working memory and social cognition was not observed in this study, this relationship was observed in previous research with more complex verbal working memory tasks (Walker & Desrocher, 2005). Researchers should further investigate this relationship. In addition, this study found that concept formation, planning, attention and word generation are related to an adolescent's ability to engage in appropriate social cognition. Deficits in these skills will significantly affect an adolescent's ability to function in the social world, and may be target areas for intervention. For example, future studies might investigate how games targeted at developing visual processing (including many video games currently available), or those involving a significant facial recognition component, might affect an adolescent's ability to encode visual social cues. Examining these possible intervention methods and their affects on social development will be important for developing appropriate intervention strategies. While many social skills programs exist to help children develop these skills, strategies targeting specific skills underlying, or related to, social cognition may enhance current social teaching methods, and allow for these skills to be incorporated more easily in a child's social database.

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Appendix A

CASE HISTORY

This information is confidential and for professional use only.

Name of person completing this form:______________________

Relationship to child:__________________________________

Child's name: ______________________________

Date of Birth: (mm/dd/yy)________________________

Current address:____

Current home phone number:____

Mother's name:____________________Age:_____ Occupation:__________________

Highest level of school completed: ____

Father's name: ____________________ Age: ____ Occupation: _________________

Highest level of school completed: ____

Marital Status: [ ]Married/Common-law [ ] Divorced [ ] Separated [ ] Widowed

Country of Origin (if not from Canada): ______________________________

If not from Canada, has your family been in Canada 5 years or more? [ ] yes [ ] no

How many siblings does this child have? [ ] 1 [ ] 2 [ ] 3 [ ] 4

This child is the [ ] 1st [ ] 2nd [ ] 3rd [ ] 4th born.

Most common language spoken in home: [ ] English [ ]
Other:________________

[ ] Combination of English and other language: ____________________

Has this child ever had or been diagnosed with (if yes, please provide further information):

ADD [ ] no [ ] yes – explain:________________

ADHD [ ] no [ ] yes – explain:________________

Allergies	[ ] no	[ ] yes – explain:________________
Anxiety	[ ] no	[ ] yes – explain:________________
Autism Spectrum Disorder	[ ] no	[ ] yes – explain:________________
Chronic sinusitis	[ ] no	[ ] yes – explain:________________
Depression	[ ] no	[ ] yes – explain:________________
Diabetes	[ ] no	[ ] yes – explain:________________
English as a Second Language	[ ] no	[ ] yes – explain:________________
Epilepsy	[ ] no	[ ] yes – explain:________________
Febrile convulsion	[ ] no	[ ] yes – explain:________________
Gifted and Talented	[ ] no	[ ] yes – explain:________________
Head Injury	[ ] no	[ ] yes – explain:________________
Hearing problems	[ ] no	[ ] yes – explain:________________
Hospitalization	[ ] no	[ ] yes – explain:________________
Language difficulties	[ ] no	[ ] yes – explain:________________
Language disorder	[ ] no	[ ] yes – explain:________________
Learning Disability	[ ] no	[ ] yes – explain:________________
Multiple ear infections	[ ] no	[ ] yes – explain:________________
Operations	[ ] no	[ ] yes – explain:________________
Other chronic illness	[ ] no	[ ] yes – explain:________________
Other psychiatric illness	[ ] no	[ ] yes – explain:________________
Sensory difficulties	[ ] no	[ ] yes – explain:________________
Vision problems	[ ] no	[ ] yes – explain:________________
Other	[ ] no	[ ] yes – explain:________________

Any routine medication? [ ] yes [ ] no What for? ______________________

Current medication: ____

At what age did this child first (in months):

Speak first words ______________ Sentences _________________

Sit on own _________________ Walk __________________

Toilet-trained: Day _____________ Toilet-trained: Night _____________

Educational History

Grade at school child is currently in: ____________________________

Child's best subjects: ____

Child's most difficult subjects: _________________________________

Has your child repeated grades? ________________

Does your child have an Individualized Education Plan? [ ] yes [ ] no

If yes, what accommodations/changes are being made? ___________________

____

Thankyou for taking the time to complete this form.

Appendix B

Research Information Form

Title of Study: Executive Function and Social Cognition in Typically Developing Adolescents

Investigators: Darlene Walker, Clinical-Developmental Psychology student, York University; Mary Desrocher, Ph.D, C.Psych., professor, York University

Purpose of Research

The purpose of this study is to investigate the relationship between executive functions and social cognition in adolescence. Executive functions are higher order processes that are involved in planning, organizing, making decisions and being flexible in our thinking. For example, executive functions make it easier for us to think about or complete two activities at the same time. Social cognition is the process through which we interpret and respond in a social situation. For example, if you wish to watch a different television show than someone else, social cognition allows us to think about types of things we would say to the person currently holding the remote control and to determine how we would react to their responses.

We are particularly interested in better understanding how children with specific deficits perform on executive function and social cognition tasks, and whether the performance on these tasks is in some way related.

This research study has been reviewed and approved for compliance to research ethics protocols by the Human Participants Review Committee (HPRC) of York University.

Description of the Study

This study will assess executive functioning and social cognition in typically developing children between 10 and 18 years of age. The assessment will be conducted in a quiet room at York University. The length of testing session will be approximately 3 to 3 ½ hours. Breaks and snacks will be provided. Parents will be asked to complete three questionnaires prior to or during the assessment.

