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PREDICTIVE OUTCOMES OF EXECUTIVE FUNCTION AND EMOTION REGULATION ABILITIES IN CHILDREN WITH ATTENTION DEFICIT/HYPERACTIVITY DISORDER

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ABSTRACT

Objective: Two major deficits associated with ADHD are executive function and emotion regulation but whether these represent similar or divergent constructs, and whether they might predict alternative outcomes is not well understood. The purpose of this study will be to examine the status of executive function and emotion regulation in children with and without ADHD, determine the degree to which they correlate with one another, and whether they have differential predictive power for a range of outcomes. **Methods**: Children with and without ADHD completed various tasks of executive function, school achievement, and socio-emotional functioning. Parents filled out questionnaires regarding their child's behaviors of emotion regulation. **Results**: Children with ADHD performed worse on measures of executive function and emotion regulation. Executive function variables significantly correlated with emotion regulation variables. Executive function performance predicted achievement performance and socio-emotional functioning, while emotion regulation performance only predicted achievement performance. ADHD moderated the relationship between executive function and socio-emotional functioning for working memory and hostile responses and for inhibitory control and questionnaires of social skill. **Conclusion**: Clinicians, parents, and teachers concerned about weaknesses of children with ADHD should be aware that the development of executive function and emotion regulation is crucial in ADHD populations struggling in academic and social environments and should be taken into consideration when developing effective treatment interventions for children with ADHD

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Introduction

What is ADHD?

Attention-Deficit/Hyperactivity Disorder (ADHD) is a psychiatric disorder that is characterized by inattentiveness, over-activity, impulsivity or a combination of all three. It is a two-dimensional disorder with inattentiveness as the first dimension and hyperactivity/impulsivity as the second dimension (Wolraich, Hannah, Baumgaertel & Feurer, 1998). The two dimensions can be split into three different subtypes—the predominately inattentive subtype, the predominately hyperactive-impulsive subtype and the combined hyperactive/impulsive/inattentive subtype (Diagnostic and statistical, 2000).

What does ADHD look like?

Official criteria for ADHD outlined in the Diagnostic and Statistical Manual of Mental Disorders - Fourth Edition is as follows (Diagnostic and statistical, 2000). The inattentive subtype is characterized by having six or more symptoms of inattention. Symptoms of inattention include not giving close attention to details; making careless mistakes in schoolwork, work, or other activities; having trouble keeping attention on tasks or play activities; not listening when spoken to directly; not following through on instructions; failing to finish schoolwork, chores, or duties in the workplace; and being easily distracted or forgetful in daily activities. In addition, persons with the inattentive subtype will have trouble organizing activities; dislike doing things that take a lot of mental effort for a long period of time (such as schoolwork or homework); or lose things needed for tasks and activities (Diagnostic and statistical, 2000).

Similar to the inattentive subtype, the hyperactive/impulsive subtype is characterized by having six or more hyperactive or impulsive symptoms. Hyperactive symptoms include fidgeting with hands or feet, excessively running about or climbing when and where it is not

appropriate (adolescents or adults may feel very restless), having trouble playing or doing leisure activities quietly, talking excessively and squirming in a seat or getting up from a seat when remaining in that seat is expected. Impulsive symptoms include blurting out answers before questions have been finished; having trouble waiting one's turn; and interrupting or intruding on others. The combined subtype is diagnosed if both the criteria for inattentive and hyperactive/impulsive are met. All of these symptoms must be at a developmentally inappropriate level and cause significant impairment. In addition, the symptoms must be present in more than one setting such as both the home and at school or work. The symptoms must also have been present prior to age seven to meet criteria for the disorder (Diagnostic and statistical, 2000).

Percentages Affected by ADHD

ADHD is one of the most prevalent psychiatric disorders diagnosed in children today, with an estimated 2.4 million children in the US meeting the DSM- IV criteria (Froehlich et al., 2007). Epidemiologic studies using standardized diagnostic criteria suggest that 3% to 6% of the school-aged population (elementary through high school) may suffer from ADHD, although the percentage of US children being treated for ADHD is at most at the lower end of this prevalence range (Goldman, Genel, Bezman & Slanetz, 2012). In comparing the gender of those diagnosed with ADHD, diagnosis of the disorder is much more prevalent in boys than in girls (Froehlich et al., 2007). This is due to the fact that many girls are less likely than boys to have their disorder identified in the first place. Low socioeconomic status children are less likely than high socioeconomic status children to fulfill the criteria for ADHD (Froehlich et al., 2007). If low SES children do fulfill the criteria, they are less likely to receive medical treatment for the disorder (Froehlich et al., 2007).

The prevalence of comorbidity of ADHD and other psychiatric disorders is high. Disorders such as conduct disorder, oppositional defiant disorder, anxiety disorders, major depressive disorder, bipolar disorder, substance abuse disorders and learning disabilities often mimic or co-exist with ADHD (Spencer, Biederman, Wilens & Faraone, 2002). Studies have found that persons with the ADHD hyperactive subtype are at a higher risk for externalizing disorders such as oppositional defiant disorder and conduct disorder while persons with the primarily inattentive subtype are at higher risk for more internalizing disorders such as anxiety disorders and major depressive disorder (Barkley, DuPaul & McMurray, 1990).

Potential Causes of ADHD: A Focus on Neurological Etiology

There has been no single cause identified to be the main contributing factor to ADHD. Most research has found that it is caused by a combination of environmental, genetic, and neurobiological deficits (Spencer, Biederman, Wilens & Faraone, 2002). For my specific research question, I will be focusing on neurobiological deficits that lead to executive dysfunction. The etiology can be examined through the subsequent connection of neurological development deficits which lead to executive function deficits which lead to the associated maladaptive behavior of the disorder.

ADHD appears to represent a developmental deficit of the prefrontal cerebral cortex and subcortical structures such as the basal ganglia. The developmental deficit in the prefrontal cerebral cortex is associated with a developmental impairment of a complex range of executive functions. According to Elliot, executive function is defined as "complex cognitive processing requiring the co-ordination of several subprocesses to achieve a particular goal" (Elliot, 2003). Barkley's theory of ADHD and executive function focuses on the inhibition of five executive neuropsychological functions in the disorder. These executive functions include non-verbal

working memory, verbal working memory, self-regulation of affect-motivation-arousal, internalization of speech, and reconstitution (behavioral analysis and synthesis) (Barkley, 1997; Spencer, Biederman, Wilens & Faraone, 2002). Deficits in these specified executive functions are what lead to the maladaptive behavior characteristic of the disorder. For example, deficits in working memory lead to the inability to remember information in the mind that will be used to guide one's actions. Lack of working memory may lead to the characteristic "forgetfulness" or "disorganization" outlined in the DSM criteria.

Long Term Outcomes of ADHD in Adulthood

Although ADHD is mostly thought of as a childhood disorder, in many cases it will continue to persist into adulthood. This persistence of the disorder has long-term importance to studies of children who are diagnosed with ADHD and how their disorder may affect their overall outcomes in adulthood. One to two thirds of those diagnosed with ADHD in childhood continue to manifest ADHD symptoms into adult life (Wender, Wolf & Wasserstein, 2006). ADHD affects between 1% and 6% of the nation's adults and may even go undiagnosed in many adults, leading to negative outcomes throughout the life span. Symptoms of ADHD in adulthood are slightly different than those experienced in childhood. ADHD symptoms are described by adults as the inability to concentrate on uninteresting topics even if those topics are important. They also say that they have difficulty paying attention in conversation and may only hear a part of what was said or may miss the drift of the conversation, talking excessively about an unrelated topic. Adults may also interrupt others or finish sentences for them due to their impulsive behaviors. Impulsivity can actually manifest itself more negatively in adults than in children. Deficits in self-control can lead to aggressive behavior, dangerous driving, impulsive purchases, risky transactions and short-lived romances and marriages. The motor restlessness symptom

may not be as evident in adults with ADHD as it is in children; however, the symptoms usually continue to persist. In situations where they are expected to sit still, adults with ADHD feel uncomfortable, become nervous and may begin kicking or tapping their feet (Trott, 2006).

Symptoms of ADHD that continue to exist in adulthood can have deleterious outcomes that include antisocial personality disorders and drug abuse disorders (Mannuzza, Klein, Bessler, Malloy & LaPadula, 1993). Additionally, adults with ADHD will have lower occupational and socioeconomic status than their non-ADHD counterparts (Mannuzza et al., 1993).

Defining Executive Function

Executive Function is thought to be one of the main deficits in children with ADHD. Executive functions comprise a range of various complex processes that are controlled by the pre-frontal cortex of the brain. The literature contains many different definitions of executive function. Overall, executive function is thought to be any "higher order" processing; defined by Dempsy, Dyehouse, and Schafer as the ability to regulate and understand one's self cognitively (2010). Executive function can also be defined as a broad term for cognitive processes and behavioral functions such as planning, working memory, inhibition, mental flexibility, verbal reasoning, multitasking, the ability to sustain attention, utilization of feedback, resistance to interference and the initiation and monitoring of action (Chan, Shum, Toulopoulou & Chen, 2008).

Executive function processes are carried out in the pre-frontal cortex. The pre-frontal cortex is the part of the brain that is important for what is called "top down" processing. Top-down processing is the type of processing that leads to the type of behavior that is controlled by internal states or intentions (Cohen & Miller, 2001). We use top-down processing to understand

an idea or form perceptions by starting with a larger concept or idea and then working our way down to the finer details of that concept or idea.

