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THE NEURAL CORRELATES OF EMOTION REACTIVITY AND REGULATION IN  
YOUNG CHILDREN WITH ADHD

A Dissertation Presented

by

CLAUDIA I. LUGO-CANDELAS

Submitted to the Graduate School of the  
University of Massachusetts Amherst in partial fulfillment  
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

September 2016

Department of Psychological and Brain Sciences

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CLAUDIA LUGO-CANDELAS

Approved as to style and content by:

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Elizabeth A. Harvey, Co-Chair

---

Jennifer M. McDermott, Co-Chair

---

Lisa S. Scott, Member

---

Sara Whitcomb, Member

---

Harold D. Grotevant, Department Chair,  
Department of Psychological and Brain Sciences

## ABSTRACT

### THE NEURAL CORRELATES OF EMOTION REACTIVITY AND REGULATION IN YOUNG CHILDREN WITH ADHD

SEPTEMBER 2016

CLAUDIA I. LUGO-CANDELAS, B.A., UNIVERSITY OF PUERTO RICO

M.A., UNIVERSITY OF MASSACHUSETTS AMHERST

Ph.D., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professors Elizabeth Harvey and Jennifer McDermott

Attention-deficit hyperactivity disorder (ADHD) is the most frequently occurring pediatric neurobehavioral disorder. Although emotion reactivity and regulation are frequently impaired in ADHD, few studies have examined these factors in preschool aged children with ADHD, and none have explored the neural correlates of emotion reactivity and regulation in this group through event-related potentials (ERPs). Children aged 4 to 7 with ( $n = 24$ ) and without ( $n = 30$ ) ADHD symptoms completed an attention task composed of four blocks: baseline, frustration, suppression, and recovery. In the frustration and suppression blocks, negative affect was induced by false negative feedback. During the suppression block, children were asked to suppress emotional expressions. Children in both groups reported increased frustration from baseline to the frustration block, but the magnitude of the increase was significantly larger for children with ADHD. Both groups showed similar increases in observed expressions of negative affect from the baseline to frustration block, but children with ADHD expressed more negative affect in both blocks. In the left frontal and frontocentral regions, typically

developing children demonstrated enhanced P3 amplitudes during the frustration block, suggesting that these children were able to allocate greater attentional control in the face of an emotional challenge. In contrast, children with ADHD symptoms did not show significant P3 enhancement during the frustration block. During the suppression block, children with ADHD demonstrated smaller reductions in self-report and observed expressions of negative affect compared to typically developing children. Typically developing children continued to demonstrate enhanced P3 amplitudes in frontal and frontocentral regions during the suppression block, compared to baseline, but children with ADHD did not. This pattern suggests that preschool aged children with ADHD are not as effective as their peers in suppressing emotions and engaging top down attention mechanisms. The present study extends a growing body of literature that suggests that emotion dysregulation is a central component of ADHD already present in the preschool years and underscores that emotional contexts may exacerbate attentional deficits in ADHD.

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## **CHAPTER I**

### **THE NEURAL CORRELATES OF EMOTION REACTIVITY AND REGULATION IN YOUNG CHILDREN WITH ADHD**

Attention-deficit hyperactivity disorder (ADHD) is characterized by symptoms of frequent inattention, impulsivity, and hyperactivity (APA, 2000). Research and theory suggest that ADHD involves a deficit in behavioral inhibition (Barkley, 1997; Barkley & Fischer, 2010), which results not only in the core symptoms of ADHD, but also in impairment in a number of associated domains (Healey, Marks, & Halperin, 2011). One such domain that may play a key role in the functioning of children with ADHD is emotional regulation (Martel, 2009). Children with ADHD have been reported to be more emotionally reactive and dysregulated compared to children without ADHD (Anastopoulos et al., 2011; Maedgen & Carlson, 2000). However, few studies have systematically explored emotion reactivity and regulation in children with ADHD, and it is thus unknown which specific aspects of these processes are impaired in this population. Event Related Potentials (ERP) may be a useful method for studying emotion reactivity and regulation processed in children with ADHD, because this method does not rely on children or their parents to accurately report children's emotional experiences. ERPs have been successfully used to identify differences in attentional and inhibitory systems of individuals with ADHD (Barry, Clarke, & Johnstone, 2003), and have been used to measure emotion processes in children without ADHD (Hajack, MacNamara & Olvet, 2010). However, no ERP studies have examined emotion reactivity and regulation in children with ADHD. Thus, although this method shows great promise for increasing our

understanding of the early development of ADHD, more research is needed in order to identify differences in emotional systems in individuals with ADHD.

## **ADHD**

ADHD is the most frequently occurring neurobehavioral disorder in children, and affects an approximate 8-12% of children and youth (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003; Faraone, Sergeant, Gillberg, & Biederman, 2003), with boys outnumbering girls 3-to-1 in community samples and 9-to-1 in clinical samples (APA, 2000). The Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013) specifies three primary ways in which ADHD can present: primarily inattentive (ADHD-PI), primarily hyperactive–impulsive (ADHD-PH) and combined (ADHD-C). Although environmental factors such as early exposure to toxins have been implicated, ADHD is thought to be largely genetic (Tripp & Wickens, 2009), with an estimated heritability of .76 (Faraone et al., 2005). The genetic mechanisms are likely complex and a number of genes have been implicated, including DAT1, DRD4, DRD5, 5HTT, HTR1B, SNAP25 (Gizer, Ficks, Waldman, 2009). These genetic and environmental factors are thought to cause dysfunction in the fronto-striatal (Dickstein, Bannon, Xavier, Castellanos, & Milham, 2006) and frontal-striatal-thalamic circuitry (Bush, 2011), which in turn result in symptoms of ADHD. Cognitive models of ADHD have posited that the core deficit in ADHD is in behavior disinhibition (Barkley, 1997), which in turn disrupts four executive neuropsychological functions, thus leading to dysfunction in a wide array of domains. One of these functions is the self-regulation of affect-motivation-arousal, suggesting that ADHD may be associated, amongst other impairments, with greater emotional reactivity and less capacity to induce and regulate emotion.

Symptoms of ADHD can cause significant disruption in a child's life, including impairment in children's family, school, and social functioning (Smith, Barkley, & Shapiro, 2007). Moreover, children with ADHD are more prone to present with comorbid neurodevelopmental and mental health conditions, including learning disabilities, conduct disorders, anxiety, depression, and speech problems, which result in even further impairment. An estimated two-thirds of US children with ADHD have comorbid conditions, and as comorbidities increase, social and educational functioning declines (Larson, Russ, Kahn, & Halfon, 2011; Sibley et al., 2011). Many of the conditions that are comorbid with ADHD involve emotion dysregulation, and theory and research suggest that the core cognitive deficits of ADHD likely result in difficulties with affect regulation (Barkley, 1997, Martel, 2009). Although difficulties with emotion regulation are likely to cause further impairment in children with ADHD, surprisingly little research has focused on emotion reactivity and regulation in children with ADHD.

Although ADHD is often not diagnosed until school-age, there is a growing body of literature evidencing that it often emerges during the preschool years (American Academy of Pediatrics [AAP], 2011; Applegate et al., 1997). In fact, the AAP has recently extended the age range for diagnosing and treating ADHD from age 6 to 18 to age 4 to 18. There is a growing body of literature finding that preschool ADHD diagnoses remain quite stable over time, with a recent study documenting that almost 90% of children diagnosed in preschool with ADHD continued to meet criteria for ADHD 6 years later (Riddle et al., 2013). However, much of the research on ADHD focuses on older children; there is a need for more research to better understand ADHD and associated areas of impairment early in development. Because the preschool years

are such an important time for the development of emotion regulation, this period represents an ideal time to study emotion reactivity and regulation processes in children with ADHD.

### **Theoretical Framework for Emotion Reactivity and Regulation**

Emotion is one of the most widely researched phenomena in psychology and is clearly a complex and multifaceted process. Theorists have identified several components involved in emotion processing. This study focused on two of these primary components: emotion reactivity and regulation (Dennis, 2006; Werner & Gross, 2010). Emotion responses involve experiential (i.e., “feelings”), behavioral, and physiological systems, whereas emotion regulation involves control systems that seek to maintain, increase, or decrease emotion responses. Emotional experiences are thought to involve a sequence that begins by paying attention to a psychologically relevant event. The situation’s valence and relevance is then appraised (Ellsworth & Scherer, 2003). These appraisals, in turn, give rise to emotion responses. Emotion regulatory processes can be employed at any point in the emotion emergence process. Of particular clinical interest is understanding when individuals experience difficulty in one or both of these components. Individuals vary greatly in both their emotion reactivity and regulation, which are both key for self-regulation (Dennis, 2006). Thus, understanding individual differences in these two aspects of emotion processing is critical.

**Emotion reactivity.** Emotional reactivity is defined as the arousability of physiological, emotional, and behavioral systems (Dennis, 2006) and is thought to reflect variability in the degree of emotional reactions in response to evocative occurrences (Tellegen, 1985). Studies exploring reactivity have generally approached this concept as

a temperamental characteristic often measured by vocal, facial, motor, and physiological indices of distress (Rothbart & Bates, 1998). Emotional reactivity is important to the study of the development of psychopathology, as studies have linked psychiatric disorders (e.g. anxiety, mood disorders, lack of behavioral inhibition) with greater levels of emotional reactivity (Larsen & Ketelaar, 1989; Leen-Feldner, Zvolensky, Feldner, & Lejuez, 2004; Zvolensky & Eifert, 2000). Individuals with increased emotional reactivity are thought to become easily aroused due to experiencing eliciting events as out of their control (Melamed, 1987).

**Emotion regulation.** Emotion regulation refers to the process through which individuals manipulate which, how, and when emotions are experienced and expressed (Gross, 1998). This concept refers both to internal and transactional processes and can be carried out consciously or unconsciously (Eisenberg, Fabes, Guthrie, & Reiser, 2000; Gross, 1999). Emotion regulation may involve many processes and can happen at various stages during the emotional generation process (Gross, 2001). Regulation processes can be broadly organized into two categories: antecedent-focused (processes that occur before the “full-blown” emotional response) and response-focused (processes that occur after the response is generated; Gross & Thompson, 2007). These regulation processes can also be further categorized into types. Types identified by Gross (2008) include situation selection and modification, attentional deployment, cognitive change, and response modulation. Of particular importance to this study is response modulation, a response-focused process that occurs late in the emotion generation process and involves influencing the emotional response directly (Gross, 2008). One important form of response modulation is expression suppression, which refers to the efforts employed in

order to assuage current emotional expressions (Gross, 2002). Response modulation is a particularly important regulation strategy for preschoolers. Managing emotional arousal within interpersonal interactions in order to achieve sustained positive engagement is one of the most important developmental tasks for preschool-aged children (Denham, 2007). The development of appropriate emotion regulation skills is crucial, as it supports the development of social competence (Halberstadt, Denham, & Dunsmore, 2001).

Difficulties with emotion regulation have consistently been linked to psychopathology, and are hypothesized to be central to its development (e.g., Aldao, Nolen-Hoeksema, & Schweizer, 2010; Gross 1998). It is thought that people who are unable to effectively manage emotional responses are at an increased likelihood of experiencing longer, more severe periods of distress (Aldao et al. 2010). Although the presence of emotion regulation difficulties does not necessarily imply the development of psychopathology, most individuals with psychopathology have deficits related to emotion regulation (Maliken & Katz, 2013). Thus, the study of emotion regulation difficulties is critical to our understanding of the development of psychopathology (Linehan, 1993).

**Interplay between emotion reactivity and regulation.** Emotion reactivity and regulation are thought to be distinct but highly related constructs. Because they are so closely intertwined, scholars have struggled with clearly differentiating emotion reactivity and emotion regulation from each other. Some have suggested (Gross, 1999) that the distinction between these concepts is that a regulated emotion is different from the unregulated emotional state. Others have posited that emotions are, to some extent, always regulated (Fridja, 1986), making these two constructs difficult to tease apart. However, studies that have examined these two components separately suggest that

reactivity (lability) and regulation play unique roles in adjustment (Eisenberg et al., 2005; Kim - Spoon, Cicchetti, & Rogosch, 2013). Moreover, it may be more feasible to tease apart the two at a neural level than at a behavior levels (Goldsmith & Davidson, 2004). Thus, continued efforts to measure these two constructs separately are warranted.

### **Development of Emotion Reactivity and Regulation in Typically Developing Children**

Emotion reactivity and regulation are believed to be heavily influenced by parenting behaviors over the first 4 years of children's lives (Kim-Spoon Cicchetti, & Rogosch, 2013). Toddlerhood is marked by high levels of negative emotion expressivity (Posner & Rothbart, 2000). However, toddlers are thought to be able to self regulate through behaviors such as self-soothing, manipulation of attention, and engagement in play (Feldman, Dollberg, & Nadam, 2011). Levels of negative affect decrease as toddlers increase employment of these behaviors (Crockenberg, Leerkes, & J6, 2008). As children enter school settings, emotion regulation skills continue to develop in the context of increasing socialization demands (Denham, 2007; Parke & O'Neill, 1999). Although adult support is still important, preschoolers are at times able to independently regulate emotions as children become more autonomous (Stansbury & Sigman, 2000). For both preschool and school-aged children, increases in emotion regulation skills are in part linked to increases in cognitive abilities that enable children to make connections between experienced emotions and regulatory tactics (Shonkoff & Phillips, 2000). During middle childhood, emotions often are not expressed as directly and strongly as children learn that goals are not always met through intense emotional expressions and that expressions are best tailored to the context and situation (Zeman & Shipman, 1996).



Accordingly, as children get older, they gradually turn to more cognitive and problem solving behavioral regulation strategies and rely less on support seeking (Saarni, 1999).

When children fail to meet these emotional development goals, academic, cognitive, social, and emotional development becomes compromised. Further, emotion reactivity and regulation atypicalities in early and middle childhood have been consistently linked to increased risk of psychopathology, and it is believed that these difficulties remain somewhat stable through adolescence (e.g. Kim & Cicchetti, 2010; Lahey et al., 1995). Thus, the understanding of emotion reactivity and regulation from a developmental perspective is crucial as it enables the early detection of developmental pathways into the development of psychopathology (Blair & Diamond, 2008).

### **Assessment of Emotion Reactivity and Regulation in Typically Developing Children**

A variety of approaches have been used to study emotion reactivity and regulation in children. These include parent and child reports of emotion, observation of emotion-related behavior, and cognitive neuroscience methods. These approaches are briefly reviewed.

**Parent and child reports of emotion reactivity and regulation.** Studies have explored emotional reactivity through parent reports of children's emotional lability (e.g., Emotion Regulation Checklist [ERC], Shields & Cicchetti, 1997; Emotion Questionnaire (Rydell, Berlin, & Bohlin, 2003) and expressivity (e.g. Emotion Expression Scale for Children [EESC]; Perwien et al., 2008). Emotion regulation has also been assessed through rating scales. Instruments assessing parental perceptions, as well as child self-reports of emotion regulation (e.g., Emotion Regulation Questionnaire for Children and Adolescents [ERQ-CA], Gross & John, 2003; Emotion Regulation Index for Children

and Adolescents [ERICA], MacDermott, Gullone, Allen, King, & Tonge, 2010; ERC, Shields & Cicchetti, 1997; Children's Anger and Sadness Management Scales [CASMS], Zeman, Shipman, & Penza-Clyve, 2001) have been shown to have good convergent validity and reliability in typically developing children (e.g. Gagne, Van Hulle, Aksan, Essex, & Goldsmith 2011; Gullone & Taffe, 2012; Shields & Cicchetti, 1997). Although these instruments allow researchers to gather information on child emotion reactivity and regulation in a rapid and non-invasive way, they are susceptible, as all self-report instruments, to rater biases. Additionally, most of these instruments assess for emotional behaviors and the specific processes of emotion reactivity and regulation are not differentiated.

#### **Observed affect and behavior in reaction to frustration or disappointment.**

Studies have also explored children's emotional reactivity and regulation through frustrating and emotion-eliciting laboratory tasks. In these tasks, the child encounters an emotional event (e.g. making desirable toys inaccessible, giving the child an empty toy box) and researchers code for reactivity and regulation behaviors (e.g., Durblin & Wilson, 2012; Robinson, McGrath, & Corley, 2001). An early, but widely used paradigm, the "disappointing gift" is an example of a task in which children are inducted to express both positive and negative affect (Saarni, 1984). Children's emotion has also been assessed by providing children with stimuli, such as a picture book, asking them to create a story line, and coding for emotional content (APS; Katz, Russ & Overholser, 1993). An array of coding systems has been developed, and these can target coding for verbal, physical, and facial expressions of emotions (e.g. Kochanska, Tjebkes, & Forman, 1998; Olino, Klein, Dyson, Rose, & Durbin, 2010) as well as for regulatory behaviors

(e.g. Cole, Dennis, Smith-Simon, & Cohen, 2009). Children's self-reported emotions, as well as coder data, suggest that these paradigms are successful at inducing affect (e.g. Durbin & Wilson 2012; Ursache Blair, Stifter, & Voegtline, 2013). These paradigms allow researchers to obtain a more objective measure of emotion reactivity and regulation behaviors. However, because reactivity and regulatory processes may co-occur in a rapid fashion, behavioral coding may not always allow for the independent assessment of both constructs.