Participation is voluntary, and your child is free to withdraw from the study or refuse to complete a task at any time. Refusal to participate in or withdrawal from the study will not jeopardize current or future relationships with the researcher and/or York University. All results are confidential, subject to examination only by the investigators. All data are coded and your name will not appear on any forms. You will be provided with a more detailed description of what we are hoping to find at the end of the study.

Potential Harms, Injuries, Discomforts or Inconvenience

The tasks used in this study do not pose any potential harm or injury to your child. They are administered in a game-like format and most require verbal responses. Some children, however, may feel uncomfortable in this situation, especially when tasks become difficult. If your child gets upset during the testing period or does not wish to continue, we will stop testing.

Potential Benefits

No direct benefits will come from this assessment. You will be contributing to the understanding of the relationship of executive functions and social interaction, an area that has not been extensively studied and much in need of research.

Confidentiality

Confidentiality will be respected and no information that discloses the identity of your child will be released or published without consent unless required by law. We will not release any information without your permission and signed consent. We will not publish any information that reveals who you are. Should you or your child wish to withdraw from the study, all information collected about your child will be destroyed. All information collected will be kept for a minimum of 2 years following completion of the research study. This information will be kept in a locked filing cabinet or storage area. All material will be shredded upon disposal.

Reimbursement

Parents may be reimbursed for out-of-pocket expenses incurred (subway tokens, gas money, parking, etc.). Children will be given a small token of appreciation for participating. Please remember, however, that participation is voluntary and your child may withdraw at any time.

If you have any questions about any aspect of this research, please contact Dr. Mary Desrocher at **(416) 736-5115 ext. 33111.** Any ethical concerns regarding this research project should be directed to the Manager of Research Ethics at York University, at **(416) 736-5914.**

Consent should be indicated on the following page.

Thank you for your time.

Consent Form – Executive Function and Social Cognition in Adolescence

I have read the information on the research information form and understand the purpose and goals of this study. I have been informed that my child's results will be confidential. I also realize that my child's participation is voluntary and that they are free to withdraw at any time without jeopardizing their relationship with the researcher and/or York University. I have also been told that there are no risks or benefits to taking part in the study. I have also been informed that I may keep the first part of the consent form, on which is printed the name and phone number of persons to contact, in the event that I may have questions about the research at some later time.

Print your name here____

Please sign here____

Relationship to participant____________________________________

Date
(mm/dd/yy)____

Principal Investigator's Signature_______________________________

Date
(mm/dd/yy)____

Appendix C

Assent Script – Executive Function and Social Cognition in Adolescence

What is the purpose of this study?
I am trying to understand how children learn and remember things. I am also looking at what kinds of things children do and say when they are with their friends or with people they don't know. I would like you to help me better understand these things.

What am I going to do?
I would like you to do some games for me. These include telling me what some words mean, making some designs with blocks, drawing, listening to some stories and telling me what could happen, remembering words and pictures and other games like this.

I would like you to try your best when playing these games. If you find it hard, just let me know if you want to stop. You can stop at any time.

How long will it take?
This will take about 3 to 3 ½ hours. We will take a break and provide a snack for part of the way through.

Are there any risks involved?
These games will not hurt you in any way. There are no risks involved. You may find some of the tasks difficult and I just want you to try the best you can. If you find something uncomfortable, we can stop.

What are the benefits for doing the study?
There are no direct benefits to you for taking part in this study. However, you will be helping us to understand how other children think and learn in similar situations. This will help us figure out how to help children who have difficulties with these types of games.

If you have any questions, please ask. If you would like to continue, please write your name on the line below.

I was present when ______________________ gave their assent to participate in this study.

Principal Investigator's Signature____

Date
(mm/dd/yy)____

Appendix D

Debriefing Script

The goal of this study is to explore the relationship of complex cognitive processes and social cognition in children. We are testing typically developing children from the ages of 10 through to 18 years old. We are interested in how children's planning, organizing and flexibility in thinking affects their socially adaptive behaviour. This is important because children are presented with a significant amount of information everyday that they must remember and interpret. This information is important for learning and we want to know how normal children remember and manipulate this information. The brain is constantly changing throughout adolescence, and new connections are being formed while others are being strengthened. Adolescents are also engaging in more complex interactions with their friends, requiring higher level skills to be successful. These skills are involved in both friendships and romantic relationships. Adolescents are also learning to be more independent and are increasing their social awareness and moral reasoning through these experiences.

Children and adolescents must go through a process of encoding, interpreting and responding to situations that are presented to them. They must look at incoming information and decide how they will respond. This interpretation and response system is thought to involve a 'database' of information from previous social interactions that can be used in the current situation. Because social interaction is often a constant exchange of both verbal (words) and nonverbal (gestures) information, a child may be interpreting, encoding and responding to many things at the same time. Therefore, they may need to keep a lot of information 'online' while interacting.

We used many different types of tasks to assess your executive functions and social cognition. We also have to control for certain things that may also affect social behaviour, such as language skills. These tasks will help us better understand how executive functions are related to social cognition. We expect that children who have significant difficulties with these higher order cognitive processes will have more difficulty in social situations.

Thank you for being a part of an original research project. Please feel free to ask any other questions you may have at this point, or in the future by calling Mary Desrocher at 416-736-5115 ext. 33111. Once again, thank you for your time and consideration.