The pre-frontal cortex is in other words used to establish internal representations of goals and the means to achieve those goals (Cohen & Miller, 2001). Executive functions are therefore the means to activate internal representations in response to environmental cues.

Processes involved in Executive Function

The literature on the processes involved in executive functions is varied and diverse in terms of which processes should or should not be considered executive functions. As previously stated, some of the cognitive processes categorized as executive functions are planning, working memory and inhibition (Chan, Shum, Toulopoulou & Chen, 2008). According to Barkley, the term executive function refers to cognitive self-directed actions that contribute to self-regulation (Barkley, 1997). The term therefore includes self-directed actions, the organization of behavioral contingencies across time, the use of self-directed speech, rules, or plans, deferred gratification, and goal-directed, future-oriented, purposive, or intentional actions (Barkley, 1997). Some of the executive function processes can be further broken down into sub-components. For example, working memory can be divided into short term storage and the processing involved in the actual content of storage (Jonides & Smith, 1999). By breaking it down even further, we can see that different parts of the frontal regions are used in the processing of working memory storage. Studies indicate that memory storage of verbal information is associated with Broca's area and left-hemisphere premotor areas. Storage of spatial information is associated with the right-hemisphere pre-motor cortex, and memory storage of object information is associated with various other areas in the prefrontal cortex (Jonides & Smith, 1999).

Although there continues to be a broad idea of what processes can be considered executive functions, these processes are generally considered to be involved in higher order processing and outside of the domain of "automatic" cognitive processes. The domain of executive function is, however, distinct from cognitive processes such as perception, sensation, and some aspects of language and memory (Pennington & Ozonoff, 1996). Overall, executive function processes can be considered the cognition that occurs immediately after perception and right before action (Pennington & Ozonoff, 1996).

Executive Function in Developing Children

The pre-frontal cortex in children is the last part of the brain to develop, as full cognitive development doesn't reach maturity until young adulthood. The development of executive functions in children continues to increase as they develop and age. In a study done by Luciana and Nelson (1998), all tasks of executive function showed age-related improvement. The most improvement occurred after the age of 8 (Luciana & Nelson, 1998).

Children's performance on frontal lobe executive function tasks is mostly dependent on task difficulty. On easy tasks, child performance cannot be distinguished from that of adults. On more complex tasks, however, children will decrease their use of strategy (Luciana & Nelson, 1998). This is particularly true when performing multiple functions simultaneously. In many studies of pre-frontal cortex development, it has been found that a stage-like emergence of pre-frontal guided behaviors becomes evident in children, with spurts in ability occurring between ages 5 and 7 (Luciana & Nelson, 1998).

Children who experience frontal lesions will have brain damage that leads to deficits in executive function. These deficits include problems with attention (either not paying attention or demonstrating over-attention to detail), poor integration of time, poor peer relations, and lack

of empathy (Pennington & Ozonoff, 1996). In addition, case-studies of early frontal legions show that these lesions may sometimes lead to the development of conduct disorder or ADHD (Pennington & Ozonoff, 1996).

Executive Function as a Deficit in ADHD

In children with ADHD, many executive functions seemed to be impaired in relation to children without ADHD. Among those with ADHD, deficits in executive function have significant negative effects on school functioning, social functioning, educational and occupational attainments, as well as adaptive social and leisure functioning (Biederman, Petty, Fried, Fontanella, Doyla, Seidman & Faraone, 2006). According to Barkley (1996), executive functions are impaired in children with ADHD mostly due to a lack of inhibition. Inhibition is the initial act of self-regulation used to delay a decision-making response that will lead to the further self-directed executive behaviors. This lack of time to make a response affects further responses involved in executive function processes. Barkley (1996) also goes on to state that these executive function deficits in children with ADHD will create further deficits in motor control of behavior moderated by internally represented information. When focusing on neurological differences in children with ADHD, we have seen decreased blood flow to the frontal lobes, the area associated with executive functions. In addition, it was found that the use of Ritalin in children with ADHD causes an increase of blood flow to the frontal lobes (Pennington & Ozonoff, 1996). Ritalin treatment also caused a decrease of blood flow to the motor cortex and primary sensory cortex, an action seen to clinically decrease distractibility and motor activity characteristic of ADHD (Pennington & Ozonoff, 1996). Overall, in many studies it has been found that children with ADHD typically do worse on tasks of executive function than their non-ADHD peers (Pennington & Ozonoff, 1996).

Processes of Executive Function measured in this Study

This study will focus on specifically measuring the executive functions of working memory and inhibition. Working memory and inhibition are two very different processes that will allow for a measure of executive function that is all-encompassing.

Working memory can be defined as a process of memory that requires simultaneous storage of information and processing of information (Baddeley, 1992). Working memory is an executive function that provides temporary storage during the manipulation of information necessary for more complex cognitive tasks (Baddeley, 1992). Tasks that involve working memory include language comprehension, learning, and reasoning (Baddeley, 1992). The process of working memory can be divided into three subcomponents: the central executive, the visuospatial sketch pad, and the phonological loop (Baddeley, 1992). The central executive is a system controlling attention that is important in tasks requiring extended attention, while also remembering important information (Baddeley, 1992). The visuospatial sketch pad manipulates visual images while the phonological loop stores and rehearses speech-based information (Baddeley, 1992).

Inhibition is thought to be a key component of executive control and is defined as the suppression of thoughts, actions, and emotions (Verbruggen & Logan, 2008). Inhibition is a vital skill as it supports flexible behavior when changes to one's environment occur. If an action is irrelevant in a situation, the reaction can be stopped (inhibited) and then replaced with an appropriate action. According to Barkley (1997), behavioral inhibition refers to three successive processes: inhibition of the initial response to an event, stopping of an ongoing process (permitting a delay in the decision to respond), and the self-directed responses that occur internally from the disruption by competing responses (1997). In children with ADHD, it is

thought that there is a deficit in response inhibition, specifically related to an executive rather than a motivational deficit (Desman, Franz & Hampel, 2008).

Defining Emotion Regulation

Another main deficit thought to be associated with ADHD is emotion regulation. Emotion regulation is the physiological, cognitive and behavioral process of successful management of emotional arousal to secure effective social functioning (Rydell, Berlin & Bohlin, 2003). Regulating one's emotions can be a task that is affected by both one's self and by others. It is thought by many researchers that the development of emotion regulation is an essential component to learn how to respond to others in socially appropriate and adaptive ways (Morris et al., 2007). The inability to develop skills of emotion regulation can lead to difficulty in regulating negative emotions such as anger and sadness (Morris et al., 2007). The inability to develop emotion regulation skills has also been linked to externalizing problems such as aggression, norm violation, and hyperactivity (Morris et al., 2007). The frustration and impulsivity caused by low emotion regulation may even lead to hostile and norm-breaking social interactions (Rydell et al., 2003). Based on these findings, high emotion regulation should promote high socially skillful behavior, leading to social competence. This lack of emotion regulation can be problematic given that peer rejections and low social skills have been linked to higher incidents of school maladjustment, delinquency, and psychopathology (Maedgen & Carlson, 2000).

Aspects of Emotion Regulation

Emotion regulation can be broken down into physiological, cognitive, and behavioral processes that are occurring (Rydell et al., 2003). The process can involve regulating positive emotions such as joy and exuberance or negative emotions such as anger, fear and sadness. A

lack of different types of emotion regulation can be linked to different problems. Specifically, fear and anxiety can be linked to internalizing problems while anger and irritability can be linked to disruptive behavior (Rydell et al., 2003). Although regulating negative emotions is significant, the regulation of positive emotions should not be ignored as a lack of emotion regulation in positive emotions can lead to low levels of prosocial behavior and externalizing problems (Rydell et al., 2003).

Emotion regulation can also be categorized by either intrinsic or extrinsic processes that are responsible for monitoring emotional reactions (Southam-Gerow & Kendall, 2002). The intrinsic aspect of emotion regulation would be a focus on how we attempt to regulate emotion, while the extrinsic aspect of emotion regulation would involve how we regulate emotions based on our behavior.

Another distinction in the construct of emotion regulation must be made between *control* and *regulation*. Control of one's emotions is viewed as a restraint of emotional processes, while regulation of one's emotions is an active adjustment of emotional behavior (Southam-Gerow & Kendall, 2002).

Development of Emotion Regulation

The development of emotion regulation in children is a crucial skill necessary to develop appropriate social and regulatory skills (Morris et al., 2007). Developing effective emotion regulation skills can serve as a prerequisite for many other developmental milestones, as intense emotions have the ability to disrupt many other psychological processes (Diamond & Aspinwall, 2003). Specifically, these skills have been considered crucial for development of state regulation, behavioral exploration, cognitive processing, and social competence (Diamond & Aspinwall, 2003). These processes can also shape the development of emotion regulation,

specifically the development of cognitive and attentional processes (Diamond & Aspinwall, 2003). Development of emotion regulation begins as infants and children initially rely on interactions with their caregivers to help regulate their emotions; however, they eventually internalize these abilities as they mature (Diamond & Aspinwall, 2003). As individuals differentiate and some become better at regulating their emotions than others, these skills carry over into adulthood where they can influence things such as problem solving, coping styles and abilities, relationship quality, and mental and physical health (Diamond & Aspinwall, 2003).

Emotion Regulation as a Deficit in ADHD

For children with ADHD, it has been suggested that deficits in behavioral inhibition are leading to deficits in emotion regulation (Barkley, 1997). This lack of emotion regulation in children with ADHD can lead to various social problems that can, in turn, lead to peer-rejection (Maedgen & Carlson, 2000). Children with the ADHD combined subtype have particularly been described as being overactive in their emotions. Their inability to control their emotions can lead to less popularity among their peers (Hinshaw & Melnick, 1995). This trend was shown in Hinshaw and Melnick's (1995) study where they compared both high aggression and low aggression children with ADHD (both with ADHD combined type) to controls on tasks of emotion regulation. They found that lower levels of emotional intensity and higher levels of effectiveness at emotion regulation were both correlated with higher social status and greater peer approval (Hinshaw & Melnick, 1995). It was also found that the highly aggressive boys with ADHD were worse at emotional regulation that the low-aggression ADHD boys and control peers. Maedgen and Carlson (2000) found that children with the ADHD combined sub-type are found to be more intense in both their positive and negative emotional displays. It was also found that children with ADHD were attempting to regulate their emotions just as much as their

non-ADHD counterparts; however, they were less successful at doing so (Maedgen & Carlson, 2000). This finding suggests that children with ADHD know what is socially appropriate, but they are unable to use this knowledge effectively. ADHD children may also have problems with shifting their emotions based on differing situational demands, showing both positive and negative emotions when they are in disappointing situations (Maedgen & Carlson, 2000).

Executive Function and Emotion Regulation

As discussed earlier, executive functions take place in the pre-frontal cortex. This area of the brain is known to be responsible for the higher order processing of executive function; however, this same area also may be responsible for the regulation of our emotions. Brain-imaging studies and neurobiological research have shown that neural circuits associated with emotion regulation and emotional experiences are integrated in the pre-frontal cortex (Diamond & Aspinwall, 2003). In addition, lesion studies in which areas of the frontal lobe have been damaged indicate a decrease in the ability to regulate emotions (Gyurak et al., 2009). Similar findings have been discovered in studies which show that individuals affected with frontal lobe epilepsy will experience emotional and personality changes (Spinella, 2007). By using an example of the emotion regulation techniques implicated in cognitive-behavioral therapy (CBT), we can find a relationship between emotion and the pre-frontal cortex. In a CBT study, when participants with a spider phobia were shown a spider film which evoked great fear, activation of the right prefrontal cortex occurred (Paquette et al., 2003). After CBT, however, prefrontal activation did not occur in the participants who used to have the spider phobia (Paquette et al., 2003). It is thought that the prefrontal activation in the study represented cognitive strategies to regulate emotion (Paquette et al., 2003). While both executive function and emotion regulation

may be seated in the same area of the brain, does that mean that these constructs are interrelated in some way? Could executive function and emotion regulation represent similar constructs?

The cognitive processes involved in emotion regulation processes involve the alteration of emotional experiences and consequences. Some have argued that emotion is the driving force that organizes and amplifies cognitive activity and is therefore the experience and expression of this activity (Dodge, 1991). Using neuropsychological testing, executive function in particular has been shown to be impaired in many emotional disorders such as depression, anxiety, obsessive compulsive disorders, and aggression (Spinella, 2007).

Hot Vs. Cold Cognition

Previously, much of the literature has focused on cognition and affect as opposing processes, specifically—hot vs. cold cognition. Cold cognition can be described as any thought process that is emotionally neutral, personally irrelevant, and completely critical and rationalized (Brand, 1987). In opposition, hot cognition is the processing that is emotionally laden, and the cognition determined by our feelings and affect (Brand, 1987). Hot cognition is also associated with a response that does not include a detailed thought process and may be more irrational than cold cognition. This is not to say that all cognition is completely disconnected from affect. The emotions can affect our cognitions in ways that we would expect to be completely free of affect. For example, when composing a piece of music or writing a novel, our emotions shape what we write and how we write (Brand, 1987). It shapes our thinking. Currently, however, emotion regulation in particular may not be as disconnected from higher order cognitive processing as previously thought.

The Relationship between Executive Function and Emotion Regulation

It has been found that to properly regulate emotions, one must use executive function processing to do so. This occurs specifically when completing tasks such as anticipating outcomes, planning, and executing responses (Gyurak et al., 2009). For example, to regulate the emotion of fear, one must perceive a threatening stimulus, anticipate a response, and then devise a plan in which to respond (Gyurak et al., 2009). The literature shows that executive function is related to emotion regulation responses in various ways, such as "reducing prejudiced behaviors, reducing biased opinions, refraining from expressing disgust in a socially unacceptable setting, and delaying gratification" (Gyurak et al., 2009). Studies of individuals showing dysfunction in prefrontal executive function systems also show dysfunction in their emotional regulation abilities (Spinella, 2007). Specifically, it has been found that negative emotional states such as anger, depression, anxiety, stress, confusion, or fatigue are correlated with dysfunction in the prefrontal systems (Spinella, 2007). In a study investigating the connection between executive function and emotion regulation, it was found that tests of executive function that reflected more complex processing such as tasks of cognitive flexibility, such as verbal fluency, had the strongest relationship with the ability to regulate emotions (Gyurak et al., 2009). It is thought that a lack of emotion regulation skills is associated with decreased executive functioning because limitations in cognitive control and working memory can weaken one's ability to regulate attention (Baskin-Sommers et al., 2012). Therefore, with a decreased ability to regulate attention, it will increase the likelihood that stimuli will acquire all attention and control externalizing behavior (Baskin-Sommers et al., 2012). Without the ability to control executive function, emotional reactions such as negative mood and aggression become difficult to inhibit and control (Baskin-Sommers et al., 2012).

Predictive Validity of Executive Function and Emotion Regulation

Among those with ADHD, deficits in executive function have significant negative effects on school functioning, social functioning, educational and occupational attainments, as well as adaptive social and leisure functioning (Biederman et al., 2006). For adults with ADHD, deficits in executive function were especially associated with a detrimental impact on academic achievement (Biederman et al., 2006). This impact on academic functioning associated with executive function deficits was beyond those deficits resulting from ADHD itself (Biederman et al., 2006). Individuals without ADHD that displayed executive function deficits also experienced significant deficits in academic outcomes; however, these outcomes were not as bad as those of individuals with ADHD who had poor executive function abilities (Biederman et al., 2006).

It is thought by many researchers that the development of emotion regulation is an essential component to learn how to respond to others in socially appropriate and adaptive ways (Morris et al., 2007). The frustration and impulsivity caused by low emotion regulation may even lead to hostile and norm-breaking social interactions (Rydell et al., 2003). Based on these findings, high emotion regulation should promote high socially skillful behavior, leading to social competence. The inability to socialize appropriately with peers can be problematic given that peer rejections and low social skills have been linked to higher incidents of school maladjustment, delinquency, and psychopathology (Maedgen & Carlson, 2000).

In summary, the two constructs of executive function and emotion regulation may represent similar constructs based on a range of different factors. Deficits in executive function and emotion regulation are common in children with ADHD; however, whether these represent similar or divergent constructs, and whether they might predict alternative outcomes (e.g.

academic vs. socio-emotional outcome) is not well understood. The goal of this research study will be to examine the status of executive function and emotion regulation in children with and without ADHD, determine the degree to which they correlate with one another, and whether they have differential predictive power for a range of outcomes.

Hypothesis 1: The literature shows us that children with ADHD indeed show major deficits in executive function skills and emotion regulation skills. Therefore, it is hypothesized that children with ADHD will have worse scores on tasks of executive function and emotional regulation than control children.

Hypothesis 2: Neuroimaging evidence shows that executive function and emotion regulation operations may exist in the pre-frontal cortex. Therefore, it has been speculated that executive function may be correlated with emotion regulation. I hypothesize that tasks of executive function will be correlated with tasks of emotion regulation such that they will be representative of similar constructs.

Hypothesis 3: Although it has been speculated that executive function and emotion regulation are similar constructs, what these constructs are predictive of in terms of future performance is not as well known. I hypothesize that high scores on executive function tasks will predict high academic achievement performance and high scores on emotion regulation tasks will predict high socio-emotional performance.

Hypothesis 4: If hypothesis 3 is correct in stating that executive function predicts school achievement and emotion regulation predicts socio-emotional functioning, then ADHD status will moderate the relationship between emotion regulation and socio-emotional functioning as well as the relationship between executive function and school achievement.

Methods

Participants

60 children between the ages of 8 and 12 were recruited from the State College, Pennsylvania area to participate in this study. The participants consisted of children with and without attention problems. 31 participants were given ADHD status and 29 of the participants were classified as controls without attention problems.

Consent and Compensation

Each participant was sent a form in which they would need to give signature consent in order to participate in the study. This form was signed and returned before any data collection occurred. A release of information form was also signed by the parent before any questionnaires were sent to the child's teacher to complete. After completion of the questionnaire, the teacher was compensated with a $10 gift card. When both the parent and child came into the lab to participate in the study, consent was again obtained from the parent to collect data about their child. The child participant also gave consent before completing any tasks in the lab. Participants were compensated with a $10 gift card if they are screened out of the study after the questionnaire phase, a $30 gift card if they were screened out of the study after the first laboratory visit, and a $100 gift card if they completed both laboratory visits.

Screening/Data Collection Procedure

To determine eligibility for this study, participants were required to be screened through three different stages of the study. In the first stage, participants were asked through a phone interview to provide general information about demographics, and the basic health and medical information of the child participating. If the child participating had been diagnosed with autism, a sensorimotor detriment, mental retardation, any neurological disability, or any disorder leading

to developmental detriments, they were deemed ineligible to participate. This protocol would eliminate any children who may attribute any cognitive deficits to those pervading disorders. In addition, if the child participating was being prescribed a stimulant medication and was unable to discontinue taking this medication 24 to 48 hours in advance to the study, they were unable to participate. Doing so would allow the performance of those participating to be unaffected by medications, showing accurate effects of how ADHD affects one's cognition and other functions. Only one child from each family was permitted to participate in the study at one time.

In the second stage of the study, parents and teachers of the participating child were asked to fill out questionnaires regarding the thoughts, feelings, and behaviors of the child participant. Parents and teachers were asked to complete the Behavioral Assessment Scale for Children- Second Addition (BASC-2), the ADHD Rating Scale-IV, the Conner's Rating Scales-Revised, and the Social Skills Rating System (SSRS).

For a participant to be assigned ADHD status in the study, both one parent and one teacher screen index must have surpassed the 84^{th} percentile, or have a T-score greater than or equal to 61. For a participant to be assigned as a control in the study, all of the screen indices were lower than the 80^{th} percentile, or had T-scores less than or equal to 58. The screen indices used to assign ADHD status included Oppositional Problems, Cognitive/Inattention Problems, Hyperactivity, ADHD Index, and DSM-IV Total Subscales on the Conner's Rating Scale and Aggression, Conduct Problems, Hyperactivity, and Attention Problems Scales on the BASC-2 questionnaire.

Both the parent and teacher were given the BASC-2 questionnaire to complete pertaining to specifically teachers or parents. The BASC-2 asks questions about the child's observable

behavior (Reynolds & Kamphaus, 2004). It is a 160-item questionnaire answered on a 4-point rating scale with answers ranging from "never" to almost always."

Both parents and teachers were required to fill out the ADHD Rating Scale-IV. The ADHD Rating Scale-IV is a questionnaire specifically pertaining to symptomology of ADHD that is classified in the DSM-IV Text Revision such as inattention, hyperactivity and impulsivity (2000). The ADHD Rating Scale is an 18-item rating scale inquiring about behaviors of the child participant with responses ranging from "never or rarely" to "always or very often" (DuPaul, Power, Anastopoulos & Reid, 1998).

The Conner's Rating Scale-Revised was given to both the parent and the teacher with parents completing the long-form version and teachers completing the short-form. The parent long-form questionnaire consisted of 80 items requiring an answer based on a 4 point rating scale ranging from "not true at all" to "very much true." The long-form consists of 18 different subscales that include Oppositional, Cognitive Problems/Inattention, Hyperactivity, Anxious-Shy, Perfectionism, Social Problems, Psychosomatic, Conners' Global Index, DSM-IV Symptom Subscales, and ADHD Index (Conners, 2000).

The SSRS questionnaire was given to both the parent and teacher to identify the social skill behaviors of children participants. Answers to each item are provided on a 4-point rating scale with responses ranging from "never" to "often" (Gresham & Elliott, 1990).

After the child was confirmed as either an ADHD participant or a control participant based on the questionnaires, they were asked to come in for two, three-hour visits to the Child Attention and Learning Laboratory at The Pennsylvania State University. During the visits, the child completed tasks in a neuropsychological battery that included computer tasks, such as the Stop Signal Reaction Time Task and the Chat Room Task; tasks from the Wechsler Intelligence

Scale for Children – fourth edition (WISC-IV); tasks from the Wechsler Individual Achievement Test – third edition (WIAT-III); and tasks from the Wide Range Assessment of Memory and Learning – second edition (WRAML-II). Child participants also filled out questionnaires related to their feelings of anxiety and depression. While the child was completing the neuropsychological battery, the parent completed the Diagnostic Interview Schedule for Children Version IV (DISC-IV). The DISC-IV is a clinical diagnostic interview used to identify a diagnosis of certain childhood psychiatric disorders. This computer based interview identifies a diagnosis for the child based on the parent's responses to their child's thoughts, feelings and behaviors (Shaffer, Fisher, Lucas, Dulcan & Schwab-Stone, 2000). The DISC-IV also determined the final classification of ADHD status for child participants. Parents also completed the Behavior Rating Inventory of Executive Function (BRIEF) and other questionnaires relating to their child's life experiences. In order to attend the second laboratory visit, non-ADHD participants were required to have an estimated Full-Scale IQ greater than 80 and less than 110.

Executive Function

In order to measure the executive function process of inhibition, the Stop Signal Reaction Time Task (SSRT) was utilized. The SSRT is a computer task that measures the inhibition of a response after it has been pre-determined (Eagle, Baunez, Hutcheson, Lehmann, Shah & Robbins, 2008). The participant is first told to press either the "X" button if an X appears on the screen or an "O" button if an O appears on the screen. In the second part of the task, the participant is told to complete the task as before; however, they are told to withhold pressing the button if a letter is shown simultaneously with a bell-chime noise.

The executive function tasks used to measure working memory were *Letter-Number Sequencing* from the Wechsler Intelligence Scale for Children – fourth edition (WISC-IV;

Wechsler, 2003), *Digit Span Forward* and *Digit Span Backward* from the Wechsler Individual Achievement Test – third edition (WAIS-III; Wechsler, 2009), and *Finger Windows Forwards* and *Finger Windows Backwards* from the Wide Range Assessment of Memory and Learning – second edition (WRAML-II; Sheslow & Adams, 2003). The *Digit Span* and the *Letter-Number Sequencing* tasks were combined into the summary variable of *Working Memory Index* to better condense the amount of variables analyzed. All three tasks of the working memory tasks tested the child's ability to recall sequences of either numbers (Digit Span and Finger Windows) or both letters and numbers (Letter-Number Sequencing) after auditory or visual delivery of those sequences. The amount of "digits" or "letters" of recall increased if the participant correctly recalled each item.

In the Letter-Number Sequencing task, participants had to remember the numbers and letters said by the tester, sequence those number and letters in the correct order, and then recall those letters and numbers correctly sequenced to the tester. In the Digit Span Forward task, the participant had to verbally recall the digits spoken by the tester. In the Digit Span Backward task, the participant did the same procedure as in Digit Span Forward, but manipulated those numbers so they were in the reverse order. The Finger Windows Forward task tested spatial working memory and had the tester present the participant with a board that had holes in it. The tester then visually presented a sequence by placing a pen through each hole in a certain order. The participant then had to recall the order by touching each hole corresponding with the holes that the tester touched, in that same order. The Finger Windows Backwards task involved the same procedure with the participant sequencing their responses in the reverse order.

Emotion Regulation

Emotion regulation was measured by specific indices in both the Behavior Rating Inventory of Executive Function (BRIEF) and the Conners' Rating Scales-Revised. The BRIEF is a questionnaire given to parents that examines the executive function behavior of their child (Giora, Isquith, Guy & Kenworthy, 2000). This questionnaire is answered using a 3-point rating scale ranging from "never" to "often." The index of emotion regulation exists within the BRIEF behavior rating scale as the sub-scale of *emotional control*. BRIEF Emotional Control is measured from scores based on statements such as, "overreacts to small problems," "has outbursts for little reason," "becomes tearful easily" and "reacts more strongly to situations than other children" (Giora, Isquith, Guy & Kenworthy, 2000).

The Conners' Rating Scale – Revised also provides an index of emotion regulation in its subscale of Conners' Global Index: Emotional Lability (Conners, 2000). This index includes items such as "temper outbursts," "cries often and easily," and "mood changes quickly and drastically" (Conners, 2000).

Academic Achievement

School achievement was assessed based on scores from the Wechsler Individual Achievement Test – third edition (WIAT-III). School Achievement included skills in reading, spelling, and mathematics, measured used the respective tasks of *Word Reading*, *Spelling*, and *Numerical Operations* (Wechsler, 2009).

Socio-Emotional Functioning

Socio-emotional functioning was measured based on participants' scores on the Chat Room Computer Task. The Chat Room Task is a computer program designed to recreate the experience of an instant-messaging "chat room" in which the participant would have to interact

with four simulated computer children (Mikami, Huang-Pollock, Pfiffner, McBurnett & Hangai, 2007). The participant was told that one of the computerized children is having a birthday party and must gain information from the computer children in order to plan a party that everyone will enjoy. The participant was informed that the children were not real; however, he or she would have to interact with them socially as if they were real in order to obtain enough information from them to plan a party.

Following the 20 minute task, the participant was asked questions about what the computer children said regarding the birthday party such as "what was the name of the birthday child" and "where should the birthday child have the party?" (Mikami et al., 2007). The participant's answers to these questions were scored as "correct, partially correct, or incorrect." A team of undergraduate research assistant coders investigated the transcript of the correspondences between the participant and the computer children. The coders measured multiple variables including: amount of responses, amount of one-word responses, and the skill level of each response. Any hostile, prosocial, or off-topic responses were also recorded. The overall interaction of the participant with the computer children was then ranked on a 7-point rating scale that assessed social skill level through inquiries such as: how real the participant's response was, how much the participant joined into the conversation, how well the participant incorporated knowledge from previous parts of the conversation, how much the participant shared things about his or her self, and how well the conversation flowed. The variables examined in this study included Chat Room Questionnaire Score (CRQS), Average Social Skill Level, amount of hostile responses, amount of prosocial responses, incorporation of knowledge, and conversational flow.

Results

Hypothesis 1: One Way ANOVA of EF and ER

Performance on measures of executive function and emotion regulation for children with and without ADHD status were submitted to a one-way between participant Analysis of Variance (ANOVA). Results of the one-way ANOVA can be found in Table 1 and Table 2. There was a significant main effect of ADHD status in tasks of executive function such that control children performed better on tasks of executive function than children with ADHD status. Children with ADHD had lower performance on tasks of working memory measured by the WISC Working Memory Index ($F(1,272)=23.35$, $p<0.001$, $\eta_p^2=.079$), WRAML Finger Windows Backwards ($F(1,222)=12.439$, $p=.001$, $\eta_p^2=.053$), and WRAML Finger Windows Forwards ($F(1,222)=9.70$, $p=.002$, $\eta_p^2=.042$). Children with ADHD also exhibited lower performance on tasks of inhibitory control ($F(1,139)=20.29$, $p<0.001$, $\eta_p^2=.127$), measured by the Stop Signal Reaction Task (SSRT).

There was also a significant main effect of ADHD status in measures of emotion regulation, such that children with ADHD showed lower abilities of emotion regulation than those without ADHD. Emotion regulation was quantified by the emotional control index as reported in the BRIEF Parent Questionnaire, and by the emotional lability index as reported in the Conners Parent Questionnaire's global index of emotional lability. Children with ADHD were rated by parents as having lower abilities in emotional control ($F(1,256)=90.40$, $p<.001$, $\eta_p^2=.261$) and as having more emotional lability ($F(1,269)=117.55$, $p<.001$, $\eta_p^2=.304$).

Hypothesis 2: Pearson Correlations between EF and ER

There were significant correlations found between many of the executive function and emotion regulation variables examined. Correlation values between executive function and

emotion regulation can be found in Table 3. Significant correlations were found between the WISC Working Memory Index and both indices of emotion regulation. A negative correlation (*r=-.136, p=.025*) was found between the WISC Working Memory Index and the Conners Emotional Lability such that children who scored high on tasks of working memory were rated by parents as exhibiting low emotional lability. A negative correlation (*r=-.162, p=.009*) was also found between the WISC Working Memory Index and the BRIEF Emotional Control such that children who performed well on tasks of working memory were rated to exhibit more emotional control.

Only one correlation between the WRAML finger windows tasks and emotion regulation indices was significantly correlated, with a negative correlation (*r=-.138, p=.043*) between WRAML Finger Windows Forward and BRIEF Emotional Control such that children who scored high on the finger windows task were rated as having greater emotional control.
The stop signal reaction task of inhibitory control correlated significantly with both measures of emotion regulation. A significant positive correlation (*r=.190, p=.025*) was found between SSRT and BRIEF Emotional Control such that children who performed better on the SSRT were rated as having more emotional control. A significant positive correlation (*r=.186, p=.027*) was also found between the SSRT and Conners Emotional Lability such that children performing well on SSRT were rated by parents as having less emotional lability.

Hypothesis 3: Correlations between EF, ER, and Achievement and Socio-Emotional Functioning

Pearson correlations of executive function with academic achievement and socio-emotional functioning can be found in Table 4. Tasks of working memory were significantly correlated with all indices of academic achievement. Inhibitory control SSRT was not correlated with performance scores on Reading (*r=-.011, p=.901*) or Spelling (*r=-.003, p=.975*) subtests of

the WIAT. The WISC Working Memory Index was positively correlated with achievement as indexed in Reading (*r=.571, p<.001*), Mathematics (*r=.491, p<.001*), and Spelling (*r=.527, p<.001*) subtests of the WIAT. WRAML finger windows forward (FWF) had a significant positive correlation with Reading (*r=.214, p=.001*), Mathematics (*r=.328, p<.001*), and Spelling (*r=.224, p=.001*) scores on WIAT subtests. WRAML Finger Windows Backwards (FWB) had a significant positive correlation with tasks of reading (*r=.167, p=.013*), mathematics (*r=.401, p<.001*), and spelling (*r=.212, p=.002*). Inhibitory control was negatively correlated with mathematic (*r=-.264, p=.002*) performance such that children scoring high tasks of SSRT performed better on WIAT Mathematics. These correlations indicate that children with high performance on tasks of executive function show high performance on tasks of school achievement.

Executive function was correlated with socio-emotional functioning, although not all indices were significantly correlated. The WISC working memory index was significantly correlated (r=*.371, p=.036*) with the Chat Room (CR) questionnaire score. WRAML FWF was significantly correlated with the average social skill level on the CR task (*r=.264, p=.036*) such that those with greater working memory abilities exhibited more skilled responses in the CR task. WRAML FWB showed significant correlations with the child's average social skill level (*r=.297, p=.012*), the total hostile responses made by the child (*r=-.270, p=.031*), how well the child incorporated knowledge from previous parts of the conversation (*r=.290, p=.020*), and how well the conversation flowed (*r=.263, p=.036*). The negative correlation between WRAML FWB and the amount of hostile responses in the CR task indicated that children scoring high on FWB gave less hostile responses throughout the CR task. The SSRT measure of inhibitory

control was significantly correlated with the CR questionnaire score (r=-.504, p=0.17) and how well the child's conversation flowed (*r=-.251, p=.048*).

Correlation values of emotion regulation with academic achievement and socio-emotional functioning can be found in Table 5. Significant negative correlations were found between all indices of emotion regulation and all tasks of academic achievement, indicating that children who exhibit greater emotion regulation also exhibit high scores on tasks of school achievement. The BRIEF rating scales of emotional control were negatively correlated with WIAT subtests of Reading (*r=-.163, p=.009*), Mathematics (*r=-.190, p=.002*) and Spelling (*-.173, p=.008*), such that those who were rated as having greater emotional control scored higher on tasks of school achievement. Conners rating scales of emotional lability were negatively correlated with tasks of school achievement such that, parents who rated their children as having low emotional lability were more likely to score high on tasks of reading (*r=-.163, p=.008*), mathematics (*r=-.195, p=.001*), and spelling (*r=-.234, p<.001*). Emotion regulation was not significantly correlated with socio-emotional functioning for any measures.

Hypothesis 4: Linear Regression of Executive Function, Emotional Regulation, Achievement, and Socio-Emotional Functioning

Linear Regression values of executive function and achievement can be found in Table 6. As expected, diagnostic status (ADHD vs. non-ADHD) significantly predicted all achievement variables (all $r^2 > .03$, all $p < 0.001$), even after covarying executive function (all $r^2\Delta > .033$, all $p < .05$). ADHD status did not moderate the relationship between any executive function and achievement variables (all $r^2\Delta < .01$, all $p > .05$).

Linear regression values of executive function and socio-emotional functioning can be found in Table 7. ADHD status significantly predicted incorporation of knowledge by the child

during the Chat Room task (r^2 = .08, t = 2.38, p= .020) even after covarying Finger Windows Forwards ($r^2\Delta$= .081, p < .05). However, ADHD status did not significantly moderate the relationship between Finger Windows Backwards and Incorporation of Knowledge ($r^2\Delta$=.003, p= .663). ADHD status did not significantly predict any other socio-emotional functioning variables after covarying executive function (all r^2 <.08 , all p > .05). However, ADHD status did moderate the relationship between Chat Room Questionnaire Score and Inhibitory Control. A significant interaction was found between the Chat Room Questionnaire Score and SSRT in which children with ADHD who had poor inhibitory control, also showed poor performance on the Chat Room Questionnaire. Both ADHD children with strong inhibitory control and control children did not show poor performance on the Chat Room Questionnaire.

ADHD status also moderated the relationship between Finger Windows Backwards and the amount of hostile responses made by the child. This significant interaction found between Finger Windows Backwards and Amount of Hostile responses indicated that ADHD children with poor working memory had a high amount of hostile responses in the Chat Room task. ADHD children with high working memory abilities and control children both had a low amount of hostile responses when completing the Chat Room task. Significant interactions can be seen in Figure 1 and Figure 2.

Linear Regression values for emotion regulation and achievement can be seen in Table 8. As expected, ADHD status significantly predicted all achievement variables (all r^2>.026, p < 0.001), even after covarying emotion regulation ($r^2\Delta$ > .050, p < 0.001). ADHD status did not moderate the relationship between any emotion regulation and achievement variables (all $r^2\Delta$ < .006, all p > .05).

Discussion

Summary

The aim of this present study was to determine the degree of correlation between executive function and emotion regulation, and whether they have differential predictive power for a range of outcomes. Additionally, results should ultimately determine under what contexts clinicians, parents, and teachers should be concerned about weaknesses in executive function and emotion regulation for children with ADHD. It was found that children with ADHD will perform lower on tasks of executive function than children without ADHD. Children with ADHD were also rated as having worse abilities in emotion regulation than children without ADHD. Many executive function measures significantly correlated with emotion regulation measures. Both executive function variables of working memory and inhibitory control significantly correlated with measures of emotion regulation, thus indicating that executive function and emotion regulation may be related.

The resulting predictive abilities found in this study may prove to be further evidence of the correlational link between executive function and emotion regulation. Executive function was found to predict both academic achievement performance and socio-emotional functioning. Emotion regulation, however, unexpectedly predicted only academic achievement and did not predict socio-emotional functioning. Additionally, ADHD status moderated the relationship between the executive function and socio-emotional functioning constructs of Chat Room Questionnaire Score and Stop Signal Reaction Task, as well as Finger Windows Backwards and amount of hostile responses.

Hypothesis 1

It was hypothesized that children with ADHD will perform significantly worse on measures of executive function and emotion regulation than their non-ADHD peers. The study's findings of poor performance on measures of executive function and emotion regulation for children with ADHD were consistent with previous research (Barkley, 1997; Maedgen & Carlson, 2000). The current findings in this study support previous literature that children with ADHD are not performing as well on these tasks as their non-ADHD peers. This means that performance on executive function and emotion regulation tasks may be of particular importance when assessing the deficits in children with ADHD and what those deficits will mean for performance in other areas that will affect their well-being. Results also indicate that ADHD as a disorder may be linked to these deficits in executive function and emotion regulation. The absence of these skills puts children with ADHD at a disadvantage when trying to perform with their non-ADHD peers. If one were to visualize a spectrum of performance, with some children performing higher on the spectrum, and others performing lower, the presence of ADHD alone puts children with the disorder at the lower end of the spectrum when assessing for executive function and emotion regulation. The areas these children struggle with due to their deficits in executive function and emotion regulation were examined in the third hypothesis.

Hypothesis 2

Previous research suggest that executive function and emotion regulation may be related such that executive function may be required to regulate emotions or that executive function tasks may require emotion regulation to complete (Baskin-Sommers et al., 2012; Gyurak et al., 2009). Consistent with previous research, a correlation was found between the two constructs of executive function and emotion regulation. This correlation existed between many of the

measured executive function and emotion regulation variables but not all of them. There was however, a correlation found between both types of executive function processes measured. Both working memory and inhibitory control correlated with the measures of emotion regulation. Because executive function is an extensive construct, encompassing many varying processes, it is important that the relationship between executive function and emotion regulation is existent within multiple different types of executive function processes. The correlation found between emotion regulation and executive function within these different types of executive function processes is important because it indicates that the relationship is all-encompassing for varying processes defined under the overall construct of executive function. This finding discredits the opposing idea that the relationship may hold true for some types of executive function processes (i.e. only inhibitory control), but not others. Overall, skills of executive function were significantly correlated with all measures of emotion regulation, suggesting a possible link between the two constructs such that they may be indicative of similar processes. The relationship found between the two constructs could be consistent with what the literature suggests: that the ability to affectively regulate emotions relies on executive function skills or the ability to exhibit executive function relies on emotion regulation. The relationship may even be more complex such that the two constructs are interdependent upon each other and indistinguishable. Emotion regulation may even exist as its own type of executive function. It may be a sub-process of executive function, categorized with others that are considered to be multi-step and "higher order" processing. If this is true, then children with ADHD who may be experiencing deficits in one construct are most likely experiencing deficits in the other construct as well. Alternatively, if a child with ADHD develops skills in either executive function or

emotion regulation, these skills may buffer deficits that they would have otherwise experienced in the other construct.

Hypothesis 3

Previous research on the predictive abilities of executive function and emotion regulation has found that deficits in executive function can lead to significant detriments in academic functioning, while deficits in emotion regulation can lead to the inability to interact with peers in a socially appropriate and adaptive way (Biederman et al., 2006; Morris et al., 2007). The present study's findings on the predictive abilities of executive function and emotion regulation were inconsistent with findings from the literature. Both executive function and emotion regulation predicted academic achievement but only executive function predicted socio-emotional functioning. The failure to find a relationship between emotion regulation and socio-emotional functioning was surprising due to much of the literature stating that emotion regulation is an essential component to learn how to respond to peers in socially appropriate ways (Morris et al., 2007).

In this present study the measures of emotion regulation from the BRIEF and Conners questionnaires were only taken from parent ratings of the child. This failure to uncover a predictive relationship between emotion regulation and socio-emotional functioning may indicate a distinction between how a child interacts emotionally in a home environment (around their parents) in comparison to how they react with their peers. A child may therefore vary in their emotional functioning among different social environments. From previous research, the Chat Room Task was found to be indicative of how children will respond in an everyday social environment with peers due to significant associations between performance on the task and various parent and teacher ratings of social and emotional behavior (Mikami et al., 2007). Use

of the Chat Room Task as a measure of socio-emotional function may be limiting, however, as the child is not actually in a face-to-face social interaction with other peers. Furthermore, even though the task was simulated to exist as a similar experience to peer interaction, the child is not actually interacting with any real children. The "computer kids" may not always recognize the response that the child types (slang terms, poor grammar, or typos), although these statements may be terms that a real peer would easily be able to respond to. Moreover, the child may not possess the typing abilities to effectively communicate with the "computer kids," an issue that would not affect a child speaking face-to-face with a peer. Overall, both measures of emotion regulation and socio-emotional functioning have limitations that may have affected the overall results obtained.

The finding that both executive function and emotion regulation predict academic achievement was unexpected but may further affirm the prediction that executive function and emotion regulation represent convergent constructs. In a study of adults with ADHD, it was found that deficits in executive function have significant negative effects on school functioning, social functioning, educational and occupational attainments, as well as adaptive social and leisure functioning (Biederman et al., 2006). The current study's findings show that deficits in executive function may especially affect academic performance in spelling, mathematics, and reading—skills that are required in all school curriculums. Results may indicate that skills in emotion regulation can be beneficial when completing school work. For example, the capacity to regulate frustration when working on a math problem for an extended period of time, or the ability to regulate anxiety before an exam can have beneficial outcomes on one's school performance. In contrast, the inability to regulate emotions may lead to poor social relationships, resulting in the overall inability to adjust to school. Failing to adapt to school can

make it hard for children to learn and achieve skills such as reading, math, or spelling. Although the majority of previous research has focused on executive function leading to academic achievement, there are some cases in which research has shown links between emotion regulation and academic achievement as well. Davis and Levine (2013) suggest that children who cannot inhibit negative affect when learning information in class will be less likely to remember educational information, interfering with their academics. The specific processes of emotion regulation that are linked to academic achievement are less known (Davis & Levine, 2013). In the literature, the link of executive function to academic achievement is more prevalent; however, its prevalence does not indicate that there cannot be a link between emotion regulation and academic achievement as well. To strengthen this finding, more research should be conducted on the relationship between emotion regulation and academic achievement and the specific processes through which this relationship exists.

Executive function performance also predicted socio-emotional functioning, a finding that indicates that executive function processes may be necessary for appropriate social interaction among peers. In the literature, executive function is more commonly associated with academic achievement; however, some studies show that it may also affect social functioning as well. In a study evaluating executive function's effects on social functioning, it was found that among children with ADHD, executive function abilities in childhood predicted social functioning abilities in adolescence (Rinsky & Hinshaw, 2011). The predictive ability between executive function and socio-emotional functioning exists, yet little is known about the specific executive function processes through which it is predictive. Further research must be conducted to fully understand the predictive relationship between these two constructs.

The amount of prosocial responses was the only variable that was unrelated to any of the executive function measures. In a study of ADHD and the Chat Room Task, few ADHD children gave prosocial responses and the presence of hostile responses was more salient as a sign of social dysfunction (Mikami et al., 2007). With a focus on social dysfunction in children with ADHD, prosocial responses may not have been frequent enough in the Chat Room Task to provide enough data for a significant relationship.

Hypothesis 4

Previous literature has found that those with ADHD who performed poorly on tasks of executive function will have the worst outcomes in academic performance (Biederman et al., 2006). The same relationship was hypothesized to be true with ADHD status moderating the relationship between executive function and academic achievement. ADHD was also hypothesized to moderate the relationship between emotion regulation skills and socio-emotional functioning. Although ADHD status did not moderate the relationship between executive function and academic achievement or between emotion regulation and socio-emotional functioning, it did unexpectedly moderate the relationship between executive function and socio-emotional functioning. The significant interaction between Chat Room Questionnaire Score (CHQS) and SSRT indicated that the children with ADHD displaying poor inhibitory control would score low on the CRQS. Children with ADHD who showed good inhibitory control, however, scored high on the CRQS. Children without ADHD scored high on the CRQS regardless of inhibitory control performance. Children with ADHD who showed poor inhibitory control may have been unable to inhibit inattention and inappropriate or unnecessary actions during the task, leading to disengagement during the Chat Room Task. The CRQS assesses knowledge of the social situation that the child just experienced. Disengagement or any other

adverse effects due to poor inhibitory control may have contributed to the child's inability to respond about the social interactions that they were tested on in the CHQS. Theses results indicate that the combination of poor inhibitory control accompanying other deficits that children with ADHD experience will collectively lead to poor socio-emotional functioning. Children with ADHD who performed well on tasks of inhibitory control may have been able to use this skill to buffer the other deficits they have due to their disorder. Children without ADHD who performed poorly on tasks of inhibitory control but still managed to perform well on the Chat Room Task may have used other cognitive skills (other than inhibitory control) to foster positive social relations during the task. Children without ADHD who performed well on tasks of inhibitory control did not have the executive function deficits present that would have led to poor socio-emotional functioning. This finding suggests that children with ADHD who have trouble controlling or suppressing certain actions or emotions may have poor social skills and maladaptive interactions with peers.

The significant interaction found between working memory and the amount of hostile responses indicates that children with ADHD who are undeveloped in their working memory skills will give more hostile responses. Children with ADHD who showed good working memory skills did not respond with many hostile responses. Children without ADHD did not answer with many hostile responses regardless of how they performed in tasks of working memory. Lack of working memory combined with ADHD status was what led to the worst results in socio-emotional functioning. Children with ADHD who have not developed advanced working memory skills may be using all of their cognitive resources to "actively remember" a child's response and in doing so, allow other ADHD deficits to affect their performance on the task. Children without ADHD who performed poorly on tasks of working memory may have

used other cognitive resources (unavailable to those with ADHD) to perform well on the Chat Room task. In contrast, children with ADHD who have skilled working memory may be able to buffer the other deficits of their disorder by possessing the skills for this one executive function process. Working memory may be particularly useful in this task as it is vital for recalling important information said in conversation and for holding responses in one's mind until it becomes appropriate to voice that response (Rinsky & Hinshaw, 2011). In the Chat Room Task, lack of working memory skills can make it hard to remember the computer kid's responses in addition to simultaneously asking new questions based on their responses. Unwanted outcomes during the task due to lack of working memory (i.e. the computer kids talking too fast, inability to understand rushed responses) may lead to frustration for the child during the task. This frustration could in turn have an effect on the amount of hostile responses the child uses during the task. The ability to use working memory in social environments may lay the foundation for greater perspective taking, greater pro-social behavior, and more peer acceptance later in life (Rinsky & Hinshaw, 2011). Deficits in working memory coupled with other deficits that children with ADHD experience may cause the inability to develop adaptive social skills and lead to poor social outcomes such as the inability to solve interpersonal problems or maintain peer relationships. Overall, these findings indicate that executive function processes are especially important for ADHD children who may be struggling socially with peer interaction. Based on these findings, interventions for children with ADHD who exhibit poor social skills should focus on developing executive function abilities.

Limitations

Although a large number of participants were included in the study, the population was drawn only from the State College area. This population is relatively analogous with a majority 83.2% Caucasian and middle class population with a mean average income of $89,785 (US Census, 2010). The lack of diversity in the sample may affect the generalizability of results to other populations. Research on low-socioeconomic communities may be particularly important as those populations are less likely to receive medical treatment for ADHD if they are diagnosed with the disorder (Froehlich et al., 2007).

Executive function is an umbrella term for many different higher-order processes that occur in the pre-frontal cortex (Chan, Shum, Toulopoulou & Chen, 2008). In this study, however, only the two processes of working memory and inhibitory control were examined. Many other processes such as planning, mental flexibility or utilization of feedback should be examined to present a more all-encompassing definition of executive function. In addition, the variables examined were mostly of working memory. Out of the four executive function variables, three measured working memory and only one measured inhibitory control. Having a more even distribution of the types of executive function studied may have led to a better overall operationalization of executive function.

The operationalization of emotion regulation was through parent reported measures. This somewhat limited the measure as emotion regulation is an internalized action of one's emotional behavior (Southam-Gerow & Kendall, 2002). If children are successfully regulating their emotions, will parents be as aware of those successful attempts or will they only recognize those that are unsuccessful? Whether or not parents can accurately predict an internalized emotional

response from their child may still be in question. Using a measure of emotion regulation abilities directly through the child may be a more accurate measure for future studies.

Future research

Although this study has found a significant relationship between executive function and emotion regulation, future research is necessary to stabilize these findings and further reinforce the connection between the two constructs. Future explorations should also focus on the specific processes within executive function and emotion regulation that may be used in the connection of the two constructs. Additionally, the direction of the relationship between executive function and emotion regulation should be examined. Does executive function rely on emotion regulation skills? Does emotion regulation ability require executive function? Or does a child need skills in both constructs in order to effectively achieve within a certain domain? With executive function and emotion regulation abilities both predicting academic achievement, research on interventions that could be developed to correct poor skills in these domains may lead to better outcomes for ADHD children struggling with academics.

Conclusion

In conclusion, this research has expanded upon what is currently known about children with attention deficit/hyperactivity disorder and their deficits in executive function and emotion regulation. The findings show a link between the two constructs and that they are predictive of similar outcomes in academic achievement. The findings also indicate that executive function has a wide range of predictive abilities, also predicting socio-emotional functioning. The development of executive function and emotion regulation is crucial in ADHD populations struggling in academic and social environments and should be taken into consideration when developing effective treatment interventions for children with ADHD.

Tables and Figures

Table 1: Means of Executive Function in ADHD and Control Groups

	ADHD		Control		
	N	*M(SD)*	*N*	*M(SD)*	*F*
WISC Working Memory Index	140	98.24 (14.00)	134	105.66 (11.19)	$F(1,272)=23.35$, $p<.001$, $\eta_p^2=.079$
WRAML Finger Windows Forward	115	9.34 (3.12)	109	10.85 (3.31)	$F(1,222)=9.70$, $p=.002$, $\eta_p^2=.042$
WRAML Finger Windows Backward	115	3.92 (2.80)	109	11.08 (2.78)	$F(1,222)=12.439$, $p=.001$, $\eta_p^2=.053$
Stop Signal Reaction Task	79	384.28 (155.59)	62	282.75 (96.23)	$F(1,139)=20.29$, $p<0.001$, $\eta_p^2=.127$

Table 2: Means of Emotion Regulation in ADHD and Control Groups

	ADHD		Control		
	N	*M(SD)*	*N*	*M(SD)*	*F*
BRIEF Parent Emotional Control	131	56.76(12.51)	127	44.86(6.60)	$F(1,256)=90.40$, $p<.001$, $\eta_p^2=.261$
Conners Parent Emotional Lability	141	57.16(12.33)	130	44.65(4.78)	$F(1,269)=117.55$, $p<.001$, $\eta_p^2=.304$

Table 3: Pearson Correlations of Executive Function and Emotion Regulation Measures

		Emotion Regulation	
		BRIEF Parent Emotional Control	Conners Parent Emotional Lability
Executive Function	WISC Working Memory Index	*-.162***	*-.136**
	WRAML Finger Windows Forward	*-.138**	*-.115*
	WRAML Finger Windows Backwards	*-.108*	*-.052*
	Stop Signal Reaction Task	*.190**	*.186**

***p < .05, **p <.01, ***p < .001**

Table 4: Pearson Correlations between Executive Function and Achievement/Socio-Emotional Functioning

	Academic Achievement			**Socio-Emotional Skills**					
	WIAT-3 Word Reading	WIAT-3 Numerical Operations	WIAT-3 Spelling	CR Questionnaire Score	Average Social Skill Level	Hostile	Prosocial	Incorporate Knowledge	Conversational Flow
WISC Working Memory Index	.571**	.491**	.527**	.371*	.143	-.128	.061	.095	.018
WRAML Finger Windows Forward	.214**	.328**	.232**	.158	.264*	.010	.167	.159	.072
WRAML Finger Windows Backwards	.167*	.401**	.212**	.370	.303*	-.270*	.124	.290*	.263*
Stop Signal Reaction Task	.011	-.264**	-.003	-.504*	-.144	.031	-.053	-.201	-.254*

***p < .05, **p <.01, ***p < .001**

Table 5: Pearson Correlations between Emotion Regulation and Achievement/Socio-Emotional Functioning

	Academic Achievement			Socio-Emotional Functioning					
	WIAT-3 Word Reading	WIAT-3 Numerical Operations	WIAT-3 Spelling	CR Questionnaire Score	Average Social Skill Level	Hostile	Prosocial	Incorporate Knowledge	Response Flow
BRIEF Parent Emotional Control	-.163**	-.190**	-.173**	-.286	-.062	.111	.027	-.101	-.206
Conners Parent Emotional Lability	-.163**	-.195**	-.234**	-.217	-.033	.064	.030	-.015	-.210

***p < .05, **p <.01, ***p < .001**

Table 6: Linear Regression Analysis- Executive Function and Achievement

	Word Reading			**Numerical Operations**				**Spelling**		
	$r^2\Delta$	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**
Predictor	*WMI (EF)*	*FWF (EF)*	*FWB (EF)*	*WMI (EF)*	*FWF (EF)*	*FWB (EF)*	*SSRT (EF)*	*WMI (EF)*	*FWF (EF)*	*FWB (EF)*
Block 1 *Executive Function*	.327***	.046**	.028*	.241***	.108***	.161***	.070**	.278***	.054**	.045**
Block 2 *ADHD*	.044***	.090***	.095***	.033**	.052***	.041**	.036*	.083***	.151***	.150***
Block 3 *Interaction*	.005	.001	.000	.000	.008	.000	.004	.000	.000	.010

***p < .05, **p <.01, ***p < .001**

Note. WMI= Working Memory Index, FWF = Finger Windows Forwards, FWB = Finger Windows Backwards, SSRT = Stop Signal Reaction Time, EF = Executive Function Variable

Table 7: Linear Regression Analysis-Executive Function and Socio-Emotional Functioning

	Chat Room Questionnaire Score		Avg. Social Skill		Hostile Response	Incorporation of Knowledge	Conversational Flow	
	$r^2\Delta$	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**
Predictor	*WMI (EF)*	*SSRT (EF)*	*FWF (EF)*	*FWB (EF)*	*FWB (EF)*	*FWB (EF)*	*FWB (EF)*	*SSRT (EF)*
Block 1								
Executive Function	.138*	.254*	.070*	.092*	.073*	.084*	.069*	.065*
Block 2								
ADHD	.070	.040	.003	.001	.003	.081*	.043	0.046
Block 3								
Interaction	.017	.263**	.003	.016	.059*	0.003	.007	0.008

***p < .05, **p <.01, ***p < .001**

Note. WMI= Working Memory Index, FWF = Finger Windows Forwards, FWB = Finger Windows Backwards, SSRT = Stop Signal Reaction Time, EF = Executive Function Variable

Table 8: Linear Regression Analysis-Emotion Regulation and Achievement

	Word Reading		Numerical Operations		Spelling	
	$r^2\Delta$	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**	**$r^2\Delta$**
Predictor	EC (ER)	EL (ER)	EC (ER)	EL (ER)	EC (ER)	EL (ER)
Block 1						
Emotion Regulation	.026**	.027**	.036**	.038**	.030**	.055***
Block 2						
ADHD	.090***	.095***	.050***	.050***	.126***	.113***
Block 3						
Interaction	.000	.000	.005	.006	.001	.004

***p < .05, **p <.01, ***p < .001**

Note. EC = BRIEF Emotional Control, EL = Conners Emotional Lability, ER = Emotion Regulation Variable

Figure 1. Interaction between Chat Room Questionnaire Score and Stop Signal Reaction Task

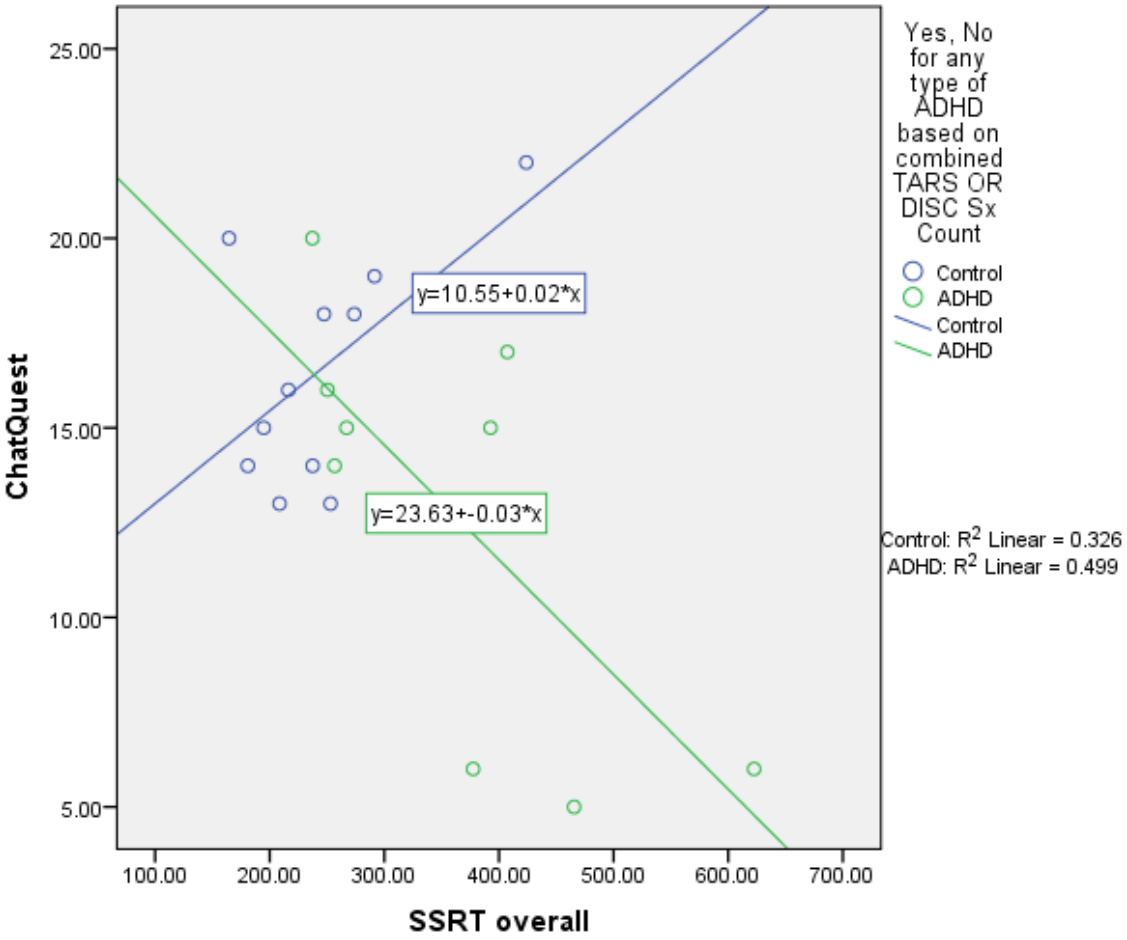
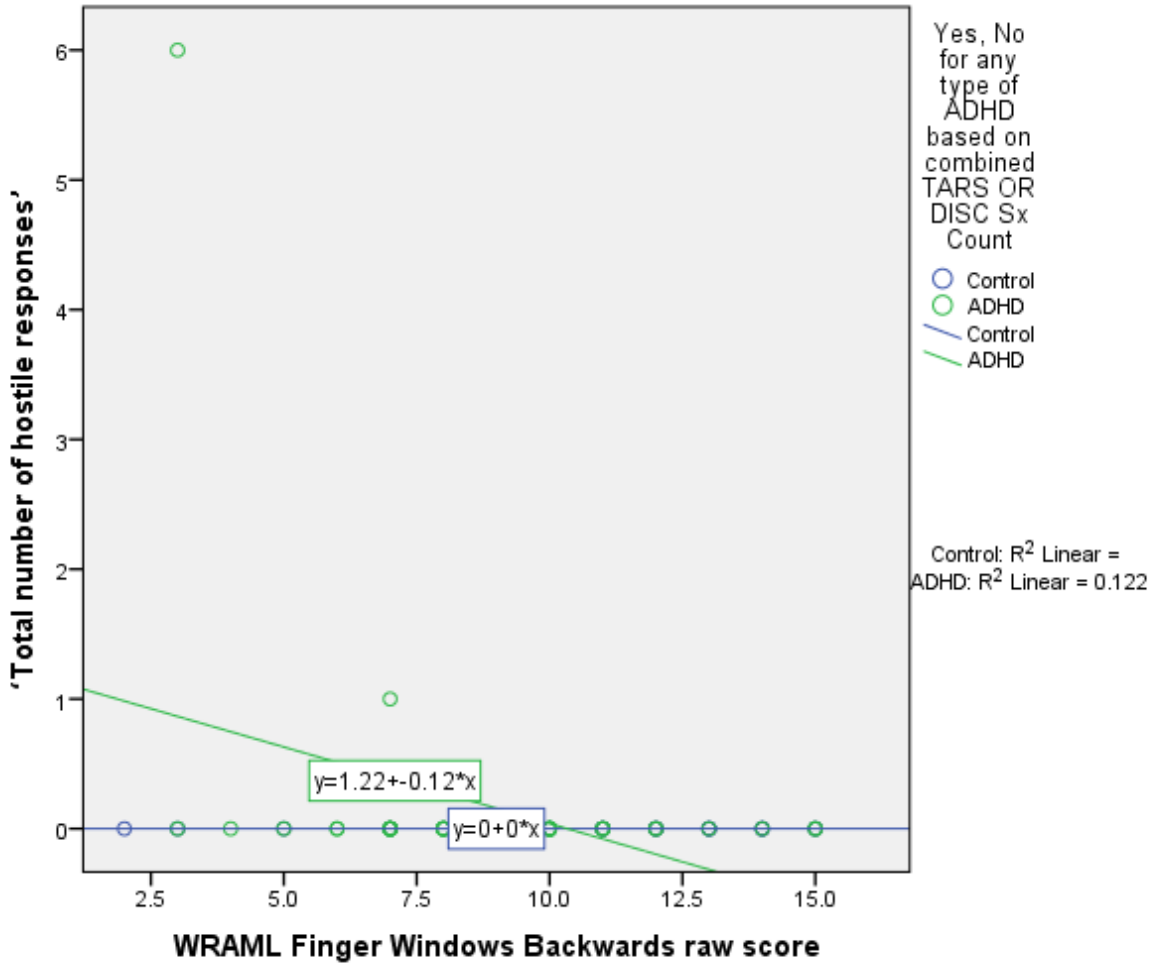


Figure 2. Interaction between Finger Windows Backward and Amount of Hostile Responses



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- Worked with cancer patients of in-patient and out-patient facilities
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Summer Camp Counselor, YMCA Camp Kon-O-Kwee/Spencer *Summer 2009-2011*
- Supervised a cabin of eight girls while managing programming, health, happiness, safety, routine duties, character and skill development
- Promoted to Head Counselor *Summer 2011*

Leadership Experience:

THON Hospitality Captain, Promotions/Alternative Fundraising *Fall 2012*
- Procure food donations totaling $300,000 for THON events throughout the year.
- Organize promotions with local restaurants to benefit THON and to build strong relationships with the businesses in the State College community.
- Oversee a Hospitality committee of 22 student volunteers
- Pick-up, receive food donations, organize and serve all meals at various THON events through the year including THON weekend

Family Relations Chair, Psi Chi THON *Spring 2012*
- In charge of communicating with Psi Chi's THON family on a weekly basis and keeping Psi Chi members up to date with any relevant information.

Logistics Team Leader, Schreyer Honors College Orientation *Spring 2012*
- Planned orientation event for 250 incoming Gateway scholars

Secretary: Savoir Fair, Penn State's Original All Female A Capella Group *Fall 2012-Present*
- Send emails to members of all important updates, upcoming events, etc.

Community Builders Team Leader, Schreyer Honors College Orientation *Spring 2011*
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Intercommittee-Captain Liaison, Hospitality THON Committee *2011- 2012*

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