Emotion Recognition and Social Behaviors in Children with Attention-

Deficit/Hyperactivity Disorder

BY

ELGIZ BAL
B.A., University of Istanbul, 2000
M.A., University of Illinois at Chicago, 2006

THESIS

Submitted as partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Psychology
in the Graduate College of the
University of Illinois at Chicago, 2011

Chicago, Illinois

Defense Committee:

Jon Kassel, Chair and Advisor
Stephen Porges, Advisor
Larry Grimm
Audrey Ruderman
Mark Stein, Psychiatry

This thesis is dedicated to my wonderful family without whom it would never have been accomplished.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVEATIONS

ADHD	Attention-Deficit/Hyperactivity Disorder
ADHD-C	Attention-Deficit/Hyperactivity Disorder - Combined Type
ADHD-PHI	Attention-Deficit/Hyperactivity Disorder - Predominantly Hyperactive-Impulsive Type
ADHD-PI	Attention-Deficit/Hyperactivity Disorder - Predominantly Inattentive
ANS	Autonomic Nervous System
BAS	Behavioral Activation System
BIS	Behavioral Inhibition System
CBCL	Child Behavior Checklist
CD	Conduct Disorder
CPRS-R:L	Conners' Parent Rating Scale-Revised: Long version
CPT	Continuous Performance Task
DANVA	Diagnostic Analysis of Nonverbal Accuract
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders
DARE	Dynamic Affect Recognition Evaluation
HALP Clinic	Hyperactivity, Attention, and Learning Problems Clinic
ODD	Oppositional Defiant Disorder
RSA	Respiratory Sinus Arrhythmia
SSRS	Social Skills Rating System
WISC-IV	Wechsler Intelligence Scale for Children-fourth edition

SUMMARY

The current study evaluated emotion recognition, social behaviors, autonomic activity, and eye gaze in 33 children with ADHD relative to 34 typically developing children between the ages of 7 and 12. The relations among these measures were also explored. It was found that children with ADHD made significantly more errors in recognizing anger and disgust than typically developing children. The results did not indicate differences in response times (i.e., latency to detect emotions), although children with ADHD qualitatively appeared to be slower than typically developing children in recognizing anger and disgust. These results suggest that the observed emotion recognition deficits in ADHD children are unlikely due to more impulsive response patterns. No significant relationship was found between visual scanning of faces (i.e., attention to the appropriate cues on the face) and the accuracy of emotion recognition. As expected, children with ADHD had more problem behaviors and social skills deficits, some of which were significantly related to the accuracy of emotion recognition. Groups did not differ on autonomic activity and eye gaze.

1. INTRODUCTION

1.1   <u>Background</u>

Attention-Deficit/Hyperactivity Disorder (ADHD) was first identified in children in the 19th century. A German physician, Heinrich Hoffman, wrote about a young child, Fidgety Phillip, who had traits of what is now called ADHD (Barkley, 2006). AHDH is an early-emerging behavioral syndrome, usually apparent by 7 years of age although the developmental precursors exist earlier than age 7 (Barkley, 1999; Nigg & Casey, 2005). ADHD has impacts on many lives and creates economic and social burdens (Nigg, 2006).

The term ADHD has been reconceptualized, redefined, and renamed many times in the history of childhood psychopathology (Lahey et al., 1988). One area in which much disagreement has occurred involves the issue of relevant subtypes, particularly the type involving inattention in the absence of motor activity (Wheeler & Carlson, 1994). Overall, ADHD has been defined as including three primary symptoms: poor sustained attention, impulsiveness, and hyperactivity. In the current diagnostic classification system (Diagnostic and Statistical Manual of Mental Disorders, DSM-IV), hyperactivity and impulsivity constitute a single impairment, resulting in three subtypes: predominantly inattentive (ADHD-PI), predominantly hyperactive-impulsive (ADHD-PHI), and combined (ADHD-C) types (American Psychiatric Association, APA, 2000). Data on ADHD-PI are limited, since nearly all research is on ADHD-C. ADHD-PHI is relatively uncommon in clinical samples after preschool (Nigg, 2006).

ADHD is characterized by a persistent pattern of inattention and/or hyperactivity-impulsivity. In the inattention domain, typical behaviors include being unable to pay attention to what is being said or done, having trouble staying organized, having difficulty following instructions and finishing tasks, being forgetful, and being easily distracted. In the hyperactivity

domain, typical behaviors include developmentally excessive activity and/or talking, difficulty remaining seated, restlessness, and reckless play. Impulsivity manifests itself as impatience, difficulty delaying responses and waiting turns, initiating conversations at inappropriate times, and interrupting others. Impulsivity may also lead to accidents and engagement in potentially dangerous activities (APA, 2000). Other associated features of the disorder include low frustration tolerance, temper outbursts, bossiness, stubbornness, excessive insistence that the requests be met, and mood lability. As a result of these behaviors, children with ADHD are far more likely than typically developing children to show academic difficulties, fall behind in school, be suspended or expelled, experience difficulties in social and family relationships, be rejected by peers, and have fewer friends (for review see Barkley 1997; Barkley, Fischer, Edelbrock, & Smallish, 1990; Nigg & Casey, 2005).

The symptoms of ADHD, such as inattention or increased activity level, are fairly persistent over development (Barkley, 1997, 1999; Nigg, 2006). In a longitudinal study spanning 8 years, Lahey and colleagues (Lahey, Pelham, Loney, Lee, & Willcutt, 2005) found that the diagnosis of ADHD was reasonably stable when persistence was defined meeting criteria for any subtype of ADHD. However, shifts from one subtype to another were observed over time. The majority of children in each subtype met criteria for another subtype at least once and a substantial minority met criteria for a different subtype three or more times. Further, the prevalence of ADHD-C and ADHD-PHI declined over the years as opposed to prevalence of ADHD-PI, which increased over the years. These findings suggest that subtypes cannot be viewed as discrete categories that are permanent over time and raise questions about the clinical utility of the DSM-IV subtypes.

ADHD occurs in approximately 3-7% of the childhood population (APA, 2000). Prevalence estimates are lower when more rigorous methods (e.g., structured interviews, multiple informants, etc.) are used (Nigg, 2006). Nigg found that unweighted prevalence estimates are 2.9% for ADHD-C, 3.2% for ADHD-PI, and 0.6% for ADHD-PHI. Polanczyk and colleagues (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007) found that the prevalence of ADHD was 5.29% worldwide. Methodological differences across reviewed studies resulted in large variability. After adjusting for these methodological differences, prevalence rates were similar across different countries in North America and Europe. However, differences in prevalence estimates were detected in studies conducted in North America and studies conducted in Africa and the Middle East. This finding can be attributed to the limited number of studies available from countries in Africa and the Middle East (Polanczyk et al., 2007). Overall, these findings argue against the view that ADHD is a culturally based construct specific to the North American culture (Polanczyk et al., 2007). Although it is unclear whether the prevalence of ADHD is increasing or whether the condition is overtreated, it is certain that the administrative prevalence has increased and medication rates have risen over the past generation (Nigg, 2006).

Male to female ratio of ADHD ranges from 2:1 to 9:1, depending on the subtype and setting (APA, 2000). Hartung et al. (2002) examined sex differences in a mostly clinic-referred sample of children with ADHD. In their sample, 67.6% of the boys with ADHD met criteria for ADHD-C, 23.8% met criteria for ADHD-PHI, and 8.6% met criteria for ADHD-PI. Of the girls with ADHD, 59.1% met criteria for ADHD-C, 18.2% met criteria for ADHD-PHI, and 22.7% met criteria for ADHD-PI. Gaub and Carlson (1997) found that boys with ADHD showed higher levels of hyperactivity, relative to girls with the disorder. This finding was supported by the teacher reports, but not the parent reports, in Hartung and colleagues' study. Further, teachers

rated boys with ADHD as more inattentive (Hartung et al., 2002). Girls with ADHD were found to have greater level of intellectual impairment although this finding may be restricted to clinic-referred children (Gaub & Carlson, 1997). Hartung et al. found no sex differences in cognitive and academic measures in their sample of children with ADHD. In general, most available research on ADHD includes boys and Caucasian samples, which limits our understanding of ADHD and how it generalizes to girls or other ethnic groups (Nigg, 2006).

A substantial proportion of children with ADHD meet criteria for oppositional defiant disorder (ODD) or conduct disorder (CD) (Barkley et al., 1990). This co-occurrence is more commonly seen in ADHD-PHI and ADHD-C. Further, girls with ADHD are less likely than boys with ADHD to meet diagnostic criteria for a comorbid disruptive behavior disorders (Gaub & Carlson, 1997; Hartung et al., 2002). In the Hartung et al. study sample, the male-to-female ratio was 3:1 among children without a comorbid diagnosis of ODD or CD and 7:1 among children with a comorbid diagnosis of ODD or CD. Mood and anxiety disorders are also commonly observed in children with ADHD and there appear to be no sex differences in internalizing symptoms (Hartung et al., 2002). Regardless of the comorbid symptomatology, children with ADHD have higher levels of inattention and impulsivity (Newcorn et al., 2001).

During development, ADHD is associated with greater risks for aggression, delinquency, early substance experimentation and abuse, driving accidents, as well as difficulties in social relationships, marriage, and employment (for review see Barkley, 1997; Barkley et al., 1990; Nigg & Casey, 2005). Molina and Pelham (2003) longitudinally monitored children with ADHD to evaluate the risk for substance use. The results suggested that the presence of ADHD in childhood was associated with increased risk for elevated use of alcohol and heavier and earlier use of tobacco and marijuana by the teenage years. The results also suggested that childhood

ODD/CD best predicted other illicit drug use. In a subsequent study, Marshal, Molina, and Pelham (2003) found that deviant peer affiliation mediated the relationship between ADHD and substance use, suggesting that children with ADHD were more likely to become involved with deviant peers and, as a result, more likely to use substances.

Family studies indicate that ADHD runs in families with a two to four-fold increased risk among first-degree relatives (Nigg, 2006). Studies evaluating familial patterns also suggest that there is a higher prevalence of mood and anxiety disorders, learning disorders, substance-related disorders, and antisocial personality disorder in family members of children with ADHD (Barkley et al., 1990; APA, 2000). In his review, Nigg (2006) states that the heritability estimates of ADHD are substantial when parent (i.e., ranges from .60 to .90) and teacher (i.e., .79) reports are considered. Early molecular genetic studies found that 'resistance to thyroid hormone' disorder attributable to thyroid hormone beta receptor gene can play a role in the development of ADHD (Nigg, 2006). However, this disorder cannot account for all cases of ADHD as its population prevalence estimate is .04%. This suggests that genetic liability of ADHD is due to many genes and that environmental risk factors interact with genetic liability (Nigg, 2006). Research has suggested many potential environmental risk factors for ADHD. In particular, prenatal exposure to substances (i.e., nicotine, alcohol, or other substances), perinatal problems (i.e., low birth weight probably due to low SES, premature birth, poor maternal nutrition, high maternal stress, domestic violence), and postnatal exposure to lead appear to contribute to behavioral and neuropsychological problems of ADHD (for review see Barkley, 2006; Nigg, 2006).

Another large area of research has focused on structural and functional brain abnormalities in children with ADHD, including reduction in total brain volume and in the size

of key brain regions (for review see Barkley, 2006; Nigg, 2006). These regions include prefrontal cortices, basal ganglia, cerebellum, and the corpus collosum. In addition, possible neurotransmitter dysfunction or imbalance, especially in dopamine, norepinephrine, and GABA, have been proposed due partly to the positive responses to stimulant medications (i.e., dopamine reuptake inhibitors and agonists) and atomoxetine (i.e., norepinephrine reuptake inhibitor) (for review see Barkley, 2006; Nigg, 2006).

1.2 **Current Theories of ADHD**

Early conceptualizations of ADHD focused on defective moral control and deficits in behavioral inhibition (for review see Barkley, 2006). More recent theories (Barkley 1997; Quay 1997) have viewed behavioral inhibition as a central impairment in ADHD and introduced the idea that deficits in executive functioning and self-regulation may account for the symptoms of inattention (Barkley, 1997, 2006).