**Neurobiology of Emotion Reactivity and Regulation.** ERPs are positive and negative voltage variations (or components) in the continuous electroencephalogram (EEG). ERPs are time-locked to the onset of an event. The event may of sensory, motor, or cognitive nature. A component is defined as neural activity generated by the performance of specific tasks (Luck, 2005). ERPs allow the analysis of underlying cognitive procedures transpiring in the brain through scalp-recorded electrical depictions (Johnstone, Barry, & Clarke, 2013). In recent years, there has been an increase in the study of emotion processing in children employing ERP methodology. Much of the literature has focused on emotional processing of affective pictures using the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Although this literature provides support for the notion that emotional responses can be readily measured using ERP in children, this literature was not reviewed because the IAPS is not appropriate for younger children. Researchers have also examined other neural correlates of cognitive systems that may be closely tied to emotion systems, including performance monitoring. Both the feedback-related negativity (FRN) and the error-related negativity (ERN) are components that are thought to be related to emotional

processes and have been found to differ in children and adults with and without ADHD symptoms (van Meel, Heslenfeld, Oosterlaan, Luman, & Sergeant, 2011; van Meel, Oosterlaan, Heslenfeld, & Sergeant, 2005). Because these components are not thought to directly measure emotion processes, this review will not focus on this literature.

Two groups of researchers have developed similar approaches to measuring neural correlates of emotion that would be appropriate for young children. Both approaches involve providing false feedback to children during a computer task to elicit negative affect, and examining the effect of this negative affect on neural indicators of cognitive processes. In one approach (Pérez-Edgar & Fox, 2005) negative affect is elicited during a Posner Task, a computer task of attention in which subjects are asked to rapidly press a key corresponding to visually presented material. The classic Posner cued-attention task (Posner & Cohen, 1984) is one of the most frequently used tasks in which attention and attention regulation are assessed (Pérez-Edgar, & Fox, 2005). It has regularly been used to assess “bottom-up” system of sensory representations (Hugdahl & Nordby, 1994), by controlling orienting to sensory stimuli. During the task, a cue is first presented on the computer screen. A target stimulus then appears in either the left or right side of the display. Subjects are instructed to respond to the target immediately after detecting it. In the modified Affective Posner task, contingencies are placed in order to elicit emotional reactions, and the effects of this induction on components that are thought to be involved in attention are examined. In particular, effects are examined on the P3, which is a positive deflection between 250 and 400 ms following stimulus onset (Picton, 1992), and on the N1, which is a negative deflection that peaks between 150 to 200 milliseconds post-stimulus onset (Wascher, Hoffmann, Sängler, & Grosjean, 2009).

The P3 is thought to index both cognitive processing and the distribution of attention (Rich et al., 2005), and is commonly related to participant's orienting and appraisal of task relevant stimuli (Schupp et al., 2003). The N1 component is related to processes geared towards assisting attention (i.e. target enhancement, discrimination; Dennis, Malone, & Chen, 2009). Both the P3 and N1 have been found to increase during the Affective Posner Task in typically developing children (Rich et al., 2005; Pérez-Edgar & Fox, 2005), suggesting that emotion can serve to increase engagement in typically developing children.

In another approach (Lamm, Granic, Zelazo, & Lewis, 2011; Lamm & Lewis, 2010; Lewis, Lamm, Segalowitz, Stieben, & Zelazo, 2006; Lewis, & Stieben, 2004), negative affect is elicited during a go/no-go task, and the effects of this induction on components associated with regulatory processes (N2) and context updating (P3) are assessed. A go/no-go task is a computer task that requires that subjects press a button when target stimuli appear on the computer screen and inhibit responding when non-target stimuli appear. Using the emotional go/nogo approach, Lewis and colleagues (2006) have found that during emotion induction tasks, children show greater N2 amplitudes during no-go trials, suggesting that when children experienced greater emotions, they required more effortful processing to inhibit their responses. These approaches are thought to provide indirect measures of emotion by assessing the effects of emotion on other cognitive processes, although the N2 may also be directly tapping emotion regulation processes. In sum, these studies suggest that ERPs are a valuable method for the study of emotion reactivity and regulation in children and are likely to be useful in assessing differences in these processes in children with ADHD.

**P3.** The P3 component is of particular interest to this study. It was originally detected in the context of oddball paradigms and thought to index context updating. Context updating refers to the process in which stimuli are evaluated against preexisting mental representations and updates are made, if needed, to the representations based on the new input (Polich, 2007). P3 amplitude is also sensitive to the demands of a task. As demands increase--particularly competing demands--attentional resources become depleted and significant reductions in P3 amplitudes are observed. Thus, the P3 is also thought to be a measure of attention resource allocation. P3 latency, on the other hand, is interpreted as the speed with which stimuli are processed, and is shown to be sensitive to individuals' cognitive abilities (Polich, 2004). In both visual and auditory ERP research, the P3 is often divided into two components, the P3a and P3b (Polich, & Comerchero, 2003). The P3a is seen in response to seeing novel visual stimuli and is maximal over frontal sites (Demiralp, Ademoglu, Comerchero, & Polich, 2001). It is believed to reflect frontal lobe activity (Linden, 2005) related to top-down monitoring and attention switching during the evaluation of incoming stimuli (Polich, 2007). Because it is closely related to frontal focal attention, it is theorized to be mediated by dopaminergic activity (Polich, 2007). On the other hand, the P3b is thought to reflect subsequent processing and be more closely related to context updating and memory storage (Polich, 2007). The P3b is maximal in parietal areas, and is thought to reflect temporal/parietal brain area activity (Brázdil et al., 2003; Polich, 2003). Due to its distribution, it is thought to reflect norepinephrine activity (Nieuwenhuis, Aston-Jones, & Cohen, 2005).

The P3 is a viable way to study cognitive processes in both typically developing and clinical populations. It demonstrates both adequate test-retest reliability (e.g., .43–

.70; Walhovd & Fjell, 2002) as well as high heritability (Polich & Bloom, 1999). Some have suggested that the P3 might eventually be used as a biomarker for disease phenotypes (Polich, 2012). Further, because most mental illnesses impact subjects' basic cognitive abilities--including attention allocation--it demonstrates great potential utility in clinical settings.

The P3 is also believed to reflect context updating and attention allocation in children. In children, the distinction between the P3a and P3b is made less often, and certainly understudied (Polich, 2007). However, studies have documented that the P3a seems to emerge at an earlier age (2 yr. olds; Wetzel, & Schröger, 2007) than the P3b (5 yr. olds; Batty & Taylor, 2002). The P3a shifts from being maximal at frontal sites during early childhood to becoming more frontocentral during adolescence (Wetzel, & Schröger, 2007). The P3b shifts from a parietal to a central parietal maximum as children reach adolescence (Coch & Gullick, 2012). Although a growing body of research suggests that the P3 has the potential to be utilized to detect and study the impact of psychopathology on attention and working memory processes, P3 amplitudes have not been normed in adults, children, or clinical populations. Thus, more research--particularly developmental research-- is needed.

### **Emotion Reactivity and Regulation and ADHD**

Theoretical models (e.g. Barkley, 1997) have proposed that emotion processing may be impaired in individuals with ADHD due to difficulties with inhibition and may significantly account for both impairment and high rates of comorbidity frequently associated with the disorder (Bunford, Evans, Becker, & Langberg, 2015; Seymour, Chronis-Tuscano, Iwamoto, Kurdziel, & MacPherson, 2014; Steinberg, & Drabick,

2015). Moreover, Martel (2009) suggested that ADHD could be conceptualized as a central emotion regulation disability, in which emotion reactivity and regulation interact with each other at behavioral levels. Further, Martel proposes that specific emotion reactivity and regulation difficulties can be related to specific symptoms of ADHD. For example, whereas high emotion reactivity may be related to all disruptive behavior disorders, impairment in control may be particular to ADHD. Following this model, children with ADHD should demonstrate difficulty regulating emotional experiences and associated behavior. Furthermore, it has been proposed that emotional dysregulation in ADHD may be responsible for poor performance on demanding tasks. For example, dysregulation may amplify the negative effects of rewards and failed expectations of rewards by eliciting intense emotional reactions that can result in distractions (Douglas, 1980). Despite the important connection between ADHD and emotion reactivity and regulation, surprisingly little empirical work has examined these aspects of emotion in children with ADHD. Moreover, the small body of research has generally failed to make clear distinctions between these two processes. Nonetheless, existing research provides support for theoretical models that suggest that ADHD substantially impairs emotion reactivity and regulation.

**Parent and child reports of emotion reactivity and regulation.** Only a handful of studies have explored emotion reactivity and regulation in children with ADHD through the use of parent and child reports. Parent reports of children with ADHD have characterized them as more emotionally labile (e.g. Anastopoulos et al., 2011; Berlin, Bohlin, Nyberg, & Janols, 2004; Seymour et al., 2012, Sjöwall, Backman, & Thorell, 2015; Sjöwall, Roth, Lindqvist, & Thorell, 2013). Studies exploring children's self-



reports have also found them to rate themselves as more emotionally reactive and less able to regulate their emotions (Seymour et al., 2012; Shea & Fisher, 1996). Although these studies provide support for the aforementioned emotion reactivity and regulation models of ADHD, more studies that are better able to differentiate emotion reactivity and regulation are necessary.

### **Observed affect and behavior in reaction to frustration or disappointment.**

Behavioral studies of children with ADHD have found them to be more emotionally reactive during emotion-eliciting tasks. For example, children with ADHD were more likely than controls to report frustration while engaging in a challenging task (Scime & Norvilitis, 2006; Wigal et al., 1998), to exhibit greater frustration when denied appropriate rewards (Douglas & Parry, 1994), and to report more frustration and give up faster while attempting to solve unsolvable puzzles (Milich & Okazaki, 1991). Maedgen and Carlson (2000) also found that children with ADHD showed higher levels of negative emotionality during a disappointing toy task in which they received an undesirable toy. However, Hoza, Waschbusch, Pelham, Molina, and Milich, (2000) did not find differences in levels of frustration during a social acquaintance task in a group of boys with and without ADHD, suggesting that emotional reactions in children with ADHD may vary depending on the context (academic versus social; Hoza, Waschbusch, Owens, Pelham, & Kipp, 2001).

A handful of observational studies have also examined emotion regulation in children with ADHD. One study found that young boys without ADHD employed more effective regulatory behaviors than boys with ADHD, and were less able to mask their emotions when instructed to do so while completing a challenging task (Walcott &

Landau, 2004). In addition, Scime and Norvilitis (2006) documented that children with ADHD reported engaging in decreased affect repair and placed less attention on their emotions during a frustration task. Studies have also evidenced that children with ADHD are less able to identify emotions they are experiencing during emotional induction tasks (Norvilitis, Casey, Brooklier, & Bonello, 2000). It is possible that difficulty with identifying emotions may be caused by attentional deficits, as children with ADHD may be unable to attend to parental modeling of emotions. It is also suggestive of a fundamental deficit in the area of emotion processing, which includes attention and identification of emotions.

**ERP components associated with emotion dysregulation in children with mood disorders.** To date, no studies have used ERP to study emotion reactivity and regulation in children with ADHD. However, there is a small body of literature on populations thought to experience impairment in these processes. Using the Affective Posner approach, Rich and colleagues (2005; 2007) found that children with bipolar disorder exhibited reduced parietal P3 amplitude during a frustration task; in contrast, children without bipolar disorder showed a slight increase in P3 during frustration. The authors suggested that children with these mood disorders were less able to regulate emotions in response to frustration, which then interfered with attention to the task at hand (Rich et al., 2005).

Using the emotional go/nogo approach, Lewis and colleagues (2006) have found that clinical groups (e.g., children with anxiety, aggression, conduct problems) show component amplitude differences. Observed increases in N2 amplitude in children with emotional or behavior problems have been interpreted as indicating that in order to

regulate their emotions, children needed to employ increased I cortical resources, which is thus suggestive of impaired emotion regulation abilities (Lewis et al., 2006). Another study by this group of researchers that explored subtypes of aggressive children found that children with comorbid internalizing and externalizing disorders showed greater N2s than children with exclusively externalizing problems in response to the same mood induction (Stieben et al., 2007). Although these studies have not explored emotion reactivity and regulation in children with ADHD, they have laid the groundwork by providing evidence that specific ERPs components are able to detect the effects of emotion in task related cognitive processes, such as attention to stimuli. These studies have also documented differences in the impact of emotion between clinical and typically developing populations. Taken together, these studies support the notion of measuring emotion reactivity and regulation via ERP components.

## **CHAPTER II**

### **THE PRESENT STUDY**

The present study examined emotional reactivity and regulation in young children with ADHD. This study focused on an important context for children's social and emotional functioning: responding to frustration (Batty & Taylor, 2006; Damasio, 1998; Knaus, 2006). Reactions to frustrating situations are critical to children's social and emotional development; children who are highly reactive to frustration are likely to encounter difficulties as they face the many frustrations in their daily lives. In addition, one type of emotional regulation strategy, the suppression of emotion expression, was examined. Emotional suppression has been related to both positive and negative social and emotional outcomes (Schutte, Manes, & Malouff, 2009; Gross & John, 2003). However, the ability to suppress emotion expression together with other regulatory strategies may be a key part of the process of controlling when and how one expresses emotions. Achieving adaptive emotional expression control is of particular importance for preschool-aged children, as it enables the development of more advanced emotion regulation strategies, as well as the development of social competence (Denham, 2007).

The primary focus of this study was on the neural correlates of emotion reactivity and regulation, measured using ERP. This method of assessing emotion reactivity and regulation in children with ADHD appears to be a promising tool for assessing children's internal states during emotional contexts. Behavioral and self-report measures of emotion reactivity and regulation were also examined to add to the small existing literature using these methods with children with ADHD, and to provide converging multimethod information on children's emotion reactivity and regulation. Emotional reactivity,

specifically in the form of negative affect, was measured in directly via coding of emotional behaviors and through child self-report of affect, and indirectly via P3 amplitudes.

In addition to expanding the existing separate literatures on emotion reactivity and regulation as measured via ERPs, self-report of affect, and expressions of negative affect coding, the present study also examined associations amongst the three measures (self-report of affect, expressions of negative affect coding, and ERP). This allowed for an examination of the validity of each measure and provided insight into whether these measures can be used interchangeably. These measure are thought to assess related but distinct constructs or processes. ERPs assessed neural changes that occur when children are placed in emotional contexts. Child self-report of affect assessed the effects of the emotional induction (e.g. Lewis et al., 2006) and provided information about the child's internal emotional experience during the tasks. Behavioral expressions of negative affect coding allowed the researchers to verify the effects of the emotional induction and the regulatory demands of the task. However, the coding of behavioral data directly measured the expression, not necessarily the internal experience, of emotion.

Studying emotional reactivity and regulation in early childhood is of enormous importance, as these years are characterized by increased emotionality, particularly around anger, empathy, shame, and guilt. In turn, early emotional experiences have been hypothesized to play a significant role in the development of sense of self, increase in autonomy, and fostering of positive social relations with peers (Abe & Izard, 1999). Thus, studying these processes at an early age might help bring a better understanding of

the development of later increases in social conflict documented in children with ADHD (Bratten & Rosen, 2000).

By exploring emotional reactivity to frustration and then subsequent ability to suppress this reactivity when requested in a sample of children with ADHD symptoms, this study aimed to increase our understanding of what emotional processes are atypical in this disorder. To better understand emotion reactivity and regulation in children with ADHD symptoms, the following questions were addressed.

**1. Do children with ADHD symptoms demonstrate heightened emotional reactivity compared to typically developing children during a frustrating task?**

- a. Do children with ADHD symptoms report experiencing more negative affect than typically developing children when participating in a frustrating task?

It was expected that all children would report increased negative affect during frustrating blocks compared to baseline trials. However, it was hypothesized that the magnitude of this increase would be larger for the group of children with ADHD symptoms.

- b. Do children with ADHD symptoms demonstrate heightened expression of negative affect compared to typically developing children when participating in a frustrating task?

It was expected that all children would demonstrate heightened negative affect (e.g. frowning, whining, sighing) during frustrating blocks compared to baseline trials.

In line with previous findings of increased reactivity in ADHD samples (Wigal et al., 1998), it was expected that the magnitude of this increase would be larger for the group of children with ADHD symptoms.

- c. Do children with ADHD symptoms demonstrate greater neural reactivity, as measured via ERPs, in response to participation in a frustrating task?

Previous research (Rich et al., 2005) indicates that negative affect typically increases attention as indicated by increased P3. However, in a sample of children with mood dysregulation, decreases in P3 have been documented, perhaps because negative affect interferes with attention in individuals who have difficulty with emotion regulation. Because children with ADHD have been shown to have deficits in emotion regulation (Scime & Norvltis, 2006), it was expected that children with ADHD symptoms will show reduced P3 amplitudes during the frustration block, compared to P3s in the baseline trials. In contrast, because negative affect is thought to increase attention in typically developing children (Rich et al., 2005), we expected children without ADHD symptoms to show larger P3 amplitudes when completing frustrating blocks than when completing baseline blocks.

**2. Do children with ADHD symptoms, compared to typically developing children, demonstrate reduced emotion regulation when they are asked to suppress their emotions during a frustration-eliciting task?**

- a. When asked to suppress emotions during a frustrating task, do children with ADHD symptoms report more negative affect compared to typically developing children?

All children were predicted to show reductions in reports of negative affect when asked to suppress emotions compared to a non-suppression frustration-eliciting task. However, we predicted that asking children with ADHD symptoms to regulate their emotions would likely result in smaller reductions in self-reports of negative affect due to difficulties with emotion regulation (Seymour et al., 2012; Shea & Fisher, 1996).

- b. When asked to suppress their emotions during a frustration task, do children with ADHD symptoms demonstrate smaller reductions in expression of negative affect compared to typically developing children?

We expected all children to show reductions in expressions of negative affect when asked to regulate their emotions compared to a non-suppression condition. Previous research by Scime and Norvilitis (2006) showed children with ADHD symptoms had a reduced ability to engage in effective emotion regulation during frustrating tasks. Therefore, we predicted that compared to typically developing children, children with ADHD symptoms would have more difficulty regulating their emotions and show smaller changes in the expression of negative affect, when switching from a non-suppression to a suppression task.

- c. When asked to suppress their emotions during a frustration task, do children with ADHD symptoms demonstrate reduced emotion regulation abilities, as measured via ERPs?

No studies have examined ERP components when children are asked to suppress emotions during a frustration task, so this part of the study was exploratory. However, child and adult ERP studies have found reductions in the



magnitude of several ERP components after asking their participants to suppress emotional experiences provoked by presenting emotion-eliciting pictures (e.g., Dennis & Hajcak, 2009; Moser, Hajcak, Bukay, & Simons, 2006). These studies suggest that ERPs are sensitive to emotion suppression processes. Because negative affect has been found to increase attention in typically developing children (Rich et al., 2005), effective emotion regulation was hypothesized to lead to a decrease in the intensity of experienced negative affect and thus to a subsequent decrease in P3 amplitudes. It was hypothesized that typically developing children would show decreased P3 amplitudes in the suppression block as compared to the frustration block because they would be successful in decreasing their negative affect. Due to the exploratory nature of this section of the study, it was unknown whether these reductions would lead to P3 amplitudes comparable to those measured in baseline trials. In contrast, it was predicted that children with ADHD symptoms would likely be less successful in regulating their emotions, thus resulting in either no, or very small differences between ERP amplitudes in the suppression block as compared to the frustration block.

## **Method**

### **Participants**

Participants were 54<sup>1</sup> young children between the ages of 4 and 7 ( $M = 6.46$ ,  $SD = 0.73$ ). The sample included 24 children with ADHD symptoms (17 boys) and 30

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<sup>1</sup> A total of 65 children were recruited. Seven children (3 ADHD) were dropped due to equipment failure, refusal to wear EEG cap or excessive movement. Four additional children (3 ADHD) were dropped from the final sample due to demonstrating outlier values ( $>3.29$  SDs away from mean; Tabachnick, & Fidell, 2013) on 5 or more P3 amplitude values of interest (all demonstrated 10 or more outlier values).

typically developing children (TD; 21 boys). The two groups did not significantly differ on gender,  $\chi^2(1) = 0.004$ ,  $p = .95$ , or parental education,  $t(52) = -0.92$ ,  $p = .36$ , (ADHD:  $M = 16.26$ ,  $SD = 1.99$ , TD:  $M = 16.80$ ,  $SD = 2.06$ ). However, children with ADHD symptoms ( $M = 6.64$ ,  $SD = 0.82$ ) were slightly older than their typically developing counterparts ( $M = 6.31$ ,  $SD = 0.63$ ),  $t(52) = 1.63$ ,  $p = .09$ . The sample was predominantly European American (European American = 43; multiethnic = 9, Latino = 1, African American = 1). Parents in the ADHD symptom group were less likely to be married ( $n = 16$ ) than parents of typically developing children ( $n = 28$ ),  $\chi^2(2) = 7.36$ ,  $p = .03$ . They were also significantly younger,  $t(36) = -2.72$ ,  $p = .01$ , (ADHD:  $M = 35.96$ ,  $SD = 6.03$ , TD:  $M = 39.78$ ,  $SD = 3.72$ ).

To be included in the ADHD symptom group, parents had to report at least six symptoms of hyperactivity on the Diagnostic Interview Schedule for Children (NIMH DISC-IV; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). We used hyperactivity symptoms as inclusion criteria rather than inattentive symptoms because ADHD Inattentive Type typically has a later age of onset (Applegate et al., 1997; APA, 2000). Further, research and theory suggests that ADHD Inattentive Type is quite different from the other two subtypes (Barkley, 1997). Parents reported that children in the ADHD symptoms group presented an average of 7.58 ( $SD = 1.10$ ) symptoms of hyperactivity/impulsivity, 5.96 ( $SD = 2.27$ ) symptoms of inattentiveness and 4.83 ( $SD = 1.86$ ) symptoms of ODD. Seventeen children in the ADHD symptom group presented clinically significant symptoms of inattention and 18 met diagnostic criteria for ODD. Children who were taking medication for ADHD were allowed to participate, but were asked to not take their medication in the 48 hours prior to the laboratory visit. Parents

reported that two children were prescribed Guanfacine, 2 were prescribed Adderall and one was taking 5 HTP, an over the counter supplement. Parents reported that all had discontinued their medication regimen at least 48 hours prior to participation, and both drugs have been documented to have duration of actions shorter than 12 hours (Biederman, Lopez, Boellner, & Chandler, 2002; Taylor & Russo, 2001). To be included in the typically developing group, participants had to display no more than three symptoms of hyperactivity on the DISC-IV. Children in the typically developing group were reported to present an average of 0.50 (SD = 0.82) symptoms of hyperactivity/impulsivity, 0.73 (SD = 1.34) symptoms of inattentiveness and 1.57 (SD = 1.74) symptoms of ODD. Six children in this group met diagnostic criteria for ODD, and no children presented significant symptoms of inattention. To be included in either group, children--via parental report--could not present evidence of intellectual disabilities, hearing or visual disabilities, receptive language delay, cerebral palsy, epilepsy, autism, or psychosis.

### **Procedure.**

Subjects for the typically developing group were recruited mainly through the University of Massachusetts Child Studies Data Base. Participants within our age range of interest were mailed or emailed an invitation to participate in the study, along with a consent form for a screening interview with the parent. This invitation was followed up with a phone call from our research team assessing their interest in participating. To recruit children with hyperactivity, advertisements for the study were placed in pediatrician offices and community centers around the Western Massachusetts area and mailed to parents in the Child Studies Database. For both groups, a phone interview

assessing the child's eligibility to participate was conducted using the ADHD and ODD sections of the NIMH DISC-IV (Shaffer et al., 2000) along with a set of questions assessing for exclusion criteria. This phone interview lasted no more than 30 minutes. Eligible families were scheduled for an appointment. All families were paid \$20 for their participation. Parents with hyperactive young children were offered a four-session complimentary parenting training group. This project was approved by the University of Massachusetts-Amherst Institutional Review Board.

Upon arrival, parents signed consent documents and children provided verbal assent. Parents completed 1) a demographic questionnaire; 2) the BASC-2 PRS (Reynolds, & Kamphaus, 2004), and 3) the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997). Graduate students conducted all sessions with the assistance of undergraduate research assistants. After consent was complete, the child was fitted with the cap for EEG/ERP collection.

**Frustration task.** Children completed a modified Affective Posner task (Pérez-Edgar & Fox, 2005). For this computerized task, children viewed a white fixation cross that appeared in the center of the computer screen for 750ms, followed by three boxes (presented as underwater treasure chests) arranged horizontally for 300ms. A cue was then presented for 200ms as a white dot that appeared in one of the boxes. Cues appeared in the central box on 20% of trials, and in the right and left boxes on 40% of the trials each. Immediately following cue presentation, a target, in the form of a yellow star, appeared in one of the boxes. The children were instructed to press the button corresponding to the location of the yellow star that remained on the screen until a response was given, for a maximum time of 1250ms (see Figure 1).

There were three trial types: valid, invalid, and control. For valid trials, the cue and target appeared in the same location. In invalid trials, the cue appeared in the outermost box opposite from where the target appeared. In control trials, the cue appeared in the center of the screen, and the target appeared on either the right or left boxes. Children completed 236 trials total across 4 blocks of the affective Posner task. Trial distribution within each block was 40% valid trials, 40% invalid trials, and 20% control trials. Trials were presented in a pseudo-random order; all participants were presented the stimuli in the same order.

Before starting the task, the children were told that the computer was having some problems and that at times the buttons got “mixed up”. They were also told that the team was trying to fix the problem, and that they should continue playing even if the buttons did not seem to be working right. Feedback was provided after every trial and indicated if the child had pressed the correct button. A “thumbs up” icon appeared if the trial was correct, and a “thumbs down” appeared if the trial was incorrect (i.e., wrong button press or no button press). Before children began the task, they were given an “underwater passbook,” and told that in order to complete the adventure they had to collect stamps. To get their passbook stamped, they needed to collect as many points as possible in each block. Children were told that after receiving four stamps, they would earn a prize. The task, including breaks between blocks, lasted approximately 18 minutes.

To induce frustration, the task was administered in four blocks and each block represented a differing affective condition (see Figure 2):

1) **Baseline Block**. Children were told that they would win or lose points for every correct and incorrect response, respectively. This condition was affectively

‘neutral’ and consisted of 40 trials. Children were given a stamp on their passbook after this block.

2) **Emotional Reactivity Block**. This condition was identical in structure to the baseline block but was designed to induce negative affect by creating frustration similar to the frustration that children often experience in their daily lives when toys or games do not work properly. It consisted of 78 trials. On 40% of these trials ( $n = 30$  trials), the button ostensibly did not work and children received inaccurate feedback that their response was incorrect. At the end of this block children were told that they did not collect enough points to be given a stamp in their passbook, but that they would receive another chance to do so. Children were reminded that we were experiencing problems with the computer, and to keep playing if the button did not work.

3) **Emotional Suppression Block**. This condition was structurally identical to the emotional reaction condition in terms of trials and inaccurate feedback; however, children were explicitly asked to suppress any display of emotions. In accordance with Bar-Haim, Bar-Av, and Avi Sadeh (2011) children were told to play so that “no one is able to know by your behavior whether you are winning or losing the game.” It consisted of 78 trials. This condition was intended to continue to elicit negative affect but simultaneously ask children to regulate their emotional expressions. At the end of this block, children were told that because the computer had been malfunctioning, they would get a stamp for both this block and the prior one.

4) **Recovery Block**. This condition was designed to allow the children to engage in the game again without frustration to allow them to return to a more positive affective state before leaving the laboratory; thus the button ‘worked properly’ once again. It

consisted of 40 trials. Children were given the final stamp on their passbook after this block.

**Self-report emotion check.** Children's experienced emotions were assessed throughout the study to obtain a measure of child-reported emotion. Children's experienced emotions were assessed with a subjective rating scale administered after each block of the frustration task. Five images depicting thermometers with increasing amounts of liquid were presented to the children. Children were asked to rate, by choosing a thermometer, how much happiness, sadness, and frustration they were feeling.

At the end of the study, subjects were provided with a prize and thanked for their participation. Parents were provided with compensation and also thanked for their participation.

**Emotion expression coding.** To assess children's emotional expressivity, both expressed affect and regulatory behaviors were coded throughout Affective Posner task. The coding system was developed by the researchers and based on an existing system designed to assess emotional expression and suppression in children (Davis, 1995). The presence/absence of positive and negative affect was coded for each 5-second epoch. Expressions of negative affect were also coded for intensity (0 = no affect, 1 = mild, 2 = moderate/strong). If negative affect was coded, the coder further specified whether the affect was a display of anger/frustration/annoyance, sadness, or worry/distress. Specific emotion reactivity and regulation behaviors were also coded. These included problem solving, seeking help, cognitively reappraising the situation, focusing on the negative, temporarily disengaging, shutting down and engaging in disruptive behaviors. Positive affect and all emotion regulation behaviors occurred very infrequently, and were thus not

included in analyses. Ratings of negative affect were summed across epochs for each block, and divided by the total number of epochs in each block, to account for the longer duration of the some blocks.

Three undergraduate research assistants, unaware of the participant's group status, coded tapes. Sixteen of the tapes were coded by two research assistants to evaluate interrater reliability. To assess interrater reliability, AC1 (sometimes referred to as the first-order agreement coefficient) coefficients were calculated for each category of negative affect. The AC1, similarly to kappa, is a measure of percent agreement that corrects for chance agreement (Wongpakaran et al., 2013). However, it is better suited for codes that have low prevalence rates. AC1 scores were .77 for overall negative affect, .87 for anger/frustration/annoyance, .99 for sadness and .90 for distress/worry.

### **Psychophysiological Recording and Data Reduction**

EEG was continuously recorded from Ag–AgCl electrodes attached to the scalp with a 64-channel Lycra Electro-Cap setup in accordance with the International 10–20 System. The main electrode sites of interest for the current study were F3, Fz, F4, C3, Cz, C4, CP3, CPz, CP4, P3, Pz and P4. NeuroScan amplifiers (with 16-bit A–D conversion) were set for high and low band pass at .01 to 100 Hz, respectively, and EEG was amplified at 1000 Hz. Impedances were maintained below 10 k $\Omega$ . Vertical eye movements were detected through two channels of electrooculogram (EOG), recorded from facial electrodes above and below the outer canthus of the left eye and two electrodes were placed on the left and right mastoids. Data were re-referenced off-line to an average mastoid reference and filtered with a 30 Hz filter (24 db/Oct). Ocular artifacts were regressed from the data in accordance with Gratton, Coles, and Donchin (1983).



EEG epochs that exceed +/- 150 uV were excluded. EEG epochs were baseline corrected and averaged for each block.

ERPs were constructed by averaging amplitudes separately for each target type. There were three target types those that were preceded by a cue in the same location (valid trials), those preceded by a cue in the opposite location (invalid trials), and those preceded by a cue in the central box (control trials). Averages were created separately for each block. The analyses focused on the mean amplitude of the P300 scored in a window of 130–400ms post stimulus onset with a 200ms pre-stimulus baseline. Trials with response times faster than 200ms and participants with fewer than 15 usable ERP trials per block were excluded from analysis. The total number of usable trials ranged from 16-40 (M = 34.28) for the baseline and recovery blocks and from 38-78 (M = 64.54) for the frustration and suppression blocks.

## **Measures**

**Demographic questionnaire.** Parents completed a short demographic questionnaire assessing contextual variables such as parent's age, marital status, parent education, and race.

**Behavior Assessment System for Children-Second Edition (BASC-2).** This rating scale assesses a broad range of psychopathology in children ages 2-21 (Reynolds & Kamphaus, 1992). The Preschool version of the BASC-2 Parent Rating Scale was used for 4- and 5-year-old children (PRS-P), and the Child version (PRS-C) was used for 6- and 7-year-old children. The scales are comprised of 134 and 160 items, respectively. These items are rated by the parent on a 4-point Likert scale that ranges from “never” to “almost always”. Four composite indexes are derived (adaptive skills, behavioral

symptom index, and externalizing and internalizing problems). The BASC-2 also yields a number of clinical scales (anxiety, aggression, attention problems, atypicality, conduct problems, depression, hyperactivity, somatization, and withdrawal). This instrument was included to assess for the presence of other co-occurring symptoms. The BASC has good reliability (.84 for the PRS-P and .92 for the PRS-C behavioral symptom indexes) and moderate validity (.75 for the PRS-P and .84 for the PRS-C emotional behavioral symptom indexes) in both school-aged and preschool samples (Reynolds & Kamphaus, 1992).

**Diagnostic interview.** The ADHD and ODD subscales of the DISC-IV were administered to parents by phone during the screening. The NIMH DISC-IV is a structured diagnostic interview that assesses for 30 pediatric psychiatric disorders (Shaffer et al, 2000). The NIMH-DISC-IV is commonly used with children aged 6 and older, and recent evidence documents its utility and adequacy in assessing children as young as 4 years old (Rolon-Arroyo, Arnold, Harvey, & Marshall, 2015). The DISC-IV has been showed to have adequate test-retest reliability with older children for the ADHD sections (.79; Shaffer et al, 2000).

**Maternal report of child emotion regulation.** Mothers completed the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997), a 24-item questionnaire that measures children's reactions to emotion eliciting events. Whereas the emotion regulation subscale assesses appropriate emotional behaviors, the lability–negativity subscale measures reactivity and mood dysregulation. The ERC has overall good validity and the lability/negativity and emotion regulation subscales have good reliability ( $\alpha = .96$

and  $\alpha = .83$ , respectively; Shields & Cicchetti, 1997). Items are rated by parents on how characteristic each item is of the child from 1 (rarely/never) to 4 (almost always).

## CHAPTER III

### RESULTS

#### **Parental Reports of Child Emotion Regulation and Behavior**

To assess group differences in parental reports of child emotion regulation and behavior, a series of one-way ANOVAs were conducted. On the Emotion Regulation Checklist, parents reported that children with ADHD symptoms displayed greater emotional lability and fewer emotion regulation skills. Parents reported on the BASC-2 that children with ADHD symptoms exhibited significantly more hyperactivity, aggression, and depression. Children with ADHD symptoms were also elevated on atypically, attention problems, and behavior symptoms, and scored lower on adaptability, activities of daily living, functional communication, social skills, and adaptive skills (refer to Table 1).

#### **Children's Self Reports of Affect**

Children's self-report of affect throughout the task was examined by conducting a mixed design ANOVA for each one of the three emotions assessed. Block was entered as a within-subjects factor and group as a between-subjects factor. Significant interactions were further explored by conducting separate repeated measures ANOVAs for each group, as well as by conducting one-way ANOVAs for each block. To directly compare magnitude of change in self-reported affect across blocks between the groups, change scores between each of the four blocks (baseline, frustration, suppression and recovery) were created for each affect variable (frustration, happiness and sadness). Specifically, change scores were created to assess the difference between baseline and frustration ( $\Delta$ Frustration), frustration and suppression ( $\Delta$ Suppression), and suppression and recovery

( $\Delta$ Recovery). Group differences in these self-report affect change scores were evaluated by conducting one-way ANOVAs with group entered as a between subjects factor.

**Self-reports of frustration.** Analyses revealed a significant main effect of block,  $F(3, 129) = 13.87, p < .001$ . Overall, children reported experiencing significantly greater levels of frustration during the frustration ( $M = 1.52, SE = 0.23$ ),  $F(1, 43) = 20.81, p < .001$ , and suppression blocks ( $M = 1.75, SE = 0.24$ ),  $F(1, 43) = 23.95, p < .001$ , compared to the baseline block ( $M = 0.60, SE = 0.13$ ). They also reported experiencing less frustration during the recovery block ( $M = 0.67, SE = 0.16$ ) compared to the frustration,  $F(1, 43) = 17.83, p < .001$ , and suppression,  $F(1, 43) = 16.38, p < .001$ , blocks. The main effect of group was not significant,  $F(1, 43) = 2.30, p = .14$ .

Analyses revealed a significant Block X Group interaction,  $F(3, 129) = 5.75, p = .001$ . To explore this interaction, separate one-way ANOVAs were conducted for each block. Self-reported frustration only differed significantly between the groups in the suppression block, where children with ADHD symptoms reported experiencing more frustration,  $F(1, 43) = 8.88, p = .01$ , than typically developing children. Means and standard deviations are displayed in Table 2 and Figure 3.

To further explore the Block X Group interaction, separate repeated measures ANOVA were then conducted for each group, with block entered as the within-subjects factor. Repeated measures contrasts indicated that each group demonstrated a similar pattern to the one described above, reporting higher levels of frustration during the frustration block, compared to baseline (TD:  $F(1, 22) = 4.88, p = .04$ , ADHD:  $F(1, 21) = 15.59, p = .001$ ). Both groups also reported lower levels of frustration during the recovery block, compared to frustration (TD:  $F(1, 22) = 6.48, p = .02$ , ADHD:  $F(1, 21) = 11.23, p$

=.003) and suppression, (TD:  $F(1, 22) = 4.35, p < .05$ , ADHD:  $F(1, 21) = 11.85, p = .002$ ). However, children with ADHD symptoms reported experiencing significantly more frustration during their suppression block, compared to their baseline,  $F(1, 21) = 25.12, p < .001$ , whereas typically developing children did not,  $F(1, 22) = 1.13, p = .30$ .

Finally, to directly examine group differences in the magnitude of change in self-reported frustration from one block to another, a one-way ANOVA with group as the between subjects factor was conducted on the baseline-frustration change scores ( $\Delta$ Frustration), the frustration-suppression change scores ( $\Delta$ Suppression), and the suppression-recovery change scores ( $\Delta$ Recovery). Results are displayed in Figure 4. These analyses revealed that the  $\Delta$ Frustration scores in self-reported frustration,  $F(1, 42) = 6.03, p = .02$ , were significantly different between groups. Children with ADHD symptoms reported a larger increase in frustration from the baseline to frustration block ( $M = 1.47, SD = 1.63$ ) compared to typically developing children ( $M = 0.44, SD = 1.04$ ). Analyses revealed that changes in frustration between the frustration and suppression block were not significantly different between the two groups,  $F(1, 42) = 1.74, p = .19$ . Finally, children with ADHD symptoms (ADHD:  $M = -1.52, SE = 2.29$ ) reported a larger reduction, at trend level, in frustration in  $\Delta$ Recovery,  $F(1, 42) = 3.69, p = .06$ , than typically developing children (TD:  $M = -0.49, SD = 0.99$ ).

**Self-reports of happiness.** Analyses yielded a main effect of block,  $F(3, 138) = 8.23, p < .001$ . Overall, children reported significantly more happiness during the baseline ( $M = 4.58, SE = 0.15$ ),  $F(1, 45) = 8.71, p = .01$ , frustration, ( $M = 4.32, SE = 0.17$ ),  $F(1, 45) = 5.83, p = .02$ , and recovery blocks ( $M = 4.79, SE = 0.09$ )  $F(1, 45) = 15.65, p < .001$ , than during the suppression block ( $M = 3.74, SE = 0.25$ ). Children also

reported less happiness during the frustration block than during the recovery block,  $F(1, 45) = 6.13, p = .02$ . There was no significant main effect of group,  $F(1, 45) = 0.08, p = .78$ . The Block X Group interaction was marginally significant,  $F(3, 135) = 2.53, p = .06$ . A one-way ANOVA conducted with the change scores revealed that children with ADHD symptoms (ADHD:  $M = -0.91, SD = 1.90$ ) demonstrated larger decreases, at trend level, in self-reported happiness in  $\Delta$ Suppression scores,  $F(1, 42) = 3.36, p = .07$ , than typically developing children (TD:  $M = -0.35, SD = 1.16$ ).

**Self-reports of sadness.** Analyses yielded a main effect of block,  $F(3, 129) = 8.92, p < .001$ . Overall, children reported significantly more sadness during the frustration ( $M = 1.07, SE = 0.20$ ),  $F(1, 43) = 14.96, p < .001$ , and suppression blocks ( $M = 1.30, SE = 0.24$ ),  $F(1, 43) = 16.38, p < .001$ , compared to the baseline block ( $M = 0.45, SE = 0.10$ ). They also reported less sadness during the recovery block ( $M = 0.60, SE = 0.15$ ), compared to the frustration,  $F(1, 43) = 7.52, p = .01$ , and suppression blocks,  $F(1, 43) = 9.17, p = .01$ . There was not a main effect of group,  $F(1, 43) = 1.45, p = .24$ .

A significant Block X Group interaction was detected,  $F(3, 128) = 2.93, p = .04$ . To interpret this interaction, one-way ANOVAs conducted separately for each block revealed that during the suppression block,  $F(1, 43) = 3.15, p = .08$ , children with ADHD symptoms reported more sadness, at a trend level. To further explore the interaction, repeated measures ANOVAs were conducted separately for each group, with block entered as the within-subjects factor. Repeated measures contrasts conducted separately for each group indicated that both groups reported more sadness in the frustration (TD:  $F(1, 22) = 11.73, p = .002$ ; ADHD:  $F(1, 21) = 8.33, p = .01$ ) and suppression blocks (TD:  $F(1, 22) = 9.91, p = .01$ ; ADHD:  $F(1, 21) = 9.80, p = .01$ ) compared to the baseline block.

However, children with ADHD symptoms also reported less sadness during their recovery block, compared to their frustration,  $F(1, 21) = 6.28, p = .02$ , and suppression blocks,  $F(1, 21) = 7.23, p = .01$ .

Finally, one-way ANOVAs revealed that the changes in self-reported sadness between the baseline and frustration blocks assessed as  $\Delta$ Frustration scores were different, at a trend level, between groups,  $F(1, 42) = 3.53, p = .07$ . Children with ADHD symptoms demonstrated a larger increase in self-reported sadness in (ADHD:  $M = 0.95, SD = 1.51$ ) compared to typically developing children (TD:  $M = 0.31, SD = 0.49$ ). Groups did not differ in  $\Delta$ Suppression scores for sadness,  $F(1, 42) = 0.32, p = .56$ . However, children with ADHD symptoms (ADHD:  $M = -1.08, SE = 0.31$ ) reported significantly greater reductions in sadness assessed via  $\Delta$ Recovery scores,  $F(1, 42) = 4.48, p = .04$ , than typically developing children (TD:  $M = -0.15, SE = 0.30$ ).

### **Expression of Negative Affect**

To assess group differences in patterns of expressed negative affect across blocks, separate mixed design ANOVAs were conducted for overall negative affect as well as each subtype of negative affect (Anger, Distress/Worry, and Sadness). Block was entered as a within-subjects factor and group as a between-subjects factor. Significant interactions were further explored by conducting repeated measures contrasts separately for each group and follow up one-way ANOVAs were run separately for each block. To directly compare differences in expressed negative affect across blocks, change scores were created representing change in expressed emotion between each of the four blocks ( $\Delta$ Frustration,  $\Delta$ Suppression, and  $\Delta$ Recovery). Group differences in the change scores were then evaluated by conducting a one-way ANOVA with group entered as a between



subjects factor. Means and standard deviations are displayed in Table 3, Figure 5, and Figure 6.

**Overall negative affect.** There was a significant main effect of block,  $F(3, 156) = 16.66, p < .001$ , for children's expressions of overall negative affect. Repeated measures contrasts indicated that children displayed significantly more overall negative affect during the frustration ( $M = 0.18, SE = 0.02$ ),  $F(1, 51) = 24.05, p < .001$ , and suppression blocks ( $M = 0.17, SE = 0.02$ ),  $F(1, 51) = 12.57, p = .001$ , compared to the baseline block ( $M = 0.08, SE = 0.02$ ). Children also displayed less negative affect during the recovery block ( $M = 0.07, SE = 0.02$ ), compared to the frustration,  $F(1, 51) = 25.23, p < .001$ , and suppression blocks,  $F(1, 51) = 22.70, p < .001$ . Results also indicated a significant main effect of group,  $F(1, 52) = 9.19, p = .01$ , such that children with ADHD symptoms ( $M = 0.17, SE = 0.02$ ) exhibited significantly more negative affect across all blocks than typically developing children ( $M = 0.08, SE = 0.02$ ). The Group X Block interaction was not significant,  $F(3, 156) = 0.73, p = .53$ . One-way ANOVAs revealed differences, at a trend level, in  $\Delta$ Suppression scores for negative affect,  $F(1, 42) = 3.50, p = .06$ , where children with ADHD symptoms ( $M = 0.24, SD = 0.14$ ) demonstrated a smaller decrease in expressions of negative affect across the two blocks than typically developing children ( $M = -0.59, SD = 0.14$ ).

**Anger.** Expressions of anger followed a very similar pattern. There was a significant main effect of block,  $F(3, 156) = 13.31, p < .001$ , and follow-up repeated measures contrasts demonstrated that children displayed significantly more anger during the frustration ( $M = 0.13, SE = 0.02$ ),  $F(1, 51) = 14.87, p < .001$ , and suppression blocks ( $M = 0.13, SE = 0.02$ ),  $F(1, 51) = 8.00, p = .01$ , compared to the baseline block ( $M =$

0.06, SE = 0.01). Children also displayed less anger during the recovery block (M = 0.04, SE = 0.02), compared to the frustration,  $F(1, 51) = 20.32, p < .001$ , and suppression blocks,  $F(1, 51) = 17.70, p < .001$ . Analyses also yielded a main effect of group,  $F(1, 52) = 10.37, p = .01$ . Children with ADHD symptoms (M = 0.12, SE = 0.02) exhibited more anger than typically developing children (M = 0.05, SE = 0.01). The Group X Block interaction was not significant,  $F(3, 156) = 0.84, p = .48$ . One-way ANOVAS conducted with the change scores revealed that the magnitude of the decrease in displays of anger reflected in  $\Delta$ Suppression scores was significantly larger for typically developing children (M = -0.62, SD = 0.11) than for children with ADHD symptoms (M = 0.16, SD = 0.16),  $F(1, 42) = 5.04, p = .03$ .

**Distress/worry.** There was a significant main effect of block for distress/worry,  $F(3, 156) = 5.55, p = .001$ . Repeated measures contrasts indicated that children displayed significantly more distress/worry during the frustration (M = 0.04, SE = 0.01),  $F(1, 51) = 9.61, p = .01$ , and suppression blocks (M = 0.05, SE = 0.01),  $F(1, 51) = 6.99, p = .01$ , compared to the baseline block (M = 0.01, SE = 0.01). Children also displayed less distress/worry during the recovery block (M = 0.03, SE = 0.01), compared to the baseline block,  $F(1, 51) = 4.02, p = .05$ . There was not a main effect of group,  $F(1, 52) = 0.30, p = .59$ , nor a significant Group X Block interaction,  $F(3, 156) = 0.44, p = .68$ . One-way ANOVAS did not reveal between-group differences in change scores across any blocks.

**Sadness.** There was a significant main effect of block for sadness,  $F(3, 156) = 3.56, p = .02$ . Repeated measures contrasts indicated that children displayed significantly more sadness during the suppression block (M = 0.03, SE = 0.01),  $F(1, 51) = 3.92, p = .05$ , than during the baseline block (M = 0.01, SE < 0.01). Children also demonstrated

significantly less sadness during the recovery block, ( $M = 0.01$ ,  $SE < 0.01$ ), than during the suppression block,  $F(1, 51) = 6.36$ ,  $p = .02$ . There was also a main effect of group,  $F(1, 52) = 8.33$ ,  $p = .01$ . Across blocks, children with ADHD symptoms ( $M = 0.03$ ,  $SE = 0.01$ ) demonstrated higher levels of sadness than typically developing children ( $M = 0.003$ ,  $SE = 0.01$ ).

The Block X Group interaction was also significant,  $F(3, 156) = 3.15$ ,  $p = .03$ . To follow-up this interaction one-way ANOVAs were conducted for each block. Groups only differed in the suppression block, where children with ADHD symptoms demonstrated significantly more sadness,  $F(1, 52) = 6.90$ ,  $p = .01$ . Repeated measures contrasts conducted separately for each group indicated that typically developing children demonstrated significantly more sadness in their frustration block, compared to their recovery block,  $F(1, 29) = 4.33$ ,  $p = .049$ . In contrast, children with ADHD symptoms demonstrated significantly more sadness during their suppression block, compared to their recovery block,  $F(1, 22) = 4.70$ ,  $p = .04$ . One-way ANOVAs utilizing change scores revealed significant group differences in sadness assessed via  $\Delta$ Suppression scores,  $F(1, 42) = 6.97$ ,  $p = .01$ , as well as  $\Delta$ Recovery scores,  $F(1, 42) = 9.03$ ,  $p = .01$ . Specifically, children with ADHD symptoms demonstrated a greater increase in sadness from the frustration to suppression block (TD:  $M = -0.01$ ,  $SD = 0.01$ , ADHD:  $M = 0.04$ ,  $SD = 0.08$ ) and a greater decrease in sadness from the suppression to recovery block (TD:  $M = 0.01$ ,  $SD = 0.01$ , ADHD:  $M = -0.05$ ,  $SD = 0.08$ ) compared to typically developing children.

## Accuracy and Reaction Times

To assess group differences in accuracy and reaction time across blocks, a set of mixed design ANOVAs were conducted. Block was entered as a within-subjects factor and group as a between-subjects factor. See Table 4 and Figure 7 for means and standard deviations.

**Accuracy.** Analyses yielded a main effect of block,  $F(3, 156) = 15.92, p < .001$ . Children demonstrated significant decreases in accuracy from the baseline block ( $M = 90.13, SE = 1.26$ ), to the frustration ( $M = 81.99, SE = 1.64$ ),  $F(1, 43) = 61.23, p < .001$ , and suppression blocks ( $M = 80.84, SE = 1.56$ ),  $F(1, 43) = 50.70, p < .001$ . They also had significantly higher accuracy during the recovery block ( $M = 87.55, SE = 1.98$ ), compared to the frustration,  $F(1, 43) = 10.14, p = .002$ , and suppression blocks,  $F(1, 43) = 11.42, p = .001$ . There was not a main effect of group,  $F(1, 52) = 15.92, p = .13$ . The Group X Block interaction was not significant,  $F(3, 156) = 0.80, p = .50$ . Group differences in the magnitude of change in accuracy from one block to another were assessed by conducting a one-way ANOVA with group as the between subjects factor on the  $\Delta$ Frustration,  $\Delta$ Suppression, and  $\Delta$ Recovery scores. One-way ANOVAs did not reveal between-group differences in change scores across any blocks.

**Reaction Time.** A significant main effect of block,  $F(3, 156) = 12.60, p < .001$ , was detected. Children demonstrated slower reaction times during the baseline ( $M = 544.84, SE = 21.48$ ),  $F(1, 52) = 16.07, p < .001$ , frustration ( $M = 540.57, SE = 20.16$ ),  $F(1, 52) = 20.05, p < .001$ , and suppression blocks ( $M = 519.94, SE = 18.31$ ),  $F(1, 52) = 9.44, p = .003$ , compared to the recovery block ( $M = 479.38, SE = 19.60$ ). Children also demonstrated significantly slower reaction times during the baseline,  $F(1, 52) = 6.07, p =$

.02, and frustration blocks,  $F(1, 52) = 8.63$ ,  $p = .01$ , compared to the suppression block. Neither the main effect of group,  $F(1, 52) = 1.28$ ,  $p = .26$ , nor the interaction between the two,  $F(3, 156) = 0.01$ ,  $p = .99$ , were significant. Finally, one-way ANOVAS did not reveal between-group differences in reaction time change scores across any blocks.

### **Neural Correlates**

To assess group differences in mean P3 amplitudes across blocks, a mixed design ANOVA was conducted with all four regions of interest (frontal, frontocentral, central and parietal) included. Region, site, and block were entered as within-subjects factors and group was entered as a between-subjects factor. Because the main effect of region was significant,  $F(3, 150) = 3.81$ ,  $p = .01$ , a set of mixed design ANOVAs were then conducted to examine patterns at each region separately. Site and block were entered as within-subjects factors and group as a between-subjects factor.

**Frontal Region.** No main effects emerged for the frontal region (F3, Fz, F4); however, a marginally significant three-way interaction was found between group, block, and site,  $F(6, 306) = 1.83$ ,  $p = .09$ . To examine the interaction, mixed design ANOVAs were conducted separately for each site (F3, Fz, & F4) and then significant interactions were followed up by conducting one-way ANOVAs for each individual block. Change scores were created ( $\Delta$ Frustration,  $\Delta$ Suppression and  $\Delta$ Recovery) to directly compare differences in P3 amplitudes across blocks. Group differences in these scores were then assessed by conducting a one-way ANOVA with group entered as a between subjects factor.

For the left frontal site of F3, analyses revealed trend level main effects of block,  $F(3, 153) = 2.53$ ,  $p = .06$ , and group,  $F(1, 51) = 2.85$ ,  $p = .10$ , that were qualified by a

significant Group X Block interaction,  $F(3, 153) = 2.72, p = .045$ . The follow-up one-way ANOVA revealed a significant group difference in the recovery block,  $F(1, 52) = 6.43, p = .01$ , where typically developing children ( $M = 5.04, SD = 4.68$ ) demonstrated larger P3 amplitudes, compared to children with ADHD symptoms ( $M = 1.81, SD = 4.61$ ).

Repeated measures contrasts conducted separately for each group at F3 indicated that typically developing children demonstrated enhanced P3s during their frustration ( $M = 3.10, SD = 3.64$ ),  $F(1, 28) = 6.17, p = .02$ , suppression ( $M = 3.43, SD = 2.59$ ),  $F(1, 28) = 8.04, p = .01$ , and recovery blocks ( $M = 5.12, SD = 4.74$ ),  $F(1, 28) = 14.34, p = .001$ , compared to their baseline block ( $M = 1.42, SD = 3.10$ ). Typically developing children also demonstrated significantly larger P3s in their recovery block,  $F(1, 28) = 4.20, p = .05$ , and marginally significantly larger P3s in their suppression block,  $F(1, 28) = 3.73, p = .06$ , compared to their frustration block. In contrast, for children with ADHD symptoms, the main effect of block was not significant,  $F(3, 69) = 0.36, p = .79$ , and repeated measures contrasts confirmed that children with ADHD symptoms did not demonstrate any significant changes in P3 amplitudes across any blocks. ANOVAs comparing change scores did not reveal significant differences between the groups at F3 in the  $\Delta$ Frustration scores,  $F(1, 51) = 0.38, p = .54$ ,  $\Delta$ Suppression scores,  $F(1, 51) = 0.60, p = .44$ , or  $\Delta$ Recovery scores,  $F(1, 51) = 1.73, p = .19$ . Grand mean waveforms are presented in Figures 9 and 10.

For the frontal midline site of FZ, there was not a main effect block,  $F(3, 153) = 2.72, p = .17$ ; however, the main effect of group was significant,  $F(1, 51) = 4.50, p = .04$ . Across all blocks, typically developing children ( $M = 3.01, SE = 0.39$ ) demonstrated

larger P3 amplitudes, compared to children with ADHD symptoms ( $M = 1.79$ ,  $SE = 0.43$ ). The Group X Block interaction was not significant,  $F(3, 153) = 1.78$ ,  $p = .32$ , nor were the ANOVAs comparing groups'  $\Delta$ Frustration,  $\Delta$ Suppression, or  $\Delta$ Recovery scores for this site.

For the right frontal site of F4, the main effect of block,  $F(3, 153) = 2.14$ ,  $p = .10$ , was marginally significant. There was not a main effect of group  $F(1, 51) = 1.11$ ,  $p = .30$ , or a Group X Block interaction,  $F(3, 153) = 0.62$ ,  $p = .63$ . ANOVAs conducted on  $\Delta$ Frustration,  $\Delta$ Suppression, and  $\Delta$ Recovery scores did not reveal significant differences between the groups at the F4 site.

**Frontocentral Region.** For the frontocentral region (sites FC3, FCz, FC4), the main effect of block was significant,  $F(3, 153) = 2.77$ ,  $p = .04$ . Children demonstrated larger P3 amplitudes during the frustration ( $M = 3.01$ ,  $SE = 0.45$ ),  $F(1, 51) = 7.813$ ,  $p = .01$ , suppression ( $M = 2.71$ ,  $SE = 0.44$ ),  $F(1, 51) = 3.95$ ,  $p = .05$ , and recovery blocks ( $M = 3.12$ ,  $SE = 0.55$ ),  $F(1, 51) = 12.32$ ,  $p = .03$ , compared to the baseline block ( $M = 1.54$ ,  $SE = 0.47$ ). A marginally significant main effect of group was detected,  $F(1, 51) = 3.86$ ,  $p = .055$ . Across all blocks, typically developing children ( $M = 3.19$ ,  $SE = 0.41$ ) displayed marginally larger P3s at the frontocentral region than children with ADHD symptoms ( $M = 12.01$ ,  $SE = 0.45$ ).

A significant Group X Block interaction was also detected,  $F(3, 153) = 2.68$ ,  $p = .049$ . To understand between group differences for each block, a set of separate one-way ANOVAs were conducted. Analyses revealed significant group differences for the recovery block,  $F(1, 52) = 8.85$ ,  $p = .004$ , where typically developing children ( $M = 4.71$ ,  $SE = 0.72$ ) demonstrated larger P3 amplitudes compared to children with ADHD

symptoms ( $M = 1.49$ ,  $SE = 0.81$ ). To examine change over blocks, separate repeated measures ANOVA were conducted for each group, with block entered as the within-subjects factor. Repeated measures contrasts indicated that typically developing children demonstrated enhanced P3s during their frustration ( $M = 3.30$ ,  $SE = 0.60$ ),  $F(1, 28) = 6.31$ ,  $p = .02$ , suppression ( $M = 3.16$ ,  $SE = 0.55$ ),  $F(1, 28) = 4.82$ ,  $p = .01$ , and recovery blocks ( $M = 4.74$ ,  $SE = 0.72$ ),  $F(1, 28) = 11.83$ ,  $p = .002$ , compared to their baseline block ( $M = 1.55$ ,  $SE = 0.58$ ). They also demonstrated marginally significant increases in P3 during their recovery block, compared to their frustration,  $F(1, 28) = 3.78$ ,  $p = .06$ , and suppression blocks,  $F(1, 28) = 3.94$ ,  $p = .06$ . In contrast, for children with ADHD symptoms, the main effect of block was not significant,  $F(3, 69) = 0.75$ ,  $p = .53$ , and repeated measures contrasts confirmed that children with ADHD symptoms did not demonstrate any significant changes in P3 amplitudes across any blocks.

ANOVAs comparing change scores only yielded marginally significant group differences in  $\Delta$ Suppression scores,  $F(1, 52) = 3.00$ ,  $p = .09$ . Children with ADHD symptoms ( $M = -1.53$ ,  $SE = 1.07$ ) demonstrated decreases in P3 amplitudes from suppression to recovery, whereas typically developing children exhibited increases in P3 amplitudes between these blocks ( $M = 1.01$ ,  $SE = 0.96$ ). Grand mean waveforms are displayed in Figures 9 and 11.

**Central Region.** For the central region, the main effects of block,  $F(3, 153) = 2.37$ ,  $p = .07$ , and group,  $F(1, 51) = 2.92$ ,  $p = .09$ , were significant at trend level. There was no significant Group X Block interaction,  $F(3, 153) = 1.76$ ,  $p = .16$ . Due to the lack of significant interaction, no follow-up analyses were conducted. However, visual inspection of the data suggested that children with ADHD demonstrated smaller P3



amplitudes across all blocks and that both groups demonstrated larger P3 amplitudes during the frustration and suppression blocks, compared to baseline.

**Parietal Region.** For the parietal region, there was not a main effect block,  $F(3, 153) = 1.32, p = .27$ . The main effect of group was marginally significant,  $F(1, 51) = 3.02, p = .09$ , and visual examination of the data suggested that children with ADHD demonstrated smaller P3 amplitudes across all blocks. The Group X Block interaction was not,  $F(3, 153) = 1.70, p = .26$ , thus no follow up analyses were conducted.

### **Intercorrelations Among Outcome Measures**

To examine relations among outcome measures, intercorrelations were conducted between children's self-reports of emotions, children's expressions of negative affect, P3 amplitudes, and parental reports of child lability and emotion regulation (see Table 5). Correlations between the variables were examined for each block, separately. For data reduction purposes, only children's expression of overall negative affect was utilized. Children's self reports of sadness and frustration were collapsed into one variable, as the two were highly correlated ( $r = .74, p = .001$ ). Only frontal (F3), and frontocentral (FC3, FCZ, FC4) P3 amplitudes were utilized, as those were the regions and sites in which the effects of emotion on attention processes were detected. For the frontocentral region, a collapsed variable was created by averaging across right, center, and left sites in that region.

Children's expression of negative affect was related to more parent-reported emotional lability on the Emotion Regulation Questionnaire in both the baseline ( $r = .28, p = .045$ ), and frustration block ( $r = .28, p = .046$ ). During the suppression block, children's self reports of frustration/sadness were positively related to expressions of

negative affect ( $r = .36, p = .01$ ) and inversely related to P3 amplitudes in the frontal ( $r = -.29, p = .04$ ) and frontocentral ( $r = -.30, p = .04$ ) regions. Emotional lability was positively related to reports of frustration/sadness ( $r = .33, p = .02$ ), and expressions of negative affect at trend level ( $r = .26, p = .06$ ) during the suppression block. Finally, parent reported emotional lability was inversely associated with P3 amplitudes in the frontocentral region on the recovery block, at trend level ( $r = -.23, p = .09$ ).

## **CHAPTER IV**

### **DISCUSSION**

The present study examined emotional reactivity and regulation during frustration in young children with and without ADHD symptoms. In regard to emotion reactivity, different patterns were observed across the measures utilized in the study. Self-reports of negative affect indicated that children with ADHD symptoms experienced greater emotional reactivity and more difficulty with emotion regulation than typically developing children. Behavioral observation data indicated that the two groups demonstrated a similar increase in expressed negative affect during frustration; however, children with ADHD symptoms expressed higher levels of negative affect across all four conditions than typically developing children. Children with ADHD symptoms demonstrated smaller reductions in self-reports and expressions of negative affect when asked to suppress emotions. Neural reactivity, in the form of the P3, further suggests that children with ADHD symptoms processed the emotional induction differently than typically developing children. Specifically, typically developing children demonstrated patterns of increasing P3 amplitudes at frontal (i.e., F3) and frontocentral regions across task conditions whereas children with ADHD symptoms showed a relatively stable P3 throughout the task, a pattern that may indicate difficulty with modulation of attentional resources in situations that elicit emotions. Implications for diagnosis and treatment are discussed.

#### **Emotional Reactivity**

As hypothesized, all children reported elevated negative affect (sadness and frustration) and decreased positive affect when faced with a frustrating task as compared

to a baseline condition. However, the magnitude of the increase in self-reported frustration from the baseline to frustration block was significantly larger for children with ADHD symptoms, and a similar trend-level pattern was found for self-reported sadness. These findings extend prior work in older children (Milich & Okazaki, 1991; Scime & Norvilitis, 2006) and reveal that preschool-aged children with ADHD symptoms are already experiencing heightened emotional reactivity compared to typically developing peers. Further, because our task was designed to elicit moderate levels of frustration, this heightened emotional reactivity is likely occurring in everyday activities and interactions.

Similar to child self-reported affect, and as expected, coded expressions of affect indicated that all children expressed greater negative affect during the frustration block compared to baseline. Interestingly, group differences revealed that children with ADHD symptoms were demonstrating greater reactivity at the start of the task compared to typically developing peers and that heightened emotional expressions were maintained across all blocks. Thus, our findings extend previous literature (Douglas & Parry, 1994; Maedgen and Carlson, 2000; Wigal et al., 1998) by suggesting that children with ADHD symptoms not only express more affect when they are feeling particularly frustrated, but they also exhibit heightened affect in situations with relatively low emotional valence. Moreover, adult research has demonstrated that hyperactivity symptoms are associated with traits commonly linked with behavioral activation (i.e., reward sensitivity and drive; Gomez, & Corr, 2010). It may be that young children with ADHD symptoms are already demonstrating a dominance of behavioral activation over behavioral inhibition. Thus, children with ADHD symptoms may have approached the entire task with heightened

emotionality from the start, as they may have been more aroused by possibility of receiving a reward and by being in a novel situation (i.e., in the laboratory).

Additionally, neural emotional reactivity was indirectly assessed via the P3 component, which is thought to index attention allocation. Because negative affect interferes with attention, it was hypothesized that smaller reductions in P3 amplitude from baseline to frustration would be indicative of less interference from emotional reactivity on attention and greater reductions would be indicative of greater influence of emotional reactivity over attention allocation. As predicted, in the left frontal and frontocentral regions, typically developing children demonstrated enhanced P3 amplitudes when faced with a frustrating task, suggesting that these children were able to allocate greater attentional control in the face of an emotional context, thus exhibiting greater emotional regulation. This finding is in line with other studies that have documented that typically developing children exhibit enhanced P3 amplitudes during more challenging tasks (DeFrance et al 1996; Jonkman et al 2000; Strandburg et al 1994, Rich et al., 2005, Rich et al, 2007).

In contrast, children with ADHD symptoms did not show significant P3 enhancement during the frustrating block in the left frontal and frontocentral regions. This finding supports past research suggesting that children with emotion dysregulation-related psychopathologies are unable to increase attention under frustrating contexts (Jonkman et al 2000; Rich et al., 2005, Rich et al, 2007). As Rich and colleagues (2005) have hypothesized, it may be that for these populations, the emotionality of the situation becomes more prevalent than for their typically developing peers and thus the emotionality utilizes more of their cognitive resources. Because attention processing

abilities are thought to have a finite limit (Desimone, & Duncan, 1995; Rich et al., 2005), emotionally dysregulated individuals are unable to allocate additional attention to the task itself. Thus, inability to increase P3 amplitudes in the frustration block in the ADHD symptom group suggests that due to increased reactivity, the emotionality of the situation consumed available cognitive resources.

It is important to note that the change scores in P3 amplitude between baseline and frustration did not significantly differ between groups. Whereas analyses suggest that both groups present differing patterns of P3 modulation across blocks when examined separately, the effects were not sufficiently large to yield significant differences between groups until recovery. Thus, it may be that compared to other psychopathologies where such between group differences are documented (i.e., pediatric bipolar disorder), emotional deficits in children with ADHD symptoms may be less severe and impairing, resulting in less pronounced differences in P3 in response to frustration. It may be that in pediatric bipolar disorder, emotional deficits may be more acute and have a larger impact on functioning, perhaps by affecting multiple systems and cognitive processes, additionally to attention allocation. This notion is supported by a study in which parents reported that impairments in emotion regulation in pediatric bipolar disorder are more severe than in ADHD and present from an earlier age (West, Schenkel, & Pavuluri, 2008). Alternatively, it is possible that the comparably younger age of our subjects may have made the emotional induction less powerful. Children in the preschool age range compared to 7-11 year olds) may have had difficulty monitoring how many trials had negative feedback, which may have diminished the intensity of the emotional induction.

Exploration of central and parietal regions did not suggest that groups were modulating P3 amplitudes differently across blocks. This pattern contrasts prior work documenting decreased P3 amplitudes during difficult and frustrating tasks in parietal sites among older children with ADHD symptoms (Jonkman et al., 2000) as well as children with pediatric bipolar disorder (Rich et al., 2005). However, an investigation that documented differences in the frontal region during an affective Posner task found increased P3 amplitudes in a sample of children at risk for depression (Pérez-Edgar, Fox, Cohn, & Kovacs, 2006), which was interpreted as indicative of less efficient activation of motivational systems in the brain induced by emotional dysregulation. The contrasting results across these studies may be due to multiple factors including: 1) the specific task utilized (i.e. Posner vs. go/no-go), 2) the type of emotional induction employed (increasing task difficulty vs. providing inaccurate feedback vs. including affective stimuli), and 3) the population examined (age and type of psychopathology). Each of these factors alone, as well as in combination, might impact differences in regional emphasis of the P3 component.

Moreover, the P3 in the current study follows a similar frontal scalp distribution as identified in the literature on the P3a, a component commonly noted in oddball and go/nogo tasks. The P3a has been described as representing top-down monitoring and attention switching during the evaluation of incoming stimuli (Polich, 2007). Given that other studies have detected deficits in top-down control efficiency and orienting in children with ADHD (e.g. Friedman-Hill, 2010; Tye, 2014; Ortega, López, Carrasco, Anllo-Vento, & Aboitiz, 2013), it may be that in young children, a P3a component is elicited when utilizing a Posner paradigm. For young children, this task may be

significantly more challenging than for older children and adults. To successfully complete the task, young children may have to engage in more top-down monitoring and this may require the recruitment of frontal cognitive resources. Taken together, these results suggest that under baseline conditions, children with ADHD symptoms are able to demonstrate comparable levels of top down monitoring. However, increased emotionality and attentional demands might exacerbate preexisting top down monitoring limitations in this population.

### **Emotional Regulation**

Research suggests that emotional suppression, specifically the suppression of sadness, increases the perception of being overwhelmed with emotions in adult ADHD (Matthies, Philipson, Lackner, Sadohara, & Svaldi, 2014). Our study supports the notion that emotional suppression, as a form of emotion regulation, is potentially both detrimental and ineffective in preschoolers with ADHD. Contrary to our hypothesis that children with ADHD symptoms would demonstrate and report either no decreases or slight decreases in levels of frustration during suppression, children with ADHD symptoms reported experiencing larger increases in frustration and anger and decreases in happiness than their peers.

Additionally, whereas the increase in expression of negative affect between the baseline and frustration blocks was similar for both groups, children with ADHD symptoms demonstrated a larger increase than typically developing children from frustration to suppression. This increase in experienced and expressed negative affect is indicative of deficits in emotion regulation abilities in ADHD. It suggests that children with ADHD symptoms were not only unable to efficiently implement the suppression



instructions, but that being asked to suppress emotions was potentially detrimental and could have exacerbated feelings of frustration. Walcott and Landau (2004) documented similar findings in 6-11 year olds, and thus this study extends the small body of research on emotion regulation by suggesting that difficulties in suppressing emotions are present in ADHD by preschool age.

Our study also extends the current body of research by exploring the impact of frustration on the experience of sadness and happiness. Of note, although children with ADHD symptoms were able to maintain comparable levels of happiness through the frustration block, instruction to suppress emotional experiences was followed by increases in sadness and decreases in happiness. It may be that for children with ADHD symptoms, being asked to suppress emotions led to an increased awareness of emotional experiences, but that for this population increased affective awareness does not necessarily facilitate, and perhaps hinders, regulation. Further research should directly examine the relationship between suppression and emotional awareness, as well as the mechanisms through which suppression is related to feeling overwhelmed in this population.

In respect to neural measures, it was predicted that typically developing children would show decreased P3 amplitudes in the suppression block as compared to the frustration block. Because negative affect has been found to increase attention in typically developing children (Rich et al., 2005), it was predicted that effective emotion regulation would lead to a decrease in the intensity of experienced negative affect and to a subsequent decrease in P3 amplitudes. Although emotional expression data and self-reports suggest that this group was better able suppress their emotional experience and

expression during this block, typically developing children continued to demonstrate enhanced P3 amplitudes in frontal and frontocentral regions, compared to baseline. It may be that typically developing children were able to modulate their emotional experiences, but also continued to allocate more attentional resources to the task due to still perceiving it as difficult, as inaccurate negative feedback was also provided during this block. It is important to note that emotional suppression, as a regulatory strategy, has been related to unfavorable outcomes and has not been documented to increase cognitive control (Gross & John, 2003; Schutte, Manes, & Malouff, 2009; Vanderhasselt, Baeken, Van Schuerbeek, Luypaert, & De Raedt, 2013). However, this study suggests that for typically developing populations, it may have been a useful short-term strategy to reduce immediate feelings of frustration, without seemingly deteriorating attention processes.

Children with ADHD symptoms did not demonstrate significantly enhanced P3 amplitudes on the suppression block compared to the baseline or frustration blocks. Lack of amplitude differences during suppression both suggests that this instruction does not lead to modulation of attentional allocation in children with ADHD and corresponds to evidence that being asked to suppress emotions in this population increases emotional distress (as evident in patterns of increased negative affect in coding and self-report data). Thus lack of P3 modulation may reflect lack of emotional regulation in the face of increasing negative affect or it may be possible that the continued lack of P3 enhancement is reflective of a taxing of attentional resources. Taxing could have been caused either by prolonged task-induced frustration or by the addition of suppression efforts. Because the blocks were not counterbalanced and children were always asked to suppress emotions after having completed the frustration block, further research needs to

better differentiate these two possibilities and assess the possible unique contribution of suppression efforts to attention allocation resources.

### **Emotional Recovery**

Children's ability to recover from a frustrating situation was not a main focus of this study, and no hypotheses were made regarding the possible differences in groups' recovery abilities. However, because the ability to recover from emotion eliciting events is an important part of emotion competency (Hemenover, Augustine, Shulman, Tran, & Barlett, 2008) that children with ADHD symptoms may struggle with (Scime & Norvilitis, 2006), group differences were explored in their patterns of emotional recovery.

Children's self-report of emotion suggested that both groups recovered to a less frustrated/sad and happier state. Although children with ADHD symptoms reported more negative affect than typically developing children during the suppression condition, their self-reported affect returned to a level that was similar to the typically developing children during the recovery block. The emotional expression data also showed that during the recovery block children with ADHD symptoms returned to an emotional level comparable to their baseline, but this level remained elevated compared to the typically developing children. This finding is in line with the notion that children with ADHD symptoms may be more emotionally expressive than their counterparts without reporting experiencing heightened emotional states. Alternatively, as mentioned above, children with hyperactivity symptoms might have approached the entire task with heightened emotionality.

Typically developing children continued to show enhanced P3s during the recovery block, which is notable considering task fatigue could have had an opposite

effect on attention allocation. Having received inaccurate negative feedback -- and the accompanying lack of points -- could have been perceived as a threat. Thus, it is possible that in typically developing populations, when top-down systems become activated, they remain active until perceived threats disappear. This might occur to sustain vigilance and be able to better detect any further variations in task difficulty or unexpected outcomes. Additionally, past studies have documented that top-down attention decreases the impact of emotionality on performance (e.g., Larson et al., 2013). Thus, typically developing children could have continued to demonstrate an increased P3 response because top-down monitoring processes contributed to the suppression of negative affect.

In contrast, children in the ADHD symptom group did not increase, but rather decreased, P3 amplitude during the recovery block. For this group, induced frustration and suppression requirements may have over-taxed attentional resources. Further, the perceived threat of not obtaining a reward might have had an opposite effect on this group. It might be that instead of increasing vigilance, the risk of losing a reward, is too overwhelming of a threat and over-taxing on attentional resources. It would appear as if the taxing of attentional resources was such that neither the proximity of a reward nor the removal of inaccurate negative feedback during the recovery block was sufficient to return their attention allocation resources back to baseline levels. However, because other emotion regulation strategies, such as emotional acceptance, have been related to faster recovery from emotional experiences in populations with ADHD, it is important to explore other emotion regulation strategies (Matthies et al., 2014). It may be that had children been requested to reappraise the situation (e.g., told to think of it as “just a game”), they could have significantly enhanced P3 amplitudes during suppression and

recovery. There is scarce empirical research on emotional reappraisal, yet studies point to its utility in both clinical populations that present with emotion dysregulation and preschool samples. Preschoolers have been shown to improve in both emotional and academic competence when asked to reappraise emotional situations (e.g., Davis & Levine, 2013). Further, research on adult bipolar disorder documented that reappraisal is an effective method of emotion regulation, successful in decreasing experienced, expressed, and physiological (e.g., skin conductance) emotional reactivity (Gruber, Hay, & Gross, 2014). Although these findings suggest that reappraisal may help children with ADHD symptoms manage emotional experiences and deter emotionality from interfering with functioning, further research needs to specifically investigate the relation between emotional recovery and attention modulation.

### **Relation Among Outcome Measures**

The present study also attempted to elucidate the relations among different methods of assessing emotional processes. Children's self-reports of affect were only related to expression of negative affect and parental reports of lability in the suppression block. Self-reports and expression of negative affect were not related in other conditions. Examination of the patterns of self reports and emotion expressions for each group suggest that this effect might have been driven by children in the ADHD symptom group, who demonstrated more affect across all blocks but did not necessarily report it. It may be that either children with ADHD symptoms are more expressive overall and that their expressions are not strongly linked to internal experiences of distress, or conversely, that they have difficulty assessing internal emotional states until these states surpass higher thresholds than in typically developing children. Differentiating whether children with

ADHD symptoms have heightened overall expression or a higher threshold for emotional awareness is an important question with potentially significant implications for the treatment of ADHD that needs to be addressed in future research. Research could determine whether ADHD treatments need to incorporate interventions geared either towards increasing alertness of internal emotional experiences or increasing monitoring of outward emotional expressions.

Correlation analyses support the validity of utilizing this frustrating task--and the accompanying coding of expressions of negative affect--as an assessment of children's emotional lability. The fact that parental reports of lability were related to greater expressions of negative affect in the baseline and frustration blocks, and marginally related to expressed affect in the suppression blocks suggests that the task elicits emotional reactions that are representative of children's typical behavior. These results provide converging evidence that the frustration block was truly a reactivity condition, in which children who are more reactive outside of the lab were also more expressive in lab. However, the relation between parental report and expressions was only marginally significant in the suppression block, which might suggest that some children managed to suppress affect, or that emotional experiences at home may be different than those in the laboratory.

Finally, in the suppression and recovery blocks, there was some evidence that smaller P3 amplitudes were related to greater self-report and expression of negative affect. This is in line with studies that have found when attentional resources become depleted, significant reductions in P3 amplitudes are observed (Polich, 2007). It might be that children who report experiencing more negative affect during the suppression block

have to exert more effort into suppressing its expression. Similarly, smaller P3 amplitudes during the recovery block were related, at trend level, to parental reports of child lability. Taken together, these results suggest that the P3 amplitude might be sensitive to emotional inductions, taxing of attentional resources, and individual differences in parent-reported emotional lability.

### **Limitations**

This study has a number of limitations. First, our sample size did not allow us to examine the role of comorbid ODD on emotion dysregulation. Because it is hypothesized that the emotional induction exacerbated preexisting attention allocation difficulties-- which are present in ADHD, but not ODD--future work may reveal that comorbid ODD accounts for group differences in emotional experience and expression data, but not for the P3 amplitude differences documented here. Second, only one type of emotion regulation strategy, suppression, was explored in this study. It is possible that children with ADHD symptoms show differential ability to regulate emotions across different strategies and future research should explore this possibility as it could have meaningful implications for treatment. Third, our ability to examine the independent effects of being asked to suppress emotions from that of increased frustration due to loss of reward is limited. Prior to beginning the suppression condition, children were informed that they had not obtained enough points during the frustration condition and were not given a stamp. Thus, increased negative affect in the suppression condition in the ADHD symptom group could have been induced not only by the suppression instructions, but also by the loss of a reward, which has been documented to be more salient in this population (Luman, van Meel, Oosterlaan, & Geurts, 2012; Rosch, & Hawk, 2013).

## **Conclusions and Future Directions**

The present study extends a growing body of literature that suggests that emotion dysregulation is a central component of ADHD. This study found evidence of increased emotional reactivity and decreased emotion regulation in young children with ADHD symptoms. Although the last decade has seen a dramatic increase in the importance placed on emotion regulation skill development, it is still not a major component of ADHD treatment, and infrequently addressed in diagnosis. Importantly, this study did not find baseline differences in children's attention allocation abilities and only documented them after an emotional induction in which the typically developing children exhibited the ability to modulate their attention across the task conditions. Thus, this study suggests that emotional contexts may exacerbate attentional deficits involved in ADHD due to increased emotion reactivity and emotion regulation impairments.



Table 1

## Parental Reports of Child Emotion Regulation and Behavior

<b>Scale</b>	<b>ADHD</b> M (SD)	<b>TD</b> M (SD)	df	F	p
BASC-2 Scales					
Hyperactivity	70.68 (10.67)	47.50 (7.39)	43	87.74	.001
Aggression	58.50 (11.42)	49.27 (7.44)	43	12.01	.001
Externalizing Problems	65.05 (9.55)	48.12 (6.96)	43	52.46	.001
Anxiety	49.50 (10.42)	46.58 (7.31)	43	0.31	.58
Depression	54.64 (12.61)	47.54 (6.56)	43	4.10	.05
Somatization	45.77 (8.58)	44.85 (7.96)	43	0.00	.95
Internalizing Problems	49.91 (9.91)	45.38 (7.54)	43	1.57	.22
Atypically	59.86 (9.17)	47.23 (6.09)	43	32.40	.001
Withdrawal	48.82 (10.85)	51.50 (7.50)	43	1.29	.26
Attention Problems	65.77 (6.36)	48.08 (7.28)	43	77.85	.001
Behavioral Symptoms Index	62.77 (8.41)	47.96 (5.23)	43	52.00	.001
Adaptability	41.00 (9.05)	51.27 (8.97)	43	14.44	.001
Social Skills	46.27 (9.87)	49.50 (9.21)	43	3.04	.09
Activities of daily living	39.77 (6.56)	52.04 (8.17)	43	32.13	.001
Functional Communication	45.48 (7.70)	50.76 (7.71)	43	5.72	.03
Adaptive Skills	42.90 (7.90)	52.04 (7.42)	43	16.12	.001
ERC					
Emotional Lability	2.37 (0.45)	1.54 (0.30)	43	47.33	.001
Emotion Regulation	3.27 (0.29)	3.51 (0.40)	43	5.41	.02

Note. Sample sizes for BASC: n = 22 (ADHD) and n = 26 (TD). Sample sizes for ERC: n = 24 (ADHD) and n = 30 (TD).

Table 2

## Self-Reports of Experienced Emotions Across Blocks

<b>Emotion</b>	<b>Block</b>	<b>ADHD</b>	<b>TD</b>
		M (SD)	M (SD)
Frustration	Baseline	0.41 (0.50)	0.78 (1.13)
	Frustration	1.77 (1.74)	1.26 (1.29)
	Suppression	2.46 (1.97)	1.04 (1.11)
	Recovery	0.73 (1.28)	0.61 (0.78)
Happiness	Baseline	4.78 (0.85)	4.38 (1.13)
	Frustration	4.35 (1.07)	4.29 (1.23)
	Suppression	3.35 (2.06)	4.13 (1.23)
	Recovery	4.83 (0.58)	4.75 (0.68)
Sadness	Baseline	0.46 (0.80)	0.44 (0.59)
	Frustration	1.36 (1.76)	0.78 (0.74)
	Suppression	1.73 (2.14)	0.87 (0.87)
	Recovery	0.55 (1.22)	0.65 (0.78)

Note. Sample sizes: n = 23 (ADHD) and n = 25 (TD).