Based on Gray's theory (1985), Quay (1997) emphasized the role of weak behavioral inhibition in ADHD. Gray (1985) proposed three systems: The fight-flight system (F/F), rewards system (later renamed as behavioral activation system, BAS), and behavioral inhibition system (BIS). The fight-flight system subserves escape behaviors and defense reactions under conditions of pain, punishment, and frustration. The BAS controls approach behaviors elicited by signals of reward and active avoidance behaviors elicited by signals of the likelihood of non-punishment. Thus, this system is responsible for maximizing rewards (approach behaviors) and for minimizing punishments in situations where behavioral responses are required (active avoidance). The BIS subserves aversive motivational functions and stops or decelerates responding under conditioned stimuli of punishment, nonreward, and novelty to bring about passive avoidance or extinction. Through the production of anxiety and fear, the system actively

inhibits appetitive behaviors when aversive consequences are anticipated. It is hypothesized that the BIS and BAS are actively opposed to each other. Based on the theory, individuals with a more responsive BIS are considered to be anxiety-prone, whereas individuals with a more responsive BAS are considered to be impulsive and prone to disinhibitory psychopathology.

Quay (1997) proposes that behavioral disinhibition (i.e., impulsivity) may result from diminished activity in the BIS. The assumption is that when the signals of conditioned punishment are detected, there is increased activity in the BIS, which results in inhibitory effect on the behavior. Thus, it is assumed that children with ADHD are less sensitive to the signals of conditioned punishment. Some of the predictions of the theory have been supported and others remain to be investigated (Barkley, 2006). For example, Gray's theory does not account for the behavioral differences between disinhibited groups. Although both ADHD and CD groups are impulsive, only CD group shows elevated levels of aggression (Beauchaine, 2001).

Similarly, Douglas (1985) talked about the role of excessive approach responding and proposed that children with ADHD are dependent upon immediate and positive reinforcement. According to Douglas' description, children with ADHD exhibit an underlying self-regulatory problem encompassing several defective processes, including disinhibition, strong inclination to seek immediate rewards, and difficulty sustaining effort. The tendency to seek immediate rewards makes the children particularly vulnerable to the arousing and distracting effects of reward as well as the frustrating effects of losing expected rewards.

According to Barkley's model (1997), the essential impairment in ADHD (mainly ADHD-C and ADHD-PHI) is a deficit involving behavioral inhibition, which refers to three processes: a) inhibition of the initial response for which immediate positive or negative reinforcement is available or has been previously associated with that response, b) stopping for

an ongoing response, which permits a delay in the decision process, and c) the protection of this delay period from disruption by competing events and responses. Barkley hypothesizes that deficit in behavioral inhibition leads to secondary deficits in certain neuropsychological abilities, including working memory, self-regulation of affect-motivation-arousal, internalization of speech, and reconstitution.

In Barkley's model (1997), self-regulation of affect includes self-directed actions, the organization of behavioral contingencies, the use of self-directed speech, deferred gratification, and goal-directed, intentional actions. Barkley (1999) states that self-regulation greatly depends on response inhibition and interference control because no actions can be taken toward an event if a response has already been made. Further, Barkley (1997) postulates that the ability to self-regulate and induce emotional states needed in the service of a goal-directed behavior may involve the ability to regulate and induce motivation and arousal states in support of such behavior. For example, children may learn to create more positive emotional states when they are frustrated or feeling angry by learning to manipulate the variables of such states. Thus, this component of the model includes the self-regulation of emotion, a capacity for objectivity and social perspective, the self-regulation of motivational states, and the self-regulation of arousal. As Barkley (1999) states, the capacity to interrupt an ongoing sequence of behavior is critical to self-regulation because if the feedback the individual is receiving for his/her pattern of responses is signaling their ineffectiveness, then, this sequence of behaviors must be interrupted.

Some evidence of poor inhibition comes from studies using motor inhibition tasks, such as go/no-go paradigms or the stop-signal task. For example, Iaboni, Douglas, and Baker (1995) examined the effects of reward and response costs on the ability to inhibit responding in children with ADHD and typically developing children. Children were tested on four different conditions

on a go/no-go learning task. Two conditions involved both reward and response costs, one response costs only, and one reward only. Both groups made significantly more commission errors (i.e., responding to passive stimuli) than omission errors (i.e., failing to respond to active stimuli), and the groups did not differ in the number of omission errors. Children with ADHD made more commission errors than typically developing children across the four conditions. Analysis on measure of responsivity suggested that children with ADHD had a stronger tendency to respond than control children. Analysis on reaction times revealed that children with ADHD responded significantly faster following response costs than following reward, whereas control children responded similarly to response costs and rewards.

In a different study (Slusarek, Velling, Bunk, & Eggers, 2001), researchers investigated the effects of different motivational incentives on the ability of children to inhibit intended or ongoing actions. For reactions that were not inhibited in the presence of the stop-signal, the children lost either 1 point (i.e., low) or 5 points (i.e., high). Successful inhibition was always awarded by winning 1 point. The researchers found no indications of deficits in sustained attention in children with ADHD. Although children with ADHD performed the task as well as typically developing children in the high incentive condition, they were less able to inhibit their reactions and had longer stop-signal reaction times in the low incentive condition.

Although the models introducing the ideas of failure of avoidance learning and of overvaluing immediate reward cues to explain ADHD appears incomplete (Nigg & Casey, 2005), behavioral inhibition may affect skills necessary for socially appropriate behavior (Friedman et al., 2003). Social impairments associated with ADHD may arise from symptoms of hyperactivity and impulsivity as children with ADHD often exhibit marked impatience, interrupt others, and blurt out comments (Beauchaine, Katkin, Strassberg, & Snarr, 2001; Friedman et al.,

2003). For a subset of children, symptoms of inattention may be viewed as indifference and uncaring (Friedman et al., 2003). Literature relevant to the social impairments will be reviewed in the following section.

1.3   Review of Social Impairments in Children with ADHD

Children with ADHD are at risk for experiencing difficulties in social interactions compared to their typically developing peers (Gentschel & MacLaughlin, 2000; Greene et al., 1996). Social difficulties experienced by children with ADHD are often overlooked (Whalen & Henker, 1985; Wheeler & Carlson, 1994). In contrast to the well established literature on the behavioral and cognitive deficits of children with ADHD, much less is known about the social deficits of this population (Greene et al., 1996). In their review paper, Whalen and Henker (1985) state that ADHD children's social troubles are pervasive and central. Interpersonal difficulties are often listed as problematic by parents and teachers. Further, these social deficits tend to be durable, recurrent, and escalating. It appears that ADHD children's social problems tend *not* to diminish over time and may, in fact, increase with age. Although not always intentional, children with ADHD engage in undesirable social behaviors to a degree that others find them irritating and objectionable. Many children with ADHD have difficulty modulating their actions in accordance with changing settings and cues (Henker & Whalen, 1999). Their social acts fall short in terms of style, content, or situational appropriateness (Whalen & Henker, 1985).

Children with ADHD usually do not lack interest in contact with other people but have difficulties attuning their behaviors to other people (Nijmeijer et al., 2008). Socially inappropriate behaviors (e.g., frequent shifts in conversation, not listening to others, initiating conversations in inappropriate times, frequently interrupting or intruding upon others, blurting

out answers to questions, and failure to recognize important social cues) and difficulty in social problem solving are commonly seen in children with ADHD (Greene et al., 1996). They may not know how to approach social situations and may have problems producing appropriate behaviors in social contexts. They appear to overestimate their social skills and attribute social successes and failures to external factors (Stormont, 2001). As a result, children with ADHD often experience social rejection from their peers (Barkley, 1998; Gentschel & McLaughlin, 2000; Landau & Moore, 1991; Whalen & Henker, 1985; Wheeler & Carlson, 1994) and have difficulty maintaining friendships because of their weak sensitivity to others' feelings (Gentschel & McLaughlin, 2000). Interestingly, literature started drawing attention to the possible link between pervasive developmental disorders and ADHD, mostly because of the overlapping social interaction and communication deficits observed in both diagnostic categories (Nijmeijer et al., 2008).

Evidence suggests that children with ADHD are aware of their unpopularity and that this awareness negatively affects their self-esteem (Wheeler & Carlson, 1994). A recent study (Ostrander, Crystal, & August, 2006) found a strong relationship between depression and ADHD in both younger and older children. Moreover, the relationship between ADHD and depression in younger children was mediated by others' judgments (i.e., parents and teachers) about social competence. In older children, self-judgments of social competence mediated the relationship between ADHD, depression, and others' judgments of social competence.

Merrell and Boelter (2001) studied a behavior rating scale assessing social and antisocial behavior in children who were reported to have been diagnosed with ADHD. The results indicated that items related to self-management, self-control, intrusive, irritable, and explosive behaviors were the most powerful in separating the groups with and without ADHD. Further,

the ADHD symptoms were found to be inversely correlated to positive social behavior and positively correlated with antisocial characteristics.

Greene et al. (1996) found that although most children with ADHD had some degree of difficulty in the social domain, a subgroup of them were severely dysfunctional (i.e., "socially disabled" group defined by a significant discrepancy between observed and expected social functioning). As they pointed out, social disability may be a byproduct of the disorder or may set the stage for other disorders (e.g., depression). In their 4-year follow-up study, Greene and colleagues (Greene, Biederman, Faraone, Sienna, & Garcia-Jetton, 1997) found that social impairments identified at baseline were strong predictors of poor social and psychiatric outcome, particularly for substance abuse and conduct disorder.

Matthys, Cuperus, and Van Engeland (1999) studied social problem-solving skills in boys with ADHD in comparison to boys with other externalizing and internalizing disorders and typically developing boys. Participants were shown several problem situations and asked to answer questions. The results suggested that problem-solving skills of boys with ADHD were affected only with respect to encoding cues (i.e., "how do you know he did it on purpose?") and response generation (i.e., "what are you going to do or say?"). However, this finding was not specific to the ADHD group, as children with ODD/CD and with ODD/CD+ADHD were also affected in these domains.

Recently, Van der Oord et al. (2005) investigated the psychometric properties of the Social Skills Rating System (Gresham & Elliot, 1990) in children with ADHD and found further evidence demonstrating that children with ADHD showed more social skills deficits than control children. Based on the ratings of all three informants, 90% of the children in the sample were

correctly classified as typically developing or children with ADHD. The evaluations obtained from the parents particularly contributed to the classification of the children.

Few studies address gender differences in social impairment associated with ADHD. Although results from a meta-analysis indicated that there are no differences in social functioning among girls and boys with ADHD (Gaub & Carlson, 1997), results from another study (Merrell & Boelter, 2001) suggested that girls displayed more social competence and lower levels of antisocial behaviors than boys. Overall, it appears that girls with ADHD have social deficits compared to typically developing girls, which include aggressive behaviors, fewer friends, and peer rejection (for review see Nijmeijer et al., 2008)

Current literature examining the effects of different ADHD treatments on psychosocial functioning suggests that cognitive behavior treatment of ADHD designed to teach the child to control his/her inattention and impulsive behavior generally does not provide clinically important changes in behavior and academic performance (for review see Pelham & Gnagy, 1999; Pelham, Wheeler, & Chronis, 1998). Social skills training may be beneficial when it is provided as an adjunctive treatment to behavioral interventions (Pelham & Gnagy, 1999). The literature suggests that clinical behavior therapy (i.e., training parents and/or teachers to implement contingency management) and more intensive contingency management approaches (i.e., token economy reward system, removal of privileges, etc.) implemented by professionals provide considerable improvements. Research findings indicate that the effects of contingency management procedures are comparable to the effects of stimulant medications (for review see Pelham & Gnagy, 1999). More intensive treatment approaches combining clinical behavior therapy and contingency management, such as the Children's Summer Treatment Program, also provide powerful treatment outcomes.

Studies examining the effects of combined pharmacological and behavioral interventions produce substantial changes although these changes are statistically equivalent to the medication alone condition (for review see Pelham & Gnagy, 1999). In the Multimodal Treatment Study for children with ADHD (Jensen et al., 1999), findings showed that medication management resulted in better outcomes than intensive behavioral treatment, and combined treatment produced better outcomes than behavioral treatment alone. However, the outcomes of combined treatment were equivalent to the outcomes of the medication management. The combined treatment, but not the behavioral treatment, was found to be superior to the community care. In another study (Abikoff et al., 2004), medication, either alone or combined with the social skills training, was found not to be sufficient to eliminate deficits in social behavior in children with ADHD. In this 2-year follow-up study evaluating the effects of methylphenidate and multimodal psychosocial treatment combined with methylphenidate, the researchers were unable to find improvements in children's social functioning.

These findings underscore the importance of further research that targets the assessment of social behaviors in children with ADHD to contribute to the development of more effective intervention approaches. Existent research ascribes the impairments in social functioning mainly to cognitive deficits (Barkley, 1997). These deficits in social skills may be related directly to the symptoms of ADHD (Greene et al., 1996; Nijmeijer et al., 2008) and/or other impairments, such as high levels of affective arousal and expression (Henker & Whalen, 1999) or misinterpreting social cues, including facial expressions of others (Friedman et al., 2003). Although Barkley (1997) speculates "the perception of others' emotions will not be affected by ADHD because such perception is nonexecutive in nature" (pp.80), the evidence, which will be reviewed next, points to the contrary.