Table 3

## Children's Emotional Displays Across Blocks

<b>Emotion</b>	<b>Block</b>	<b>ADHD</b>	<b>TD</b>
		M (SD)	M (SD)
Negative affect	Baseline	0.112 (0.164)	0.040 (0.048)
	Frustration	0.224 (0.157)	0.142 (0.149)
	Suppression	0.223 (0.19)	0.109 (0.144)
	Recovery	0.102 (0.174)	0.040 (0.074)
Sadness	Baseline	0.011 (0.039)	0.002 (0.007)
	Frustration	0.025 (0.058)	0.005 (0.009)
	Suppression	0.052 (0.102)	0.003 (0.009)
	Recovery	0.014 (0.038)	0.002 (0.007)
Anger	Baseline	0.086 (0.138)	0.026 (0.037)
	Frustration	0.162 (0.124)	0.105 (0.129)
	Suppression	0.159 (0.140)	0.063 (0.097)
	Recovery	0.062 (0.157)	0.015 (0.040)
Distress	Baseline	0.022 (0.062)	0.011 (0.025)
	Frustration	0.047 (0.084)	0.034 (0.063)
	Suppression	0.043 (0.090)	0.046 (0.097)
	Recovery	0.036 (0.074)	0.024 (0.055)

Note. Sample sizes: n = 23 (ADHD) and n = 30 (TD).

Table 4

## Task Accuracy and Reaction Times Across Blocks

	<b>Block</b>	<b>ADHD</b> M (SD)	<b>TD</b> M (SD)
Accuracy	Baseline	87.73 (10.68)	91.25 (9.55)
	Frustration	80.56 (12.51)	83.2 (11.29)
	Suppression	77.63 (13.5)	83.86 (9.07)
	Recovery	85.12 (18.39)	90.29 (9.81)
RT	Baseline	561.25 (106.72)	524.51 (187.07)
	Frustration	559.23 (105.35)	519.6 (172.55)
	Suppression	538.35 (96.43)	499.28 (156.44)
	Recovery	499.2 (142.73)	457.48 (141.33)

Note. Sample sizes: n = 24 (ADHD) and n = 30 (TD).

Table 5  
Intercorrelations Amongst Outcome Variables

	1	2	3	4	5	6
Baseline						
1. SR: F/S	--					
2. SR: Happiness	.24 <sup>†</sup>	--				
3. NA	.92 <sup>***</sup>	.07	--			
4. F3 amplitude	.60 <sup>***</sup>	.06	.31 <sup>*</sup>	--		
5. FC amplitude	-.10	-.09	-.21	.03	--	
6. ERC: Labilty	-.09	.03	-.13	.12	.08	--
7. ERC: ER	-.24 <sup>†</sup>	-.14	-.28 <sup>*</sup>	-.04	.68 <sup>***</sup>	.05
Frustration						
1. SR: F/S	--					
2. SR: Happiness	-.07	--				
3. NA	.12	.12	--			
4. F3 amplitude	.13	.00	.14	--		
5. FC amplitude	.03	-.04	.14	.94 <sup>**</sup>	--	
6. ERC: Labilty	.06	.20	.28 <sup>*</sup>	-.09	-.15	--
7. ERC: ER	-.03	-.03	-.19	-.05	.00	-.64 <sup>**</sup>
Suppression						
1. SR: F/S	--					
2. SR: Happiness	-.49 <sup>**</sup>					
3. NA	.36 <sup>*</sup>	-.11				
4. F3 amplitude	-.29 <sup>*</sup>	-.11	-.33 <sup>*</sup>			
5. FC amplitude	-.30 <sup>*</sup>	.02	-.16	.81 <sup>**</sup>		
6. ERC: Labilty	.33 <sup>*</sup>	-.17	.26 <sup>†</sup>	-.11	.00	--
7. ERC: ER	-.12	-.03	-.05	-.04	-.05	-.64 <sup>**</sup>
Recovery						
1. SR: F/S	--					
2. SR: Happiness	-.46 <sup>**</sup>					
3. NA	.16	-.16				
4. F3 amplitude	-.02	-.01	-.07			
5. FC amplitude	-.03	-.03	-.11	.88 <sup>**</sup>		
6. ERC: Labilty	-.08	.04	.18	-.20	-.23 <sup>†</sup>	--
7. ERC: ER	-.06	.08	-.07	-.02	.00	-.64 <sup>**</sup>

Notes: SR:F/S: Self reports of frustration/sadness, SR:Happiness: Self reports of happiness, NA: negative affect, ERC: Emotion Regulation Checklist, ER: Emotion Regulation. Ns = 49-54. ; \*\*\* p < .001, \*\* p < .01, \*p < .05, † p < .10 .

Figure 1

Task structure

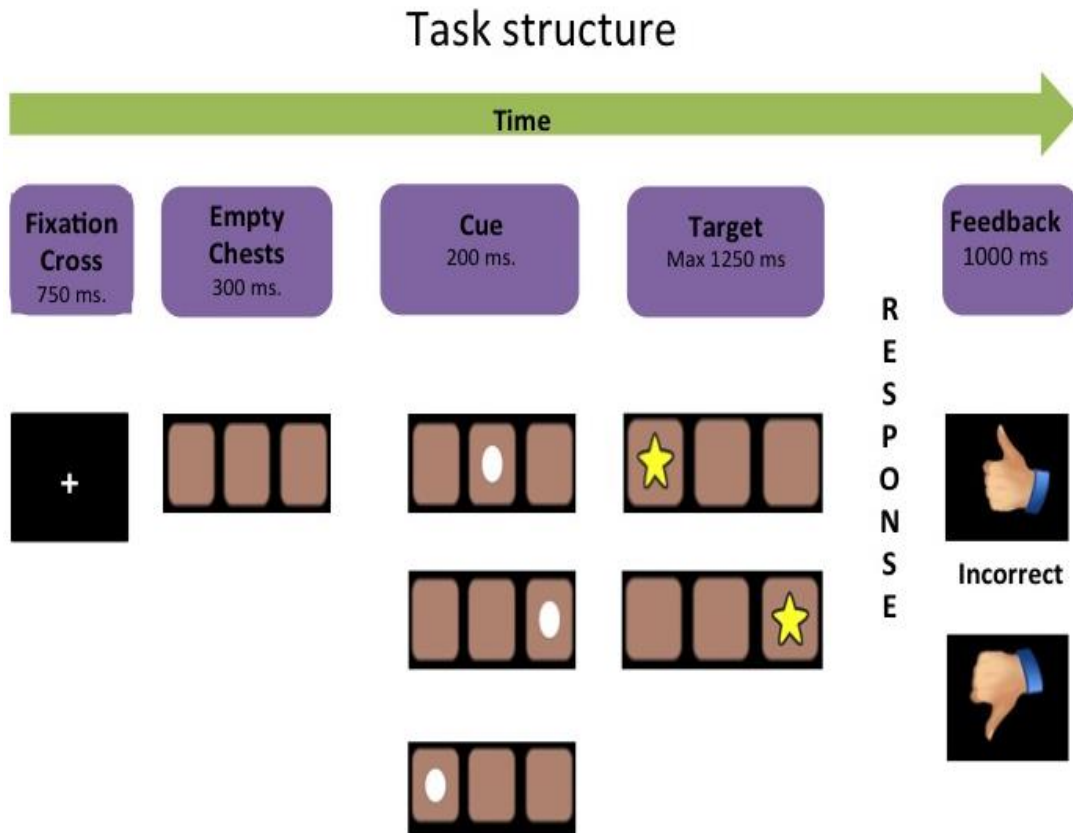


Figure 2

Task conditions

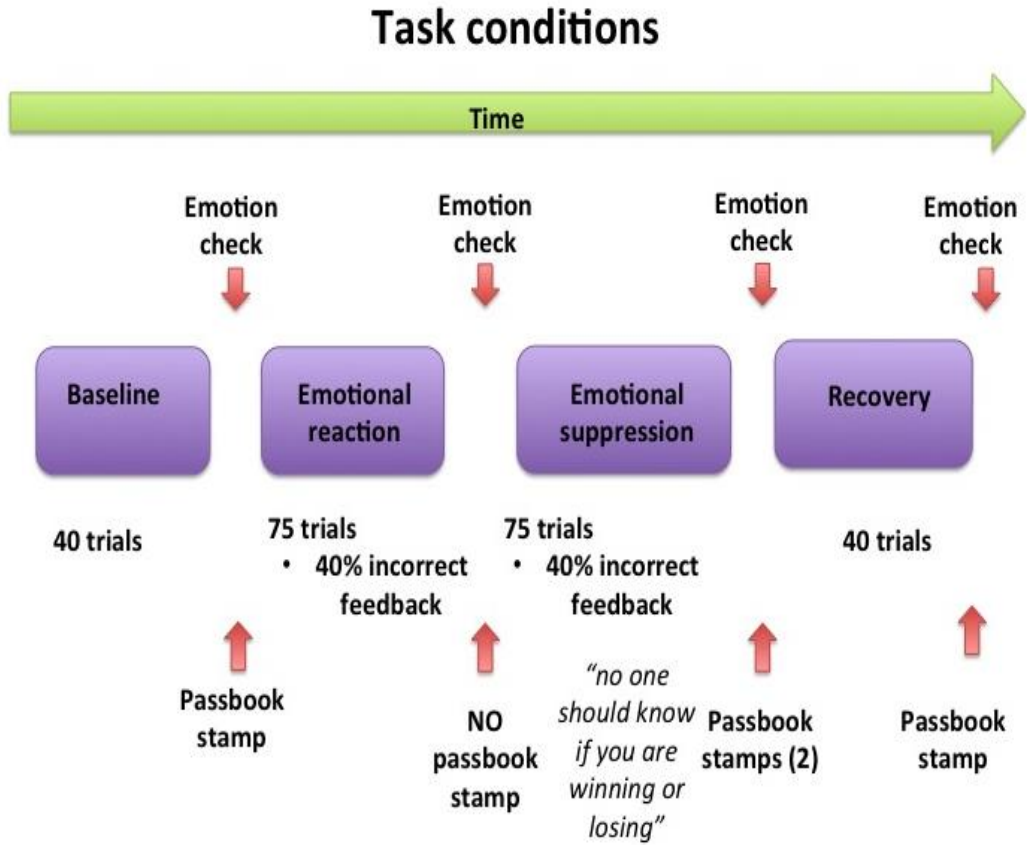


Figure 3

Children's Self-Reports of Experienced Emotions Across Blocks

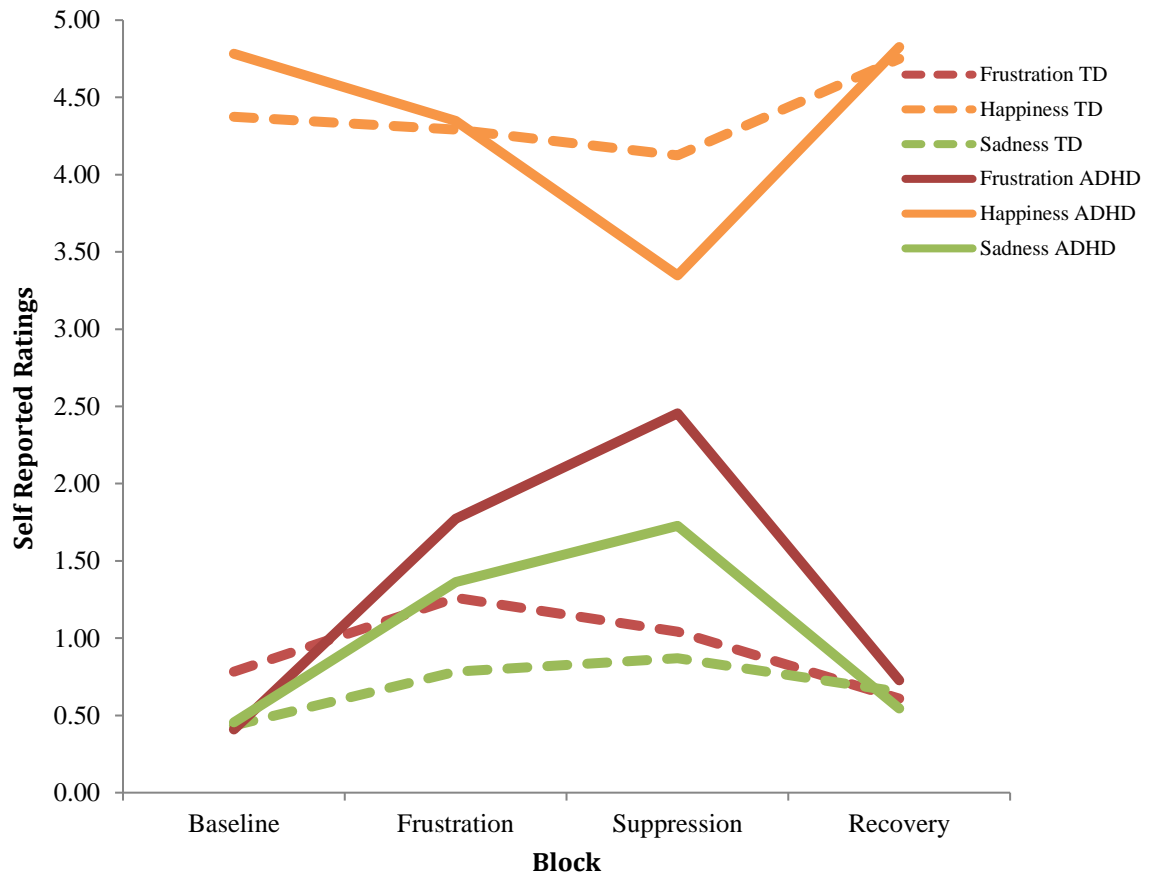
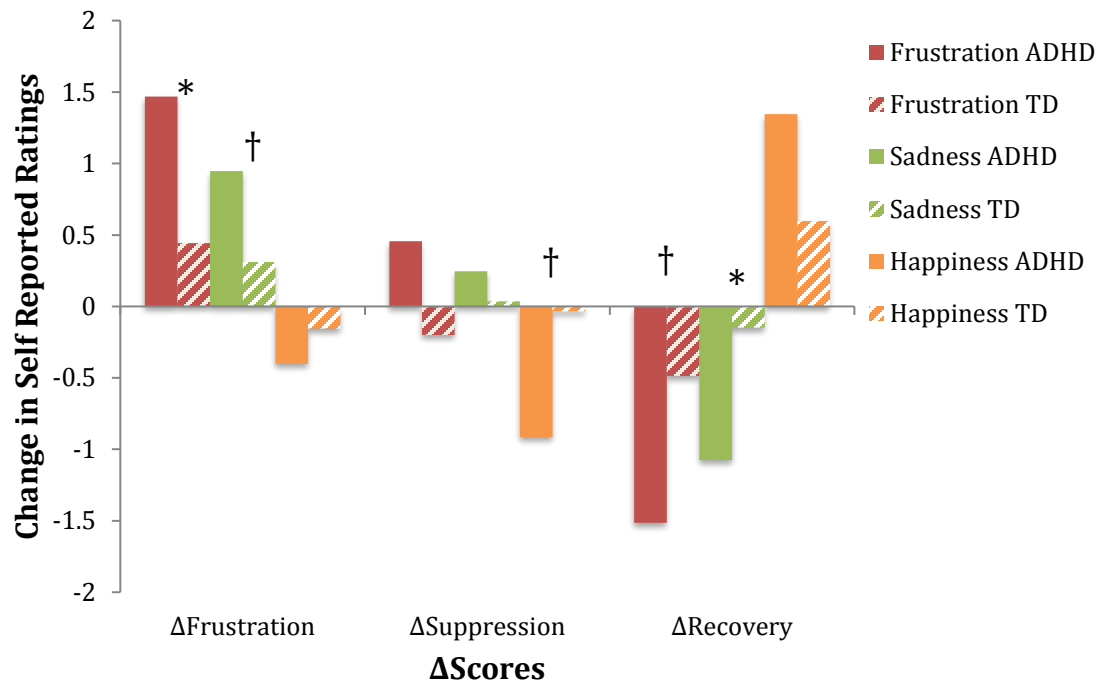




Figure 4

Change Scores in Children's Self-Reports of Experienced Emotions Across Blocks



Note: \* $p < .05$ , †  $p < .10$

Figure 5

Children's Expression of Negative Affect across Blocks

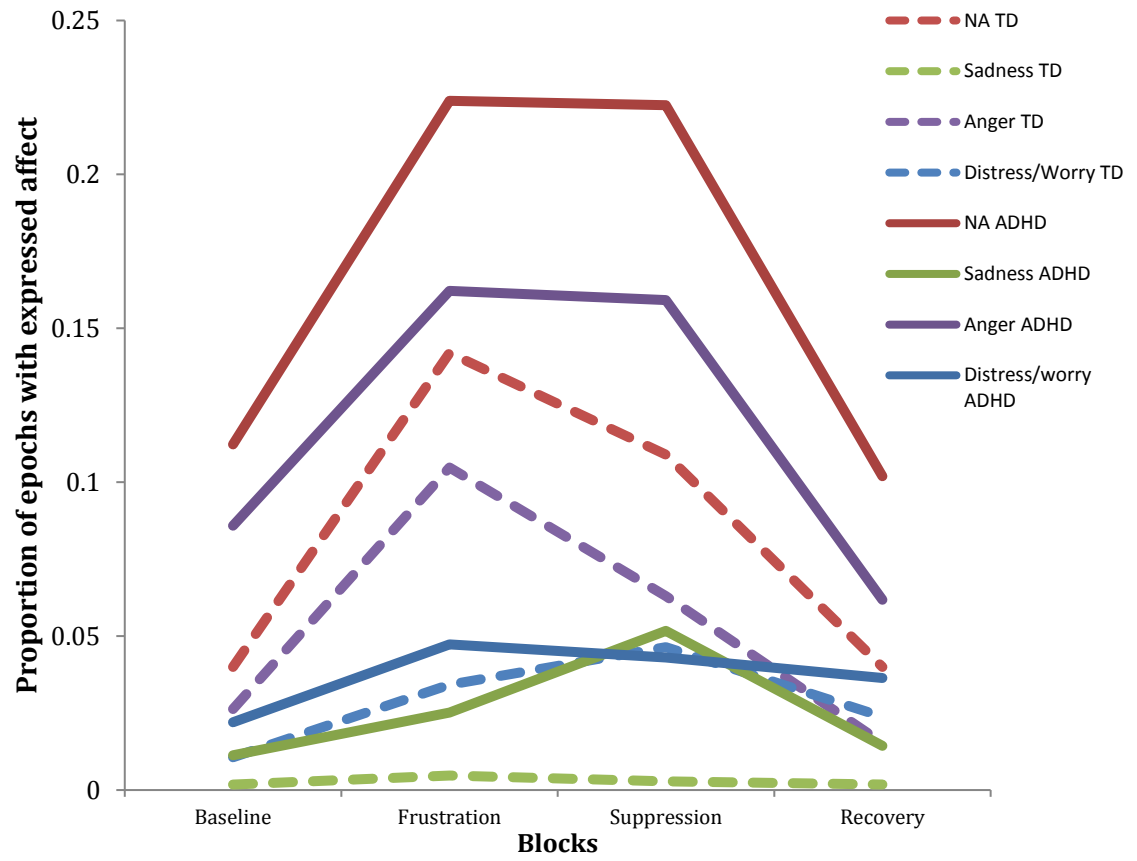
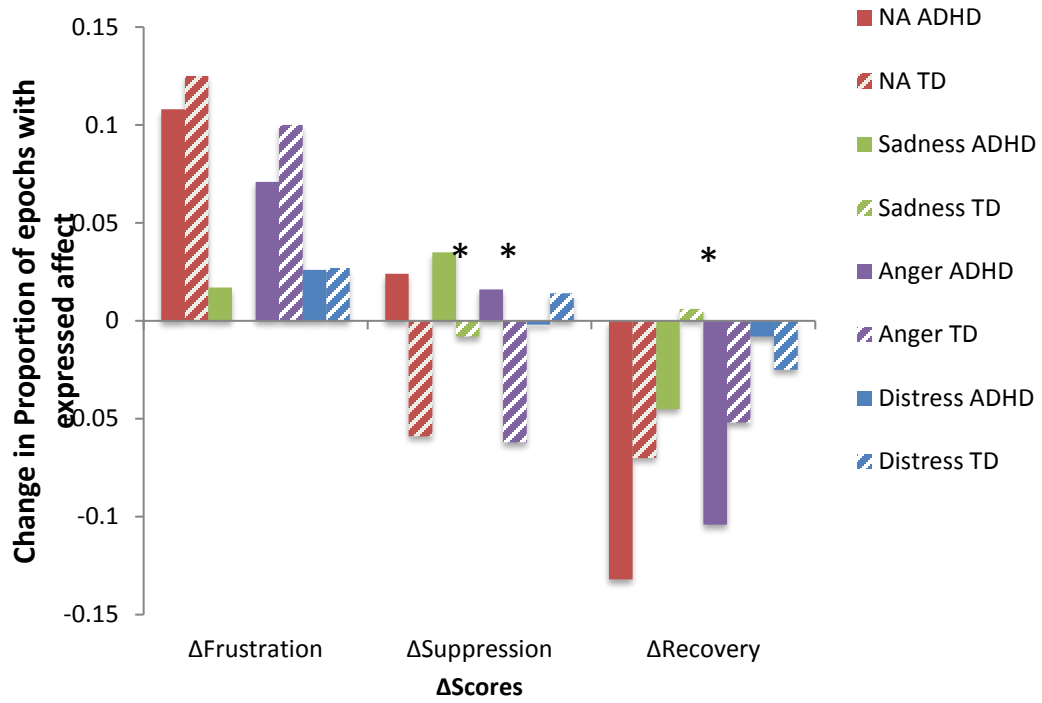


Figure 6

Change Scores in Children's Expression of Negative Affect across Blocks



Note: \*p < .05, † p < .10

Figure 7

Accuracy and Reaction Time in milliseconds (ms) Across Blocks

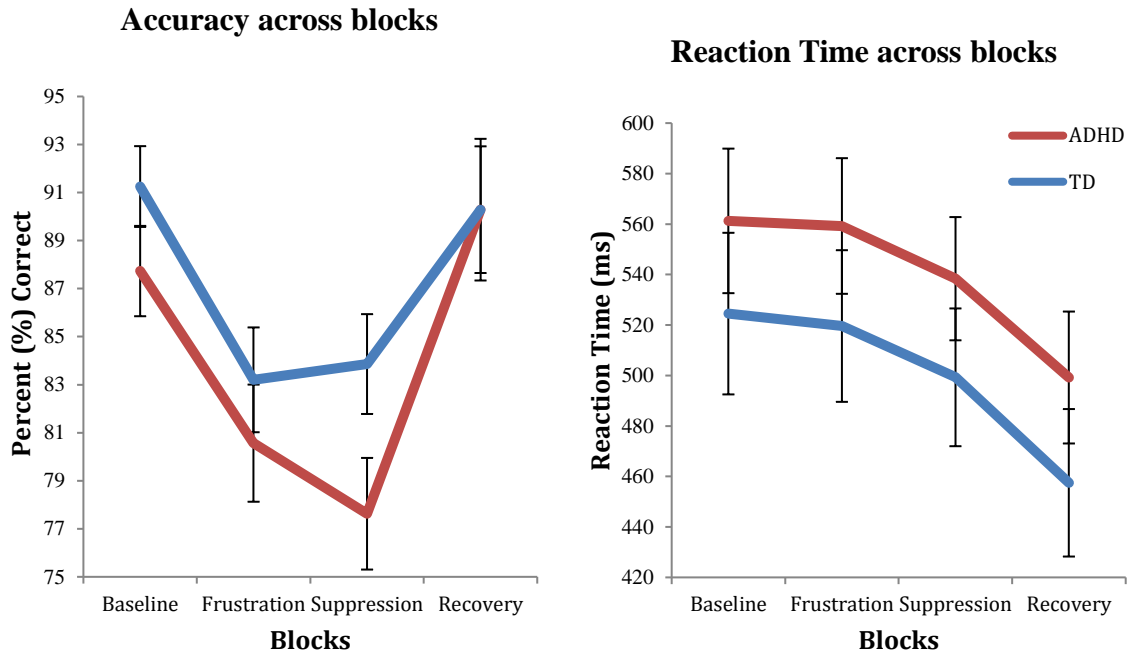
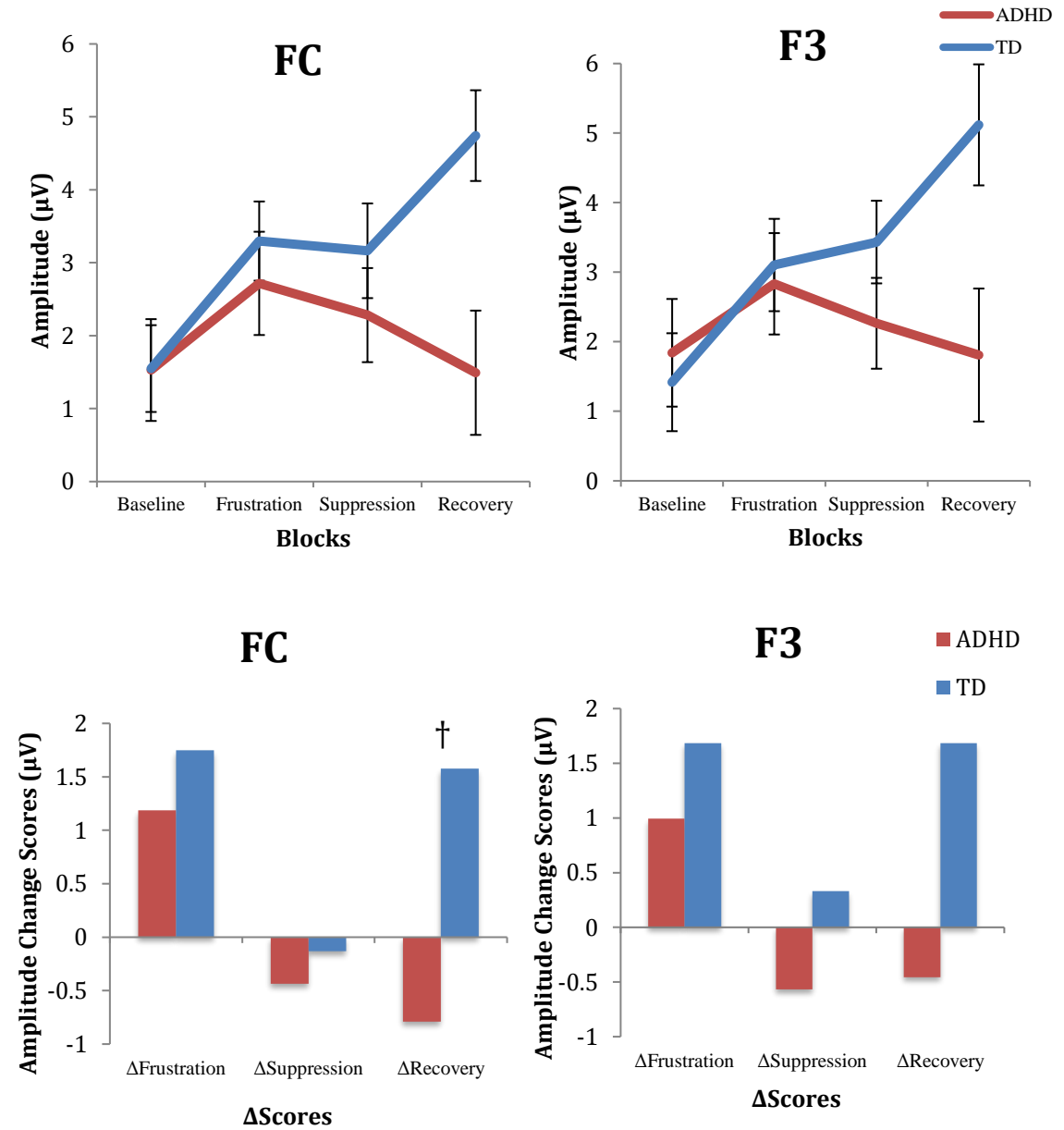


Figure 8

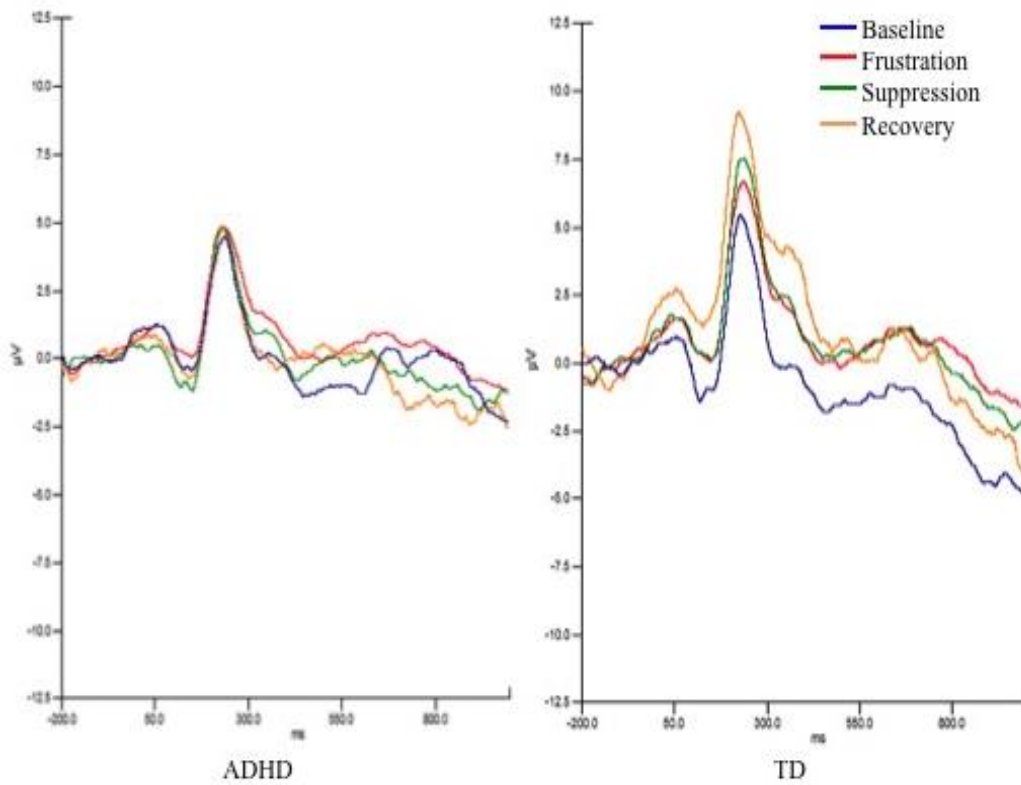
Mean P3 Amplitudes and Change Scores Across Blocks



Note: \* $p < .05$ , †  $p < .10$

Figure 9

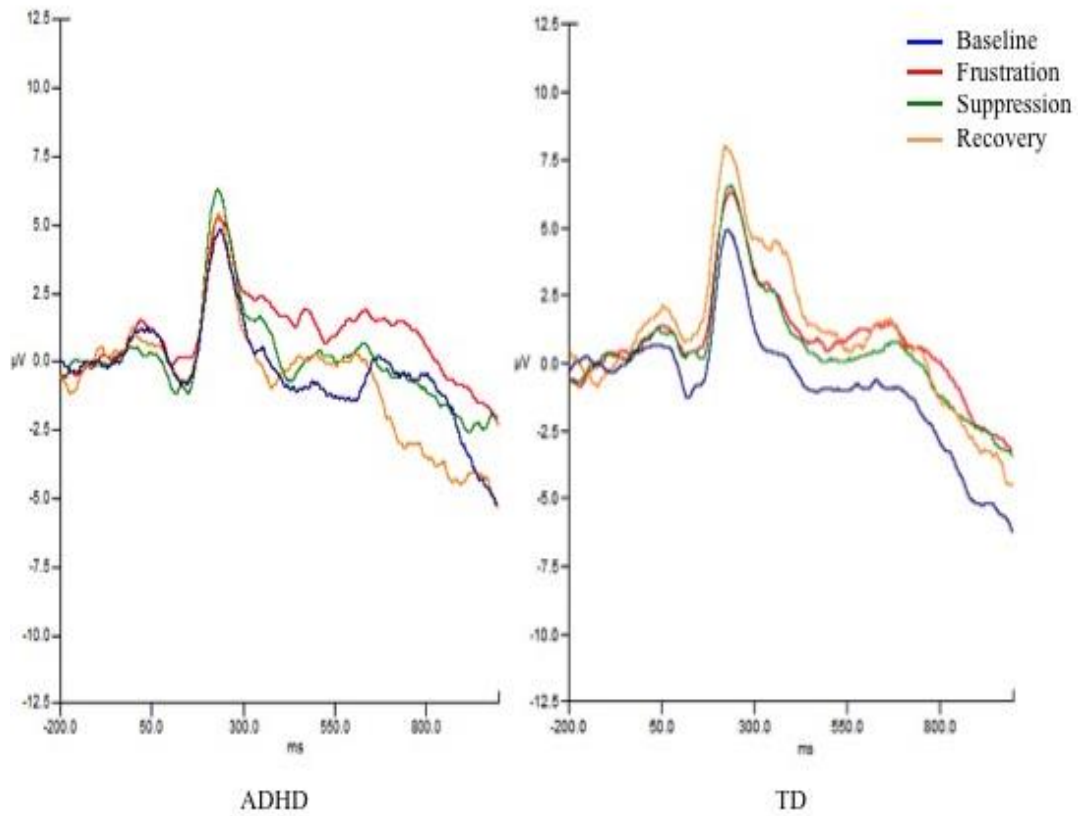
Grand averaged event-related potential waveforms showing the P300 amplitude at electrode F3



Note: The x-axis represents latency in milliseconds and the y-axis represents amplitude in microvolts.

Figure 10

Grand averaged event-related potential waveforms showing the P300 amplitude at the Frontocentral Region



Note: The x-axis represents latency in milliseconds and the y-axis represents amplitude in microvolts.

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