1.4   <u>**Review of Emotion Recognition Skills in Children with ADHD**</u>

One of the emerging research areas assessing social deficits in children with ADHD is the study of emotion recognition. Understanding people's emotions is a key element in social interactions to comprehend the message conveyed and to be able to give appropriate responses. Further, emotion recognition is one of the major components in establishing a relationship with another person and in developing emotional reciprocity. Accurate recognition and interpretation of others' facial expressions help the child decide when to make socially acceptable statements and provide guidance in interpersonal transactions (Izard, et al., 2001).

Research shows that understanding emotions relates positively to adaptive social behavior and negatively to measures of internalizing behaviors (for review see Izard et al., 2001) and behavioral problems (Blair & Coles, 2000). The ability to recognize and label emotions predicts children's social competence (Mostow, Izard, Fine, & Trentacosta, 2002) and is linked to social adjustment (Izard et al., 2001). Thus, consistent misconception and misinterpretation of emotion cues or frequent failure to perceive them could impede the development of social competence (Izard et al., 2001). The possibility exists that children with ADHD do not respond to subtle cues that signal the need for thoughtful social analysis (Whalen & Henker, 1985).

Several studies have been conducted to assess the ability of emotion recognition in children with ADHD. Singh and colleagues (1998) used photographed faces displaying six basic emotions (i.e., anger, disgust, fear, happiness, sadness, and surprise) and asked the participants to match each emotion with an emotional story read to them. Overall, children identified the six emotions only 74% of the time. Happiness was correctly identified by 94%, sadness by 86%, disgust by 76%, surprise by 66%, anger by 65%, and fear by 61%. Twenty six percent of children with ADHD misinterpreted fear as surprise, 23% of children misinterpreted surprise as

fear, and 22% of children misinterpreted anger as disgust. This study had several limitations including the lack of a control group and a standardized diagnostic assessment. Nonetheless, the findings suggested a deficit in emotion recognition in children with possible ADHD compared to general population.

Cadesky, Mota, and Schachar (2000) studied non-verbal social cue perception (Diagnostic Analysis of Nonverbal Accuract, DANVA; Nowicki & Duke, 1994) in children with ADHD, with CD, with ADHD and CD, and typical children (control group). Four emotions (i.e., anger, fear, happiness, sadness) were presented to participants using photographed faces. The control and ADHD+CD groups were most accurate, followed by the ADHD and CD groups. Specifically, ADHD and CD groups were less accurate than the control group on all emotions, except anger. Compared to the CD group that tended to misinterpret emotions as anger, the ADHD group made errors in a random fashion and the pattern of errors was similar to that of the control group. In summary, the study findings suggested that the ADHD group made more mistakes than the control group, yet both groups made the same types of mistakes. This finding suggests that the deficits in the ADHD group may be due to inattention or other regulatory processes.

Corbett and Glidden (2000) examined the ability of children with ADHD to perceive emotional facial expressions and emotional speech intonations. Photographed faces depicting six basic emotions and a neutral response (i.e., anger, disgust, fear, happiness, sadness, surprise, and neutral) and sentences depicting four emotional intonations were presented to the participants along with measures of behavioral inhibition (i.e., matching familiar figures test and go/no-go task) and memory tests. Results indicated that children with ADHD performed significantly different on all measures, except for the go/no-go task. Discriminant function analysis suggested

that 85% of the variance is explained by Pictures of Affect test, highlighting deficits in the perception of affect in classifying participants. However, it was noted that the deficits in attention may contribute to inaccurate or incomplete encoding of affective stimuli.

Pelc, Kornreich, Foisy, and Dan (2006) investigated the recognition of four emotions (i.e., anger, disgust, happiness, sadness) in children diagnosed with ADHD, predominantly inattentive type, using photographs with the 30% and 70% intensity levels. They found that children with ADHD made significantly more recognition errors than typically developing children. There were no differences between the groups in decoding happiness and disgust, however, children with ADHD made more errors when recognizing anger and sadness. Further, ADHD children's overall decoding accuracy, especially for anger, was found to be correlated with interpersonal problems. Self-rating of the task difficulty revealed lack of awareness of decoding errors in the ADHD group.

Kats-Gold, Besser, and Priel (2007) studied emotion recognition in children who had elevated scores on the Conners' Rating System Revised (Conners, 1997) and its relation to children's social skills assessed by Social Skills Rating System (Gresham & Elliot, 1990). The researchers used photographed faces depicting one of four basic emotions (i.e., anger, fear, happiness, sadness). In addition to accuracy measures, reaction time (i.e., latency to detect the emotion or speed of emotion recognition) was also obtained. The results indicated that at-risk children presented longer reaction times and made more recognition errors than the comparison group, suggesting that longer reaction times did not improve recognition accuracy. Specifically, at-risk children confused different emotions (i.e., anger, happiness, and sadness) with fear and anger with sadness. Because they displayed a tendency to interpret emotional facial expressions as sad or fearful, the authors concluded that at-risk children exhibit a negative bias, which

challenges the results and the conclusion of the study conducted by Cadesky and colleagues (2000). Supporting the existing literature, at-risk children exhibited lower social skills and higher behavioral problems. Impaired recognition of facial affect was found to be associated with social skills and behavioral problems in the at-risk group only.

Yuill and Lyon (2007) studied understanding of emotional expressions in children with ADHD using emotional and non-emotional photographed faces. Preliminary analyses indicated that children with ADHD performed more poorly than typically developing children during the presentation of both emotional and non-emotional faces. However, when the researchers examined the impact of impulsive responding, the results showed that the ADHD group performed no worse than the control group on the non-emotion task but still performed poorer on the emotion task. This result pattern indicates that children with ADHD have deficits in processing emotional information not just by general cognitive limitations, but also by impairments in understanding links between expressed emotions and situations (Yuill & Lyon, 2007).

Most recently, a study was conducted by Boakes and colleagues (Boakes, Chapman, Houghton, & West, 2008) to investigate the possible emotion recognition deficits across different stimulus formats in boys with ADHD. The study used static and dynamic stimuli, and dynamic stimuli presented within a relevant context. Further, the six basic emotions (i.e., anger, disgust, fear, happiness, sadness, and surprise) were presented in two modes: cartoons and real-life. The stimuli were chosen from contemporary TV shows. Results suggested that boys with ADHD exhibited significant impairments when recognizing disgust and fear. These impairments were consistent across the cartoon and real-life portrayal modes and across the static, dynamic, and dynamic-contextualized trials.

As opposed to the findings summarized above, two studies (Shapiro, Hughes, August, & Bloomquist, 1993; Guyer et al., 2007) did not find differences between children with and without ADHD on emotion recognition. Shapiro and colleagues (1993) found that children with ADHD, overall, were no different than typically developing children on the Minnesota Tests of Affective Processing. However, the results indicated that younger children with ADHD were more impaired than both older children with ADHD and typically developing children. Guyer et al. (2007) examined the specificity of facial expression labeling deficits in youth with anxiety and/or mood disorder, ADHD and/or CD, bipolar disorder, severe mood dysregulation, and typical development. Four emotions (i.e., anger, fear, happiness, and sadness) depicted in photographed faces were used (DANVA; Nowicki & Duke, 1994). The results indicated that children with bipolar disorder and severe mood dysregulation made more recognition errors compared to all other groups. In this study, children with ADHD and/or CD performed similarly to the control group. The authors explained this finding by participants' older ages based on the findings of Shapiro et al. (1993).

Although they are limited in number, some studies suggest that deficits in emotion recognition in children with ADHD persist into adulthood. For example, Rapport and colleagues (Rapport, Friedman, Tzelepis, & Van Voorhis, 2002) found that adults with ADHD performed worse in affect recognition than did adults without ADHD. Further, the impairment was not related to gross perceptual processes, fundamental abilities in face recognition, or attentional aspects of affect perception. However, the researchers found that intensity of experienced emotion moderated affect recognition. In adults with ADHD who reported greater intensity, experienced emotion was inversely related to affect recognition. The results of this study also

indicated that the ADHD group took significantly longer to select the emotions than did the control group.

In summary, research on emotion recognition in children with ADHD provides mixed results. Although there is an overall conclusion that children with ADHD tend to show deficits in emotion recognition, some studies do not support this conclusion. There may be several possible reasons for these contradictory findings, one being that the experimental stimuli are almost always different across studies. A second possibility might be the great degree of heterogeneity of the disorder and differences in characterization of the groups. More often, studies include children diagnosed with different subtypes of ADHD and comorbid psychopathology. Further, in several studies, the diagnosis of ADHD is not confirmed using the standardized diagnostic tools. A third possibility is that gender differences might play roles in these different findings as some studies include only boys, whereas others include both boys and girls.

On a final note, almost all of the studies summarized above have a potential limitation in that photographs of posed facial expressions may not be ecologically valid (Guyer et al., 2007). Posed photographs do not fully capture the details of spontaneous nonverbal communication that occur in real-life social interactions. Although Boakes and colleagues (2008) found impairments across the static and dynamic trials, more research using dynamic stimuli (e.g., videos) is needed in the area to broaden our knowledge and understanding of emotion recognition deficits in ADHD population. Further, it appears that there is only one study examining latency to detect emotions (i.e., reaction times) in children with ADHD. Finally, to date, studies investigating the relationship between emotion recognition and social skills in children with ADHD are lacking. There appears to be one study (Kats-Gold et al., 2007) specifically investigating the possible

linkage between social skills and emotions recognition. Although the findings indicated that impaired emotion recognition was related to social skills and behavior problems, this study included children who were at risk for having ADHD and not children who were diagnosed with ADHD using standardized procedures.

Thus, there is still a need for more research in this area to replicate the previous findings and to overcome the limitations of previous studies. Further research in the area will enable us to better understand emotion recognition deficits and their relation to social behavior in children with ADHD. The information gained from this and earlier studies may help researchers design interventions that include appropriate opportunities to sharpen skills of detecting and interpreting emotion signals in facial expressions. Basic emotion recognition abilities provide the foundation for other components of preventive programs, such as facilitating the development of empathy, prosocial behavior, and social problem-solving skills (Izard et al., 2001). The amelioration of social skills in children with ADHD is important not only for the daily functioning but also for long-term adjustment and adaptation (Whalen & Henker, 1985).

1.5 **Review of Visual Scanning and Fixation in Children with ADHD**

Children with ADHD may be at increased risk for deficits in their ability to accurately recognize facial expressions of emotion because their inattention and impulsivity might predispose them to make increased errors through not attending to the individual parts that provide differential cues (Singh et al., 1998). Although some studies failed to show actual attention deficits in children with ADHD (e.g., Van der Meere, Wekking, & Sergeant, 1991), others found deficits in sustained attention under conditions of slow presentation rate of stimuli (e.g., Van der Meere, Shalev, Börger, & Gross-Tsur, 1995).

Previous studies have demonstrated that certain emotions are more expressed on specific regions of the face. For example, negative emotions are expressed more on the upper part of the face whereas positive emotions are expressed more on the lower part of the face (Dimberg & Petterson, 2000). Further, positive relationships were found between dwell time and number of fixations to the eyes and both accuracy of facial expression recognition and speed of facial expression recognition (Hall, Hutton, & Morgan, 2010). Thus, an individual may reach inaccurate conclusions about the environment if he/she fails to look for relevant cues or to integrate what she/he has seen (Morrison & Bellack, 1981). Based on the previous literature, it is reasonable to assume that better visual attention to specific face regions, especially the eyes, may result in better performance in emotion recognition. Assuming that children with ADHD show attention deficits, it is important to determine whether visual inattention is related to emotion recognition deficits in these children.

Information gathered from visual processing using eye tracker technology would clarify the nature of the emotion perception impairment in children with ADHD as distinct scanning strategies may underlie the difficulties these children experience in recognizing emotional facial expressions. If emotion recognition deficits are due to inattention and impulsive responding, children with ADHD would be expected to show no bias to any particular emotion (Marsh & Williams, 2006). Preliminary analysis from a study (Marsh, et al., 2000) examining scanpaths to facial expressions of emotion in individuals with first-episode schizophrenia and ADHD support this hypothesis and indicate that participants with first-episode schizophrenia showed restricted scanning style across all faces evidenced by fewer fixations of a longer duration, a shorter scanpath length, and a shorter distance between fixations. In contrast, participants with ADHD showed an extensive pattern of scanning evidenced by longer scanpath lengths. However, to

date, there appears to be no study investigating the visual scanning and fixation in children with ADHD during tasks assessing emotion recognition. Thus, the current study would contribute important and unique information to the literature in this area.

1.6   Social Behavior and Its Link to Autonomic Nervous System: The Polyvagal Theory

The Autonomic Nervous System (ANS) plays an important role in regulating physiological arousal and inhibition during stress. Porges (1995, 1997, 1998, 2001, 2003) introduced the Polyvagal Theory, which describes how the phylogenetic development of the ANS results in increased neural control of the heart via the myelinated vagal system with a proposed parallel enhancement in social communication. The theory focuses on how a specific component of the ANS, the vagus, is involved in the expression of several behavioral, physiological, and psychological features associated with social behavior. The vagus, the Xth cranial nerve, originates in the brain stem and projects to many organs, including the heart. Because the vagus contains both efferent (i.e., motor) and afferent (i.e., sensory) fibers, it promotes dynamic feedback between brain and the heart to regulate homeostasis. The theory emphasizes that the vagus has two distinct efferent pathways with different source nuclei: unmyelinated vagal efferent fibers originating in the dorsal motor nucleus and myelinated vagal efferent fibers originating in the nucleus ambiguus (Parent, 1996). Of special importance to social behavior and emotional regulation is the linkage in the brainstem between the source nuclei that regulate the striated muscles of the face and head (used in signaling emotion) and the myelinated vagus, which originates in the nucleus ambiguus.

Based on the neurophysiological and neuroanatomical distinction between the two branches of the vagus, the theory includes a description of three stages in the evolution of the neural regulation of the ANS and the corresponding behaviors that are supported by each stage.

In the most primitive state, the neural regulation of the ANS is dependent on the unmyelinated vagus and its lower motor neurons located in dorsal motor nucleus. The behavioral strategy supported by this state is immobilization (e.g., feigning death, vaso-vagal syncope, and behavioral shutdown). In the second state, the neural regulation of the autonomic nervous system includes the sympathetic-adrenal system and its lower motor neurons in the spinal cord. The behavioral strategy supported by this state is mobilization (e.g., fight-flight behaviors). In the third state, the primary neural regulation shifts from the sympathetic-adrenal system to the myelinated vagus and its lower motor neurons located in the nucleus ambiguus and upper motor neurons located in the motor cortex. This final stage, the Social Engagement System consisting of the neural regulation of the myelinated vagus and the striated muscles of the face and head, promotes behaviors associated with social engagement and communication. Through evolution, the brainstem nuclei that regulate this newest system became integrated with the nuclei that regulate the muscles of the face and head. In the theory, the Social Engagement System includes regulation of the opposing muscles (i.e., obicularus occuli) of the eye lids (i.e., influencing gaze), facial muscles (i.e., expression), middle ear muscles (i.e., extracting the human voice from background noise), muscles of chewing (i.e., ingestion), muscles of the larynx and pharynx (i.e., vocalizing), and muscles of head turning and tilting (i.e., gesture and orienting). The theory proposes that deficits in the Social Engagement System would compromise spontaneous social behavior, social awareness, emotional facial expressions, prosody, and language development.

In the theory, the myelinated vagus is conceptualized as a "vagal brake," which provides a neural mechanism to rapidly change visceral state by slowing or speeding the heart (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996). Neurophysiologically, the vagal brake provides a mechanism to support the metabolic requirements for mobilization and

communicative behavior. For example, during stressful conditions, the vagal brake is released to increase heart rate. When the vagal brake is released, the myelinated vagus withdraws and the neural influence on the heart is decreased. Functionally, the vagal brake enables the individual to rapidly engage and disengage with others and to promote calm behavioral states. The index of this neural influence via the myelinated vagus is referred to as cardiac vagal tone and can be quantified by measuring the amplitude of Respiratory Sinus Arrhythmia (RSA). High amplitude RSA indicates a strong neural influence to the heart via the myelinated vagus, whereas low amplitude RSA indicates a weak vagal influence on the heart.

Based on the assumptions of the theory, social behavior is thought to be dependent on the physiological state, with calm physiological states promoting enhanced social behavior. Healthy social interactions includes not only generating appropriate responses (e.g., vocalizations, orienting) but also being aware of and sensitive to others' behaviors, including facial expressions. This would allow the person to adapt his/her own behavior according to the situational demands. Thus, it is hypothesized that the range of emotional expression, quality of communication, and the ability to regulate behavioral state would be related to the physiological state of the individual.

In support of the theory, RSA has been found to be related to several childhood disorders, including internalizing and externalizing, and adaptive and maladaptive behaviors (for review see Beauchaine, 2001). The work by Porges and colleagues suggests that RSA is a psychophysiological marker of behavioral reactivity and emotionality in infancy. For example, it was found that high RSA infants displayed more interest, more joy, and more look away behaviors toward a stranger compared to low RSA infants (Stifter, Fox, & Porges, 1989). Studies examining the relationship between RSA and social engagement documented that better

regulation of RSA is related to better social engagement (e.g., Bazhenova, Plonskaia, & Porges, 2001). Fox and Porges (1985) reported that preterm neonates with greater amplitude RSA had better outcomes at 8 and 12 months than those with lower amplitude RSA. In these infant studies, RSA appears to mark the capacity for active engagement of infants with the environment, as reflected by temperamental reactivity, attentional capacity, and negative emotionality. In toddlerhood, RSA marks measures of social competence, emotion regulation, and expression of positive affect (for review see Beauchaine, 2001). Recently, Vaughan Van Hecke et al. (2009) investigated RSA and temporal-parietal electroencephalogram activity in children with and without autism while participants viewed videos of a familiar and an unfamiliar person reading a story. The results indicated that higher baseline RSA was related to higher levels of Social Skills and lower levels of Problem Behaviors on the Social Skills Rating System (Gresham & Elliot, 1990). Moreover, the children with autism had significantly lower baseline RSA relative to the typically developing children.

Overall, these studies suggest that neural regulation of the heart (as indexed by RSA) might be predictive of positive developmental outcomes and emergent spontaneous social behavior. Studying social behavior and identifying children who have difficulties in social interactions have important implications for developmental psychology and psychopathology, as the consequences of social isolation might result in loneliness, low self-esteem, anxiety, and depression (Fox, Henderson, Marshall, Nichols, & Ghera, 2005).

Behavioral and social engagement requires sustained attention, which is accompanied by vagally mediated inhibition of heart rate (Suess, Porges, & Plude, 1994). When psychological stress is imposed by increasing task difficulty, heart rate increases are observed. In this respect, the more effort the person allocates, the lower the RSA. Suess and colleagues (1994) found that

fourth- and fifth-graders with higher baseline RSA, higher heart period variability, and slower heart rates performed better compared to children with lower baseline RSA during the first minutes of a continuous performance task (CPT). They also found that vagal tone decreased along with heart rate accelerations during the CPT, indicating that the task performance was effortful and required attention. In this study, however, only typically developing children were included, restricting the range in levels of both vagal tone and individual differences in attentional processing.

Other studies investigated the associations between CPTs and heart rate variability in children with ADHD. In some studies 0.10-Hz component was selected as an index of effort allocation (i.e., the more effort allocated, the smaller the 0.10-Hz component). Although not universally accepted, this component of heart rate variability appears to be more closely related to the vasomotor and blood pressure regulatory circuit. Further, even though it is also a strong indicator of vagal activity, it is unclear whether it is reflecting influences from the dorsal vagal circuit as well. In one study (Börger et al., 1999), it was found that children with ADHD had greater 0.10-Hz component compared to typically developing children, indicating that, overall, the effort allocation was less in the ADHD group than in the control group. Further, this was associated with poor test performance over time. In children with ADHD, performance deterioration over time was about three times as much relative to the control group. Overall, children with ADHD responded more variably than the typically developing children. The finding that the effort allocation was less in the ADHD group compared to the control group was replicated in a following study in the condition with a slow presentation rate but not in the fast presentation rate (Börger & Van der Meere, 2000).

Beauchaine and colleagues (2001) compared groups of male adolescents with ADHD and ADHD/CD with typical controls while completing a motor task, which included reward administration and removal, and while watching a video about a peer conflict. It was found that children with ADHD and ADHD/CD showed reduced electrodermal responses compared to controls. The ADHD/CD group showed reduced RSA at baseline compared to children with ADHD and controls. No differences were found between children with ADHD and control children on RSA. Similarly, Crowell et al. (2006) were unable to find significant changes in RSA at baseline and during reward.

Overall, a few studies investigated the ANS variables, particularly RSA, in relation to tasks requiring attention. In two studies (Beauchaine et al., 2001; Crowell et al., 2006), no differences were found between children with ADHD and typically developing children in RSA during the baseline and the task presentation. Suess and colleagues (1994) found a relationship between increased vagal regulation of the heart and better performance during the first two minutes of the CPT. To date, no study has evaluated the possible relationship between RSA and social behaviors by including children with ADHD and thereby increasing individual differences in the sample.

1.7   Specific Aims and Hypotheses

The current study aims to evaluate and to contrast the accuracy of emotion recognition and latency to detect emotions in children with ADHD (ADHD group) and typically developing children (control group) when children are presented with facial expressions of six basic emotions (i.e., anger, disgust, fear, happiness, sadness, and surprise). A second goal of the study is to evaluate the relationship between emotion recognition and social behaviors measured by Social Skills Rating System (Gresham & Elliot, 1990) in children with ADHD compared to

typically developing children. A third goal of the study is to examine whether emotion recognition and social behaviors are related to certain physiological and behavioral variables, including RSA and visual fixation.

Based on the literature and previous findings, the current study hypothesizes that children in the ADHD group will display more errors and longer response rates when recognizing emotions than typically developing children. It is also hypothesized that deficits in emotion recognition may be related to overall visual attention patterns. Specifically, it is expected that children who look longer at the upper face region (e.g., eye region) will be more accurate and faster at recognizing emotions, especially negative emotions, compared to the children who look less at the upper face region. In addition, the current study hypothesizes that the deficits in emotion recognition, if observed, would be related to social impairments in children with ADHD compared to typically developing children. Finally, it is anticipated that the amplitude of RSA will be related to the emotion recognition and social behavior.

2. METHOD

The study was reviewed and continuously approved by the University of Illinois at Chicago Internal Review Board.

2.1   Participants

The study included two groups – 33 children with inattentive (ADHD-PI) and combined (ADHD-C) subtypes of ADHD (ADHD group) and 38 typically developing children (control group) between the ages of 7 and 12[1]. Children in the ADHD group were recruited from the Hyperactivity, Attention, and Learning Problems (HALP) clinic directed by Dr. Mark A. Stein at the University of Illinois at Chicago. Diagnosis of ADHD was established through a clinical interview with parents and children, screening measures (e.g., Conners' Parent Rating Scale-Revised: Long version; CPRS-R:L; Conners, 1997) and a computerized test (CPT-II; Conners, 2000) at the HALP clinic. Further, children with ADHD were evaluated for comorbid disorders, including learning issues, mood and anxiety disorders, and behavioral problems. The children in the control group were recruited from the Chicago area via public solicitation (e.g., internet ads, announcements at area schools).

To increase ecological validity, children with comorbid psychopathology (i.e., mood disorders, anxiety disorders, learning disorders, oppositional defiant disorder, etc.) in the ADHD group were allowed to participate in the research. However, children with mental retardation (i.e., full scale IQ scores below 70), autism spectrum disorders, psychotic disorders, neurological disorders, and medical conditions requiring regular use of medication were excluded. Exclusionary criteria in the control group included scores above the clinical cut-off on the DSM-IV oriented scales of the Child Behavior Checklist for Ages 6-18 (CBCL; Achenbach and

Rescorla, 2001) as well as Conners' Parent Rating Scale-Revised: Long version (CPRS-R:L; Conners, 1997), and full scale IQ scores below 70.

Four children in the control group were excluded from the research for various reasons: Three children scored above the clinical cut-off on the CBCL and CPRS-R:L, and 1 child did not return for cognitive assessment. These reductions resulted in an effective sample size of 33 children in the ADHD group (23 males and 10 females) and 34 children in the control group (18 males and 16 females). In the ADHD group, 21 children were diagnosed with ADHD-C and 12 children were diagnosed with ADHD-PI. Overall, the mean age in years was 9.33 ($SD = 1.76$) for the ADHD group and 9.94 ($SD = 1.63$) for the control group. Parents of 2 children in the ADHD group and 4 children in the control group declined to provide information about their ethnicity. For the remaining participants, 74% percent of participants in the ADHD group were European American, 23% were African American, and 3% were Asian. Forty seven percent of the participants in the control group were European American, 43% were African American, and 10% were Asian. Parents of 2 children in the ADHD group and 2 children in the control group declined to provide information about their income. For the remaining participants, 74% percent of the participants in the ADHD group had a yearly income over $50,000 and 26% had under $50,000. Forty seven percent of the participants in the control group had yearly income over $50,000, 47% had under $50,000, and 6% received public assistance. There were no statistically significant differences between the groups based on age, $t(65) = -1.47$, $p = .15.$, gender, $\chi^2(1, N = 67) = 1.98$, $p = .21$, income levels, $\chi^2(2, N = 63) = 5.80$, $p = .06$, and ethnicity, $\chi^2(2, N = 61) = 4.97$, $p = .08$.

IQ was measured using the primary subtests of the Wechsler Intelligence Scale for Children-fourth edition (WISC-IV; Wechsler, 2003). The WISC-IV scores include a measure of

overall ability referred to as the Full Scale IQ score and four index scores (i.e., Verbal Comprehension, Perceptual Reasoning, Working Memory, and Processing Speed), each of which measures a specific cognitive ability. The WISC-IV consists of a number of subtests or tasks from which the IQ and index scores are derived. The reliability coefficients for the index scores range from .88 to .97 with a median of .92. The mean FSIQ score was 96.94 (SD = 15.74) in the ADHD group and 101.30 (SD = 12.97) in the control group, a non-significant difference, $t(64)$ = -1.23, p = .22[2]. Sample characteristics are reported in Table 1.

Medication use was noted for every child. In the control group, 2 children took asthma medications as needed. In the ADHD group, 12 children were on ADHD medications (i.e., 1 child took Adderall, 5 children took Concerta, 1 child took Focalin, 1 child took Ritalin and Concerta, and 4 children took Strattera).

Fourteen children in the ADHD group had comorbid diagnoses, including oppositional defiant disorder, learning disabilities (i.e., reading, math, and writing), developmental coordination disorder, nonverbal learning disability, adjustment disorder with anxious mood, enuresis, expressive language disorder, and generalized anxiety disorder.

TABLE I

PARTICIPANT CHARACTERISTICS (*N*, MEAN AGE, MEAN IQ SCORES, ETHNICITY, AND INCOME)

		ADHD	Control
N		33 (23 boys, 10 girls)	34 (18 boys, 16 girls)
Mean Age (*SD*)		9.33 (1.76)	9.94 (1.63)
Mean IQ (*SD*)	Verbal Comprehension	99.70 (15.99)	104.21 (15.92)
	Perceptual Reasoning	100.18 (19.33)	101.24 (14.42)
	Working Memory	95. 97 (14.14)	99.32 (11.51)
	Processing Speed	91.73 (14.93)	96.79 (12.09)
	Full Scale IQ	96.94 (15.74)	101. 30 (12.97)
Ethnicity[†]	European American	74%	47%
	African American	23%	43%
	Asian	3%	10%
Income[††]	Over $50,000	74%	47%
	Under $50,000	26%	47%
	Public assistance	-	6%

[†] Four parents in the ADHD group and two parents in the control group declined to provide ethnicity information for their child.

[††] Two parents in the ADHD group and two parents in the control group declined to provide information about their annual income.

2.2 **Screening Measures**

     1. **Conners' Parent Rating Scales-Revised: Long version (CPRS-R:L)**

     The CPRS-R:L assesses Oppositional Problems, Cognitive Problems/Inattention, Hyperactivity, Anxious-Shy Behavior, Perfectionism, Social Problems, and Psychosomatic symptoms in children and adolescents. The CPRS-R:L provides a reliable, accurate, and relatively brief measure of parental perceptions of children's behavior. The psychometric properties of the CPRS-R:L appear adequate as demonstrated by good internal reliability coefficients (i.e., ranges from .75 to .94) and effective discriminatory power (i.e., sensitivity = 92.3%, specificity = 94.5%, false positive rate = 5.5%, false negative rate = 7.7%) (Conners, Sitarenios, Parker, & Epstein, 1998).

     In the current study, parents of children in both groups were asked to complete the CPRS-R:L to assess the symptoms of ADHD and other externalizing behaviors.

     2. **Child Behavior Checklist for Ages 6-18 (CBCL)**

     The CBCL assesses children's competencies and behavioral and emotional problems. The CBCL offers a comprehensive approach for assessing adaptive and maladaptive functioning. The Syndrome Scales consists of several subscales, including Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, and Aggressive Behavior. The CBCL has good psychometric properties as demonstrated by high test-retest reliability (i.e., ranges from .95 to 1.00) and internal consistency (i.e., ranges from .78 to .97).

     In the current study, parents of children in both groups were asked to complete the CBCL. For the children in the control group, this ensured that they were within the range of

typical development and displayed typical behaviors. For the children in the ADHD group, the CBCL provided more information about the comorbid problems and psychopathology.

2.3   Measure of Social Behavior

To assess social behaviors, parents of participants in both groups were asked to complete the Social Skills Rating System (SSRS; Gresham & Elliot, 1990). The SSRS measures social skills, problem behaviors, and academic competence in children and adolescents. It consists of two main scales (i.e., Social Skills and Problem Behaviors) and several subscales (i.e., Cooperation, Assertion, Responsibility, Self-Control, Externalizing Problems, Internalizing Problems, and Hyperactivity). Internal consistency for parent form ranges from .87 to .90 on social skills and from .73 to .87 on problem behaviors.

The SSRS has widely been used in studies investigating social behavior, including in children with ADHD. A study (Van der Oord et al., 2005) examining the factor structure of SSRS specifically in children with ADHD supported the factor structure and internal consistency on the SSRS-Teacher version. Three out of four scales were also supported on the SSRS-Parent version; the factor "Responsibility" was not supported. Since it is difficult to obtain teacher reports from all participants, in the current study SSRS-Parent version was used.

2.4   Physiological Measures

1.   Heart Rate and RSA

Heart period data were collected continuosly with Biopac (Biopac Systems, Inc., Santa Barbara, CA) to monitor sequential R-R interval. Three Ag/AgCl self-adhering electrodes (Conmed Corp., Utica, NY) with a contact area of 10 mm diameter were placed on participants' chests. The peak of the R-wave of the ECG was detected from each sequential heart beat and the R-R interval was timed to the nearest msec. Heart period data were visually inspected and edited

off-line with CardioEdit software (Brain-Body Center, University of Illinois at Chicago).

Outliers are caused by failure to detect an R-peak, inaccurate detections of R-waves, or

ventricular arrhythmias. Editing consists of integer arithmetic (i.e., dividing intervals when

detections were missed and/or adding intervals when spuriously invalid detections occurred).

Consistent with the procedures developed by Porges (1985), RSA was calculated using the

CardioBatch software (Brain-Body Center, University of Illinois at Chicago).

Heart periods were re-sampled every 250 ms. In the current study, RSA was defined in a

frequency band consistent with the spontaneous breathing frequency of children (i.e., from .24 to

1.04 Hz). Amplitude of RSA was calculated by summing the variances across the band of

frequencies associated with spontaneous respiration. The natural logarithm of the extracted

variance for each successive 30 second epoch was calculated as the measure of the amplitude of

RSA. The average across all epochs within the baseline was used to characterize individual

differences in cardiac vagal tone. These procedures are statistically equivalent to frequency

domain methods (i.e., spectral analysis) for the calculation of the amplitude of RSA when heart

period data are stationary (Porges & Byrne, 1992) with correlations between the two methods

approaching unity (Denver, Reed, & Porges, 2007).

2.   Eye Gaze

To collect and quantify the eye-gaze data, an eye-tracking system (ASL Eye

Tracker 6000) was used (ASL, Bedford, MA). This system is composed of an illuminated

optical pan/tilt/zoom camera, a video head tracker unit, a control computer, and a stimuli

presentation computer. To optimize the accuracy of the pupil coordinates obtained by the optical

camera, the eye-tracking system is equipped with a video head-tracking unit that uses pupil

recognition software (HHI, Fraunhoffer Institute, Germany). The eye-tracking system uses edge

detection algorithms to locate and track corneal reflection and bright-pupil location and collects the X-Y coordinates of the separation between these two using an optical camera. The system then transposes these coordinates to correspond to locations on the monitor showing the stimuli being viewed.

To quantify visual fixations, three regions of interest (i.e., EYE, MOUTH, OFF) were created. The EYE region included the area from the mid-forehead to the mid-nose on the vertical axis and between the anterior temporal areas adjacent to the corner of the eyes on the horizontal axis. The MOUTH region included the area from the inferior aspect of the nose to the chin on the vertical axis and between the lip corners on the horizontal axis. The OFF region included all valid fixations on the presentation monitor that were not in the EYE or the MOUTH regions. Since the videos were of unequal durations, fixation duration percentage (i.e., looking time in each region as a percent of total fixation time during the data segment) was selected as the metric used in the analyses. Average fixation duration percentage was calculated across the presentations of each emotion for each region.

2.5 **Experimental Stimuli**

The Dynamic Affect Recognition Evaluation (DARE; Porges et al., 2007) was used for the standardized presentation of the emotional expressions. The DARE stimuli were developed from the Cohn–Kanade Action Unit-Coded Facial Expression Database. The database includes approximately 2,000 image sequences from more than 200 human subjects. In the current research, a modified version of the stimuli developed by Cohn and colleagues (Cohn, Zlochower, Lien, & Kanade, 1999) was used[3]. The stimuli included uncompressed video files (i.e., series of still images) consisting of six basic emotions (i.e., anger, disgust, fear, happiness, sadness, and surprise). These images were morphed and the final videos included a face starting with a

neutral expression and slowly transitioning into one of the six target emotions. In the current study, video length varied (ranging from 10–33 seconds) depending on the number of the frames in the original image sequences, which was independent of emotion category (i.e., duration of the videos did not vary in a systematic way among emotions). The DARE software was synchronized with the eye tracking and physiological monitoring equipment to insert event markers representing the beginning and ending of each video. The DARE software also provided an output file showing the order of the videos presented and the latency to recognize the emotions.

2.6   Procedure

Children in the ADHD group received their diagnostic assessments at the Hyperactivity, Attention and Learning Problems (HALP*)* clinic. Children who met the eligibility criteria were invited to participate in the research. A brief phone screening interview was conducted with parents of typically developing children who responded to the study ad and expressed interest in the research study as part of the control group. Upon arrival at the laboratory, experimental procedures were explained to the parent(s) and child, and informed permission and assent forms were obtained. After the screening measures and cognitive assessment were completed, the researcher placed three ECG electrodes on the participants' chests to record sequential heart periods. The participants were asked to sit quietly in a comfortable chair facing a 19-inch LCD monitor, and the eye-tracking system was calibrated to each participant. Two minutes of baseline heart period data were collected while sitting quietly. Following the baseline, the video stimuli were presented in three phases (please see Figure 1).

Figure 1.   Sample images from a happiness video.
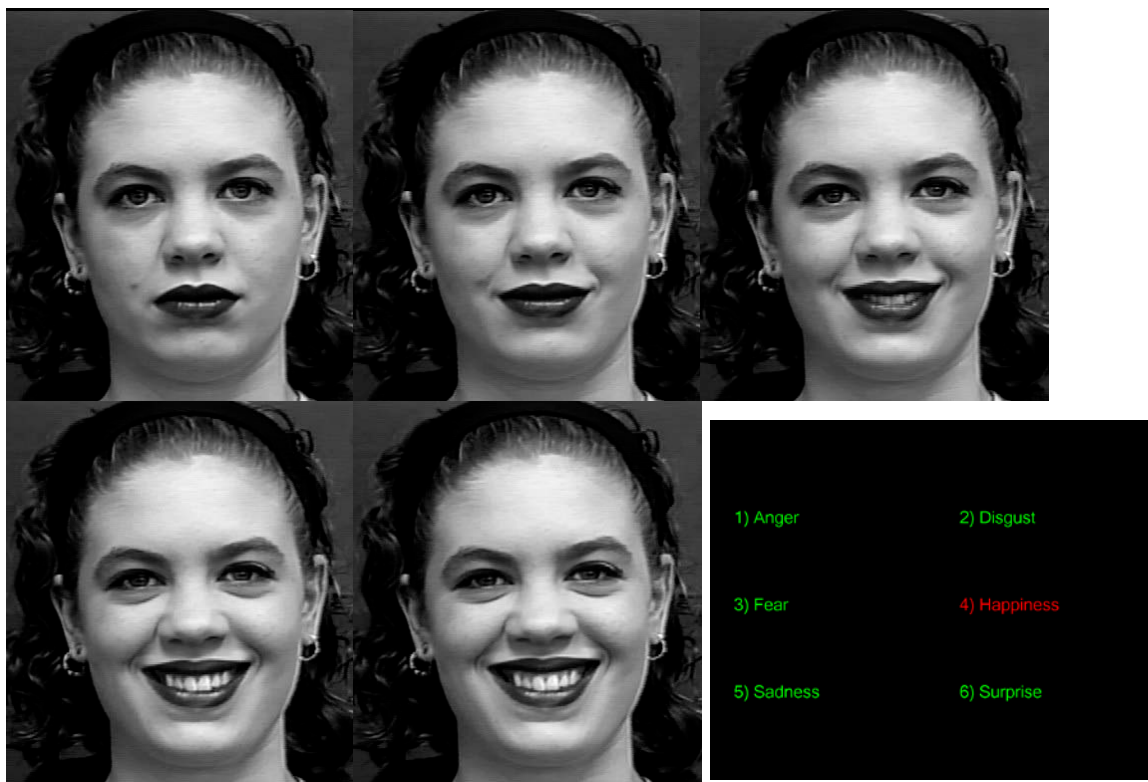
During Phase 1, one set of movies consisting of each emotion was presented in a random order. After each movie, a new screen with six emotion labels appeared, highlighting the name of the emotion that was just presented. The experimenter also named the emotion aloud for the participant. Phase 1 provided participants with the opportunity to familiarize themselves with the emotion labels. During Phase 2 and 3, participants were presented with similar movies. The participants were given a small handheld box with a button and asked to push the button as soon as they could identify what emotion was being posed. Synchronous with the button press, the video stopped and a new screen with the six emotion labels appeared. The participants were asked to identify which of the six emotion labels best represented the emotion that had just been presented. If the child pressed the button prematurely before knowing what emotion was being posed, or watched the entire video without pressing the button and did not know what emotion was being posed, the trial was treated as missing data. Phase 2 included one example of each emotion and was used as a practice session for Phase 3 (e.g., pressing the button and naming the emotion presented). Both Phase 1 and 2 were repeated if necessary until the participant understood the task. During the Phase 3, participants were shown six sets of movies for each of the six emotions (i.e., 36 videos) and were asked to push the button and name the emotion. Physiological data were collected continuously during the entire presentation. After the video presentation was completed, 2 minutes of post baseline heart period data were collected while participants were sitting quietly. The participants were given $25 in the control group and $10 in the ADHD group for their time and participation in the research. Because children in the ADHD group spent less time in the laboratory for the experiment, the compensation for time was prorated.

3. RESULTS

3.1   Accuracy of emotion recognition

To examine whether groups were different in accuracy of emotion recognition, an error variable was generated by summing the errors across the six replications within each emotion during Phase 3. Descriptive statistics of errors for each emotion within each group are presented in Table 2. Because the distribution of errors was skewed, non-parametric analyses were performed to examine group differences for each emotion using Mann-Whitney U tests. As illustrated in Figure 2, the results indicated that the ADHD group made significantly more errors than the control group to anger, $z = -3.158$, $p = .002$, and to disgust, $z = -2.094$, $p = .036$. Descriptive statistics for each emotion are presented in Table 2. As presented in Table 3, qualitative analyses of error patterns indicated that 36% of responses to anger were disgust, and 22 % of responses to disgust were anger and 17% were fear in the ADHD group. Analysis indicated significant differences between boys and girls on disgust errors only, $z = -2.4$, $p = .017$, with males making significantly more errors ($M = 2.51$, $SD = 1.91$) than females ($M = 1.42$, $SD = 1.53$). Across groups, there was a positive relationship between disgust errors and WMI scores, r $(65) = .26$, $p = .033$, indicating that children with higher WMI scores made more errors on disgust. Correlational analyses did not indicate significant relationships between emotion recognition errors and the age of the participants across groups.

Additional exploratory analyses were conducted to evaluate potential differences between the ADHD-PI and ADHD-C groups, as well as medicated and non-medicated ADHD children using Mann-Whitney U tests. The analyses did not indicate statistically significant differences

between the ADHD-PI and ADHD-C groups, as well as between medicated and non-medicated

ADHD children.

TABLE II

DESCRIPTIVE STATISTICS (*M* AND *SD*) FOR SUM OF ERRORS AND LATENCY TO
RECOGNIZE EMOTIONS (Z-SCORES) FOR EACH EMOTION IN THE ADHD ($N = 33$)
AND CONTROL ($N = 34$) GROUPS

	ERRORS		*LATENCY*	
	ADHD Group	*Control Group*	*ADHD Group*	*Control Group*[*]
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Anger	2.24 (1.46)	1.18 (1.24)	.32 (.77)	.01 (.54)
Disgust	2.45 (1.66)	1.74 (1.96)	.36 (.82)	.00 (.66)
Fear	2.12 (1.63)	1.94 (1.70)	.04 (.70)	-.00 (.60)
Happiness	.09 (.38)	0.00 (0.00)	.15 (1.2)	-.00 (.76)
Surprise	.52 (.83)	.53 (1.38)	.03 (.54)	.00 (.74)
Sadness	.55 (.62)	.91 (1.00)	.29 (.77)	-.00 (.58)

[*] The control group does not have z-scores of 0.00 due to one missing trial during disgust and three missing trials during anger stimuli.

Figure 2.   Accuracy of emotion recognition. The data are reported as the mean value of
              total errors summed across 6 trials within each emotion.
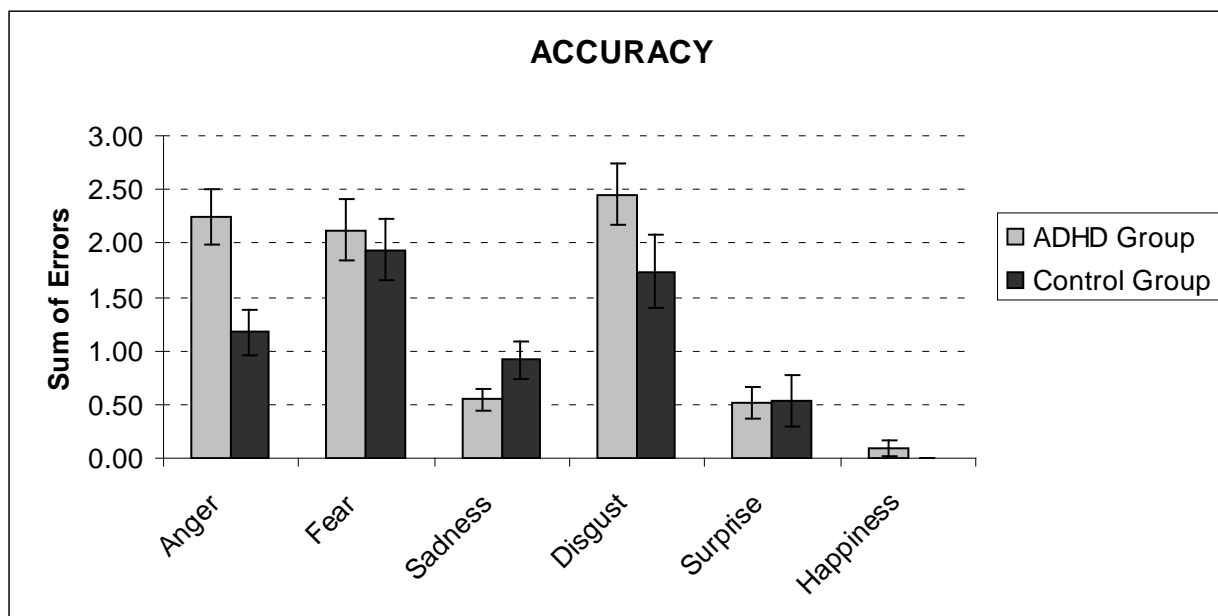
TABLE III

ERROR PATTERNS IN EMOTION RECOGNITION IN THE ADHD ($N = 33$) GROUP

		Emotions Presented					
		Anger	Disgust	Fear	Happiness	Sadness	Surprise
Errors in %	Anger	-	22	6	0	7	3
	Disgust	36	-	4	1	0	1
	Fear	3	17	-	5	3	8
	Happiness	0	1	0	-	0	1
	Sadness	2	2	4	0	-	1
	Surprise	1	1	8	0	0	-

3.2   Latency to detect emotions

Because the duration of the videos varied randomly depending on the number of the

frames in the original image sequences, response rates (in seconds) on all trials were transformed

to z-scores based on the mean and standard deviation of the control group's performance on each

emotion video prior to the analysis of group differences. The z-scores were averaged across six

replications within each emotion. Latencies were calculated for all valid responses, including

errors. The z-transformed data were then analyzed using repeated-measures ANOVAs to

examine group differences and group by emotion interactions. The averaged z-scores for each of

the six emotions served as the repeated measure. The Huynh-Feldt correction was used to adjust

for sphericity violations when necessary. As illustrated in Figure 3, the analyses examining

difference between the ADHD and control groups did not indicate statistically significant group

effect, $F(1, 65) = 1.99$, $p = .163$, group by emotion interaction, $F(4.18, 271.94) = 1.26$, $p = .285$,

or effect for emotion, $F(4.18, 271.94) = 1.31$, $p = .264$, suggesting that the ADHD group was not

consistently slower or faster in identifying the emotions than the control group. However, the

qualitative examination of the descriptive statistics, as well as one-way ANOVA analysis,

indicated a trend towards differences in latency to recognize anger and disgust. Specifically,

children with ADHD appear to be slower in recognizing anger, $F(1, 65) = 3.64$, $p = .061$, and

disgust, $F(1, 65) = 3.94$, $p = .051$, than typically developing children. Descriptive statistics for

each emotion are presented in Table 2. Analysis did not indicate significant differences between

boys and girls on any of the emotions. Across groups, there was a positive relationship between

latency to detect anger and WMI scores, $r (65) = .26$, $p = .034$, as well as a positive trend

between latency to detect disgust and WMI scores, $r (65) = .24$, $p = .051$.

Figure 3.   Latency to recognize emotions. The data are reported as the mean value of z-scores averaged across 6 trials within each emotion.
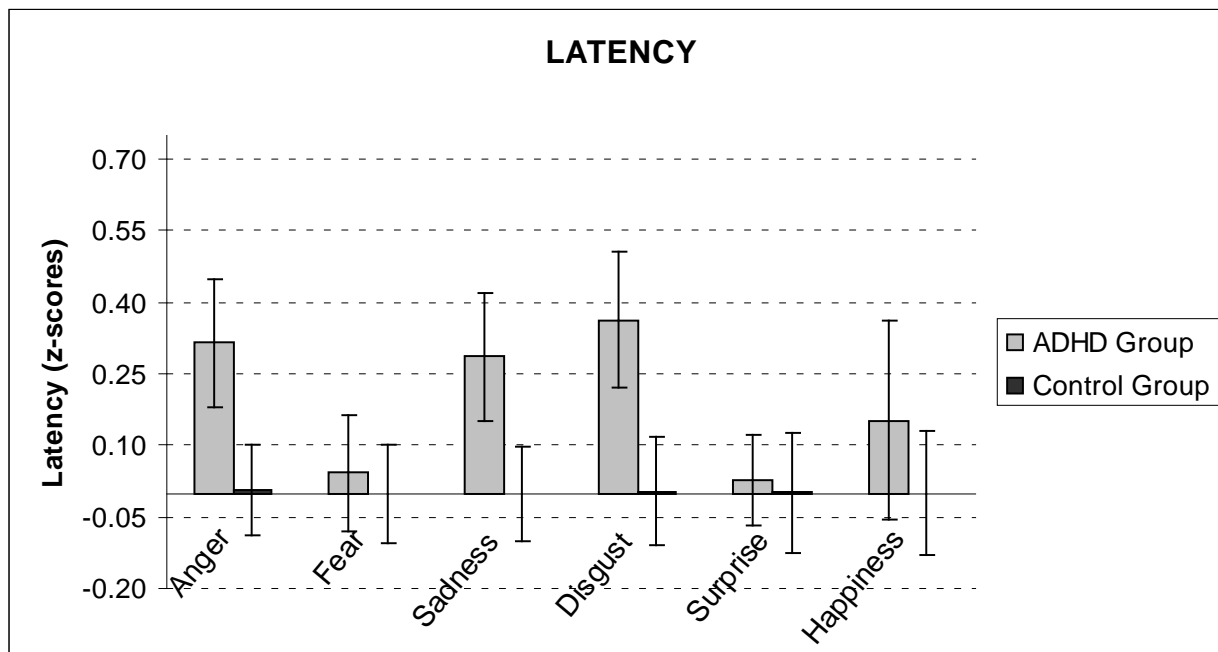
These findings indicate that children with higher WMI scores are slower in recognizing anger and possibly disgust. Further, the analyses indicated significant negative correlations between PSI scores and latency to detect anger, $r(64) = -.36$, $p = .003$, disgust, $r(64) = -.35$, $p = .004$, fear, $r(64) = -.29$, $p = .020$, and sadness, $r(64) = -.25$, $p = .042$, indicating that children who have lower processing speed are slower in recognizing these emotions. Correlational analyses did not indicate significant relationships between latency to detect emotions and the age of the participants across groups.

Additional exploratory analyses were conducted to evaluate potential differences between the ADHD-PI and ADHD-C groups using repeated-measures ANOVAs. Results indicated statistically significant effect for emotion, $F(3.87, 120.10) = 2.58$, $p = .042$, no group by emotion interaction, $F(3.87, 120.10) = 1.88$, $p = .120$, and no group effect, $F(1, 31) = 3.51$, $p = .071$. Similarly, ADHD children who are medicated and non-medicated were compared using repeated-measures ANOVAs. Results indicated statistically significant effect for emotion, $F(3.83, 118.85) = 3.03$, $p = .022$, group by emotion interaction, $F(3.83, 118.85) = 3.21$, $p = .017$, and no group effect, $F(1, 31) = .092$, $p = .764$. The emotion by group interaction was examined using simple effects tests. The groups were significantly different on anger, $F(1, 31) = 5.63$, $p = .024$, with the medicated children ($n = 12$) displaying longer latency ($M = .71$, $SD = .57$) to recognize anger than the non-medicated children ($n = 21$; $M = .09$, $SD = .79$).

3.3   Eye gaze

Due to technical difficulties, eye gaze data from 4 children in the ADHD group and 6 children in the control group were not available. Prior to analyses, fixation duration percentage was averaged across six repetitions within three regions (i.e., EYE, MOUTH, OFF) for each emotion during Phase 3. The data were analyzed using repeated-measures ANOVAs to examine

group differences and interactions for each region. Averaged fixation duration percentage for each region for the six emotions served as the within-subjects variables and diagnostic group served as the between-subjects factor. The Huynh-Feldt correction was used to adjust for sphericity violations when necessary. For all regions (i.e., the OFF, EYE, and MOUTH regions), no group differences or emotion by group interactions were found. The analyses only identified significant effects for emotion [OFF, $F(5, 270) = 2.80$, $p = .017$; EYE, $F(3.38, 182.55) = 43.01$, $p = .000$; and MOUTH, $F(3.68, 198.63) = 45.40$, $p = .000$]. Figure 4 illustrates group means for each region for each emotion in the ADHD and control groups.

Additional exploratory analyses were conducted to evaluate potential differences between the ADHD-PI and ADHD-C groups using repeated-measures ANOVAs. For the OFF region, no significant group differences, effects for emotion, or an emotion by group interaction were found. For the EYE region, no group differences were found. The analyses identified significant effects for emotion, $F(3.90, 105.35) = 11.93$, $p = .000$, and an emotion by group interaction, $F(3.90, 105.35) = 5.29$, $p = .001$. The emotion by group interaction was examined using simple effects tests. The groups were significantly different on happiness, $F(1, 27) = 9.60$, $p = .005$, with children with ADHD-C ($n = 20$) focusing less on the EYE region than children with ADHD-PI ($n = 9$) when happiness was presented. For the MOUTH region, no group differences were found. The analyses identified significant effects for emotion, $F(3.72, 100.43) = 14.58$, $p = .000$, and an emotion by group interaction, $F(3.72, 100.43) = 5.74$, $p = .000$. The emotion by group interaction was examined using simple effects tests. The groups were significantly different on fear, $F(1, 27) = 4.68$, $p = .040$, and on happiness, $F(1, 27) = 7.56$, $p = .011$, with children with ADHD-C ($n = 20$) focusing more on the MOUTH region than children with ADHD-PI ($n = 9$) when fear and happiness were presented.

Figure 4. Fixation duration percentage for the OFF, EYE, and MOUTH regions for each emotion.
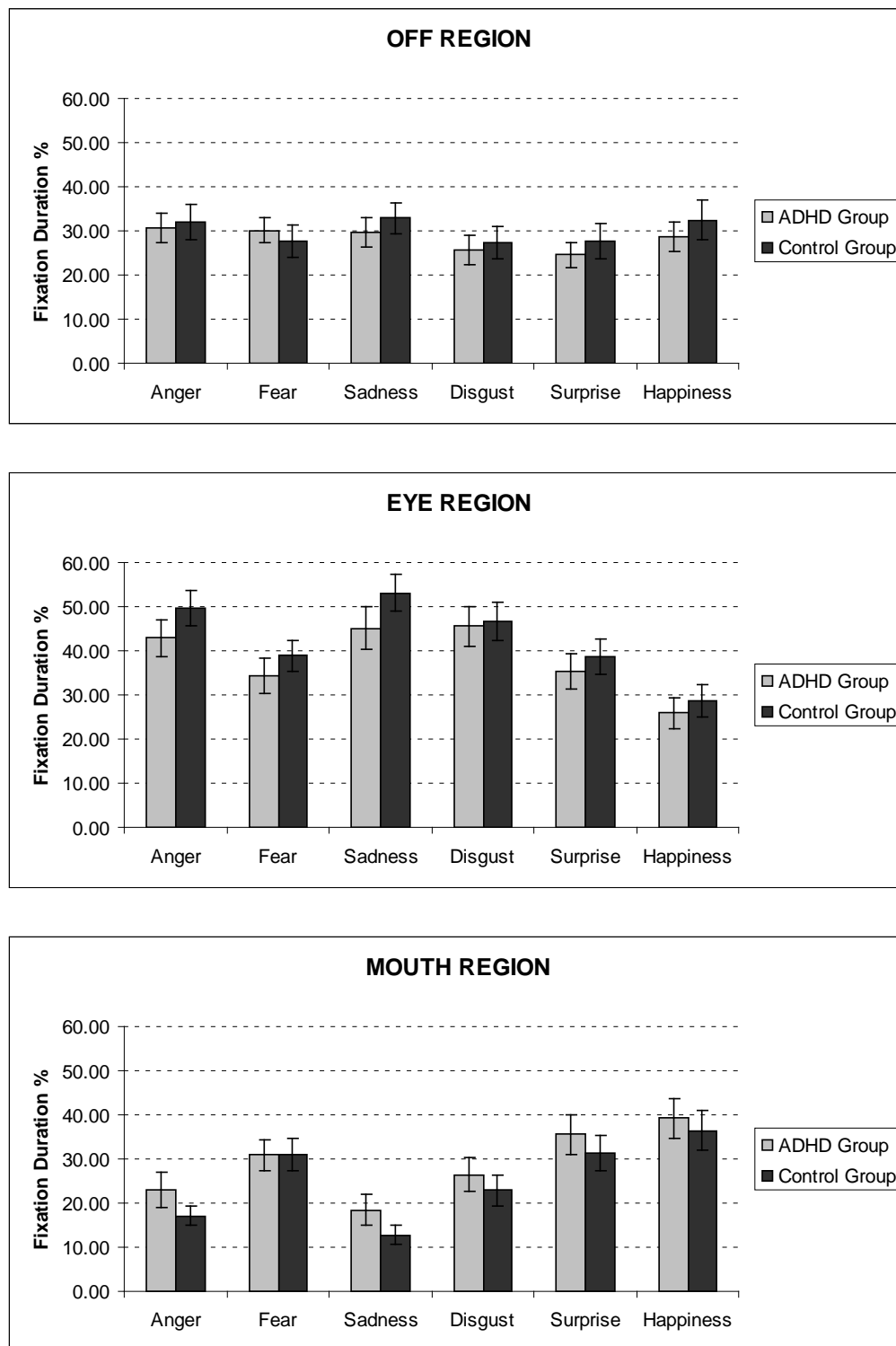
Further exploratory analyses were conducted to evaluate potential differences between the medicated and non-medicated children in the ADHD group using repeated-measures ANOVAs. No effects were found for the OFF region. Significant emotion effects were identified for the EYE region, $F(3.36, 90.81) = 20.48$, $p = .000$, and the MOUTH region, $F(3.21, 86.67) = 19.13$, $p = .000$.

3.4 **Heart rate and RSA**

Because previous studies report that RSA is significantly reduced during tasks requiring sustained attention (e.g., Suess, Porges, & Plude, 1994), the analyses presented were based only on data recorded during the two minutes of baseline period, while the participant was in a stable calm state. One-way ANOVA analyses did not indicate statistically significant differences between the ADHD and control groups on RSA and heart rate. Similarly, there were no differences between children with ADHD-PI and ADHD-C as well as medicated and non-medicated ADHD children on RSA and heart rate. Descriptive statistics are presented in Table 4.

TABLE IV

DESCRIPTIVE STATISTICS (*M* AND *SD*) FOR BASELINE RSA AND HEART RATE IN
THE ADHD (*N* = 33) AND CONTROL (*N* = 34) GROUPS

	ADHD		Control	
	M	*SD*	*M*	*SD*
RSA	6.67	1.23	6.50	1.25
Heart Rate	83.31	9.25	83.19	8.93

3.5   Social Behaviors

To evaluate group differences on social behaviors as measured by SSRS, one-way ANOVA analyses were conducted[4]. Analyses indicated significant differences on the two main scales – Social Skills, $F(1, 62) = 7.55$, $p = .008$, and Problem Behaviors, $F(1, 62) = 26.68$, $p = .000$. Similarly, the groups were significantly different on all the subscales, including Cooperation, $F(1, 62) = 28.42$, $p = .000$, Assertion, $F(1, 62) = 7.51$, $p = .008$, Responsibility, $F(1, 62) = 9.99$, $p = .002$, Self-Control, $F(1, 62) = 11.08$, $p = .001$, Externalizing Problems, $F(1, 62) = 17.41$, $p = .000$, Internalizing Problems, $F(1, 62) = 43.71$, $p = .000$, and Hyperactivity $F(1, 61) = 68.98$, $p = .000$. Overall, the results indicate that children with ADHD score lower on Social Skills and higher on Problem Behaviors. Descriptive statistics are presented in Table 5.

Exploratory analyses evaluating the differences on social behaviors between ADHD-PI and ADHD-C groups using the one-way ANOVA identified differences only on the Internalizing Problems subscale, $F(1, 31) = 5.13$, $p = .031$, with children with ADHD-PI displaying higher scores (i.e., more internalizing behaviors, such as anxiety, sadness, and poor self-esteem). Further exploratory analyses were conducted to evaluate the differences on social behaviors between medicated and non-medicated children with ADHD using the one-way ANOVA. The results indicated significant differences between these subgroups on the Problem Behaviors scale, $F(1, 31) = 5.99$, $p = .020$, and the Hyperactivity subscale, $F(1, 31) = 12.63$, $p = .001$, suggesting that medicated children displayed less hyperactivity (i.e., excessive movements and impulsive actions) and fewer problem behaviors that may interfere with social skills performance.

TABLE V

DESCRIPTIVE STATISTICS (*M* AND *SD*) FOR SCALED AND STANDARD SCORES OF
THE SOCIAL SKILLS RATING SYSTEM IN THE ADHD (*N* = 33) AND CONTROL (*N* = 31)
GROUPS

	ADHD		Control	
	M	*SD*	*M*	*SD*
Cooperation	8.76	2.53	12.42	2.96
Assertion	13.48	2.94	15.74	3.63
Responsibility	11.67	3.20	14.16	3.11
Self-Control	11.70	3.82	14.45	2.64
Social Skills[*]	92.52	20.02	105.16	16.51
Externalizing	4.09	2.60	1.68	1.96
Internalizing	4.73	2.25	1.42	1.69
Hyperactivity	6.69	3.04	1.35	1.91
Problem Behaviors[*]	106.21	19.02	87.71	6.17

[*] Presented in standard scores.

3.6   <u>**Correlations between emotion recognition and eye gaze**</u>

To examine whether eye gaze (i.e., fixation duration percentage) was related to latency to recognize emotions and errors in emotion recognition, correlations were calculated between eye gaze data for each region within each emotion and the mean latency z-score for each emotion (i.e., mean latency across 6 replications within each emotion) and the sum of errors (i.e., total errors across 6 replications within each emotion) within each group.

1.   <u>**Accuracy**</u>

There were no significant correlations between eye gaze for OFF, EYE, and MOUTH regions and the sum of errors across 6 replications within each emotion[5] in the ADHD and control groups. Exploratory analyses were conducted to evaluate the possible relationship between eye gaze and emotion recognition in children with ADHD-PI and ADHD-C. No significant relationships were found in the ADHD-C group for the MOUTH, EYE, OFF regions. In the ADHD-PI group, a positive relationship was found between disgust errors and MOUTH region (during disgust videos), r (7) = .90, p = .001, and negative relationship was found between disgust errors and EYE region (during disgust videos), r (7) = -.73, p = .027. These results suggest that children with ADHD-PI who focused more on the eye region made fewer errors and children who focused more on the mouth region made more errors in recognizing disgust. A positive relationship was also found in the ADHD-PI group between fear errors and OFF region (during fear videos), r (7) = .74, p = .024, indicating that children who focused more on the OFF region made more errors in fear recognition.

2.   <u>**Latency**</u>

There were no significant correlations between eye gaze for OFF, EYE, and MOUTH regions and the mean latency z-score for each emotion across 6 replications in the

control group. In the ADHD group, a negative relationship was found between mean surprise latency z-score and EYE region (during surprise videos), $r(27) = -.41$, $p = .028$, indicating that ADHD children who focused more on the eye region had shorter response time when surprise videos were presented. Exploratory analyses revealed no significant relationship between eye gaze for each region and latency in children with ADHD-PI and ADHD-C.

3.7   **Correlations between emotion recognition and social behaviors**

To examine whether social behaviors measured by SSRS were related to latency to recognize emotions and errors in emotion recognition, correlations were calculated between SSRS scales and the mean latency z-score for each emotion (i.e., mean latency across 6 replications within each emotion) and the sum of errors (i.e., total errors across 6 replications within each emotion) within each group.

1.   Accuracy

Significant positive relationships were found between the SSRS Cooperation subscale and fear errors, $r(31) = .36$, $p = .042$, and disgust errors, $r(31) = .37$, $p = .034$, suggesting that ADHD children who had higher scores on Cooperation (e.g., compliance behaviors) made more errors in fear and disgust. In addition, in the ADHD group, a negative relationship was found between the SSRS Hyperactivity scale and anger errors, $r(30) = -.38$, $p = .030$, suggesting that ADHD children with high Hyperactivity scores (i.e., excessive movement and impulsive reactions) made fewer errors on anger. In the control group, significant negative relationships were found between SSRS Internalizing scores and anger errors, $r(29) = -.40$, $p = .026$, and disgust errors, $r(29) = -.39$, $p = .030$, suggesting that typically developing children with higher internalizing scores (e.g., anxiety, sadness, poor self-esteem) made fewer errors on anger and disgust.

Exploratory analyses were conducted to evaluate the possible relationship between social behaviors and emotion recognition errors in children with ADHD-PI and ADHD-C. In the ADHD-C group, a significant positive relationship was found between the SSRS Cooperation subscale and disgust errors, r (19) = .49, p = .024, suggesting that children with ADHD-C who had higher Cooperation scores made more errors in disgust. In the ADHD-C groups, significant negative relationships were found between SSRS Hyperactivity subscale and anger errors, r (18) = -.63, p = .003, as well as Internalizing subscale and fear errors, r (19) = -.44, p = .047. These results suggest that children with higher Hyperactivity scores made fewer errors in anger and children with higher Internalizing scores made fewer errors in fear. No significant relationships were found in the ADHD-PI group between social behaviors and emotion recognition errors.

2.   Latency

A significant positive relationship was found in the ADHD group between SSRS Self-Control and latency to detect surprise, r (31) = .35, p = .043, suggesting that ADHD children with higher scores on Self-Control had longer detection time during surprise videos. In addition, in the ADHD group, a negative relationship was found between SSRS Hyperactivity and latency to detect anger, r (30) = -.40, p = .025, suggesting that children with higher Hyperactivity scores in the ADHD group displayed shorter latencies to detect anger. In the control group, significant positive relationships were found between the latency to detect anger and SSRS Externalizing scale, r (29) = .39, p = .029, as well as SSRS Problem Behaviors scale, r (29) = .42, p = .018, suggesting that typically developing children with higher Externalizing and Problem Behaviors scores displayed longer latencies to detect anger.

Exploratory analyses were conducted to evaluate the possible relationship between social behaviors and latency to detect emotions in children with ADHD-PI and ADHD-C. In the

ADHD-C group, significant negative relationships were found between the latency to detect anger and the Hyperactivity scale, r (18) = -.63, p = .003, and SSRS Problem Behaviors scale, r (19) = -.45, p = .043. In addition, there was a significant negative relationship between the Hyperactivity scale and latency to detect disgust, r (18) = -.47, p = .036. These results suggest that children with ADHD-C who have higher scores on Hyperactivity display shorter latencies to detect anger and disgust. Similarly, children with higher Problem Behaviors scores also display shorter latencies to detect anger. No significant relationships were found in the ADHD-PI group between social behaviors and latency to detect emotions.

3.8   Correlations between emotion recognition and RSA and heart rate

To examine whether RSA and heart rate were related to latency to recognize emotions and errors in emotion recognition, correlations were calculated between cardiac variables and the mean latency z-scores and the sum of errors within each group.

1.   Accuracy

No significant relationships were identified between the cardiac variables and emotion recognition errors in the ADHD group. A significant relationship was identified in the control group between surprise errors and baseline heart rate, $r(32)$ = -.34, p = .050, indicating that typically developing children with higher heart rate made fewer recognition errors when surprise videos were presented.

Exploratory analysis identified significant relationships in the ADHD-PI group between baseline heart rate and total surprise errors, $r(10)$ = .61, p = .036, and total fear errors, $r(10)$ = .58, p = .050, indicating that children with ADHD-PI who had higher heart rate made more recognition errors when surprise and fear were presented. No significant relationships were identified in the ADHD-C group.

2.   **Latency**

The correlational analysis did not indicate significant relationships between baseline RSA and heart rate and the mean latency z-scores either in the ADHD or in the control group. Exploratory analysis did not also identify any significant relationships in the ADHD-PI and ADHD-C groups.

3.9   Correlations between social behaviors and RSA and heart rate

To examine whether baseline RSA and heart rate were related to social behaviors assessed my SSRS, correlations were calculated between cardiac variables and SSRS scales within each group. Significant correlations were identified only in the control group between baseline RSA and Cooperation, $r(29) = .47$, $p = .007$, Externalizing Behaviors, $r(29) = -.46$, $p = .009$, and Problem Behaviors, $r(29) = -.42$, $p = .019$. These results suggest that typically developing children with high baseline RSA had higher cooperation scores, lower externalizing behaviors, and lower problem behaviors. No significant correlations were found when the groups were combined.

Exploratory analysis did not identify any significant relationships between the cardiac variables and social behaviors in the ADHD-C group. In the ADHD-PI group, there were significant relationships between the Assertion scale and baseline heart rate, $r(10) = -.69$, $p = .013$, suggesting that children with ADHD-PI who had higher heart rate scored lower on Assertion. In addition, significant relationships were identified between the Internalizing scale and baseline heart rate, $r(10) = .68$, $p = .014$, suggesting that children with ADHD-PI who had higher heart rate displayed more internalizing behaviors.

4. DISCUSSION

The current study evaluated emotion recognition, social behaviors, autonomic activity, and eye gaze in children with ADHD relative to typically developing children. The relations among these measures were also explored. Since social deficits have received limited interest in the ADHD literature, especially compared to the behavioral and cognitive deficits, a major goal of the current study was to explore some of the underlying reasons behind and possible correlates of these deficits. To our knowledge, the current study is the first to collectively evaluate the relations between emotion recognition, social behaviors, eye gaze, and autonomic activity in children with ADHD. In addition, to date, no research has directly evaluated the differences in emotion recognition in children with different subtypes of ADHD. Although this was not one of the main goals of the current study, exploratory analyses were conducted to examine these possible differences, as children with ADHD-PI may display different social impairments compared to children with ADHD-C. However, due to low statistical power and small sample size, these findings will not be discussed in detail in this section.

The results of the current study supported one of the primary hypotheses that children with ADHD would display more errors when recognizing emotions compared to typically developing children. It was found that children with ADHD made significantly more errors in recognizing anger and disgust than typically developing children. This finding is consistent with some of the previous literature (Boakes et al., 2008; Kats-Gold et al., 2007; Pelc et al., 2006; Singh et al., 1998). Further examination of the emotion recognition errors showed that children with ADHD misinterpreted anger as mostly disgust and disgust as mostly anger and fear. Of note, fear was misinterpreted mostly as surprise and surprise was mistaken mostly for fear. This

pattern of misinterpretation in children with ADHD is also consistent with the previous literature (Singh et al., 1998). Across groups, it was found that males made more errors than females when recognizing disgust. Higher empathy skills in girls compared to boys have been demonstrated by previous work (Garaigordobil, 2009).

Some researches in the field hypothesized that children with ADHD would not be impaired in emotion recognition. For example, Barkley (1997) argued that the perception of emotion is nonexecutive in nature and would not be impaired in ADHD. However, the current findings point to the contrary. The results of the current study also argue against the assumption that the deficits in emotion recognition would be attributed to the symptoms of the disorder, such as inattention and impulsivity. If emotion recognition deficits were due to general cognitive dysfunction, such as inattention or impulsiveness, children with ADHD would be expected to make more errors than typically developing children across all emotions (Marsh & Williams, 2006). However, the results of the current study suggest difficulties in recognizing certain emotions (i.e., anger and disgust), and this may be more indicative of problems in social perception, rather than cognitive or executive processes. Although the results of the current study indicated a positive relationship between working memory and disgust errors, this finding is spurious and should be replicated with a larger sample before further explanations are posed. No other significant relationships were found between intelligence and decoding of emotions in the current study. If difficulties recognizing anger and disgust in the ADHD group were due to the failure to attend to the appropriate cues on the face (i.e., inattention), we would have expected to see differences in eye gaze during the presentation of anger and disgust videos between the groups. However, our hypothesis that the accuracy of emotion recognition would be related to patterns in scanning faces was not supported by the current findings. Overall, the time

spent on the OFF, EYE, and MOUTH regions was comparable between children with ADHD and typically developing children, and there were no significant correlations between eye gaze and emotion recognition errors in the ADHD and control groups. Although the results of the correlational analyses indicated that children with ADHD-PI who spent more time on the eye region made fewer disgust errors as opposed to children who spent more time on the mouth region, this finding should be interpreted conservatively due to small sample size and low statistical power. Alternatively, it is also possible that the technology and measure (i.e., regions of interest, fixation duration percentage) used in the current study to assess visual scanning are not sensitive enough to pick up potential differences between the groups. For example, a recent study (Hunnius, de Wit, Vrins, & von Hofsten, 2011) found that infants and adults displayed an "avoidant looking pattern" (i.e., reduced dwell times and relatively less fixations to the inner features of the face, which was defined as the region containing the eye, nose, and mouth area) in response to threat-related emotional expressions. Thus, examining other regions on the face, in addition to eye, mouth, and off regions, may provide better understanding of the role of visual scanning in emotion recognition.

The results also did not indicate differences in response times (i.e., latency to detect emotions), which can be viewed as a measure of impulsivity, between children with ADHD and typically developing children. In fact, children with ADHD qualitatively appeared to be slower than typically developing children in recognizing anger and disgust. This is consistent with the findings of Kats-Gold et al. (2007), indicating that children with ADHD needed more time to recognize anger and disgust expressions; however, these longer reaction times did not improve their recognition accuracy. Thus, the observed deficits in anger and disgust recognition in ADHD children are unlikely due to more impulsive response patterns. Further, if this were true,

more global deficits across all emotions would be expected. Interestingly, the results indicated that children who have lower processing speed are slower in recognizing negative emotions, including anger, disgust, fear, and sadness. This finding is important and suggests that children with ADHD who have processing speed weaknesses may need more time to process facial expressions, at least when the emotions are presented only visually. Further, the difficulty recognizing particularly negative emotions also suggests that positive emotions may be easier to recognize for children with ADHD, which is consistent with previous work (Braaten & Rosen, 2000).

As mentioned above, the specific difficulty recognizing anger and disgust has been demonstrated by previous research (Boakes et al., 2008; Kats-Gold et al., 2007; Pelc et al., 2006; Singh et al., 1998). For example, Singh and colleagues (1998) found that 22% of ADHD children misinterpreted anger as disgust. The results of the current study showed that children with ADHD misinterpreted anger mostly as disgust and disgust mostly as anger and fear. Developmentally, children's emotion recognition performance improves gradually, and the use of emotion labels increases with age in a systematic order. Widen and Russell (2003) found that happy, angry, and sad labels emerge early and are more accessible, whereas scared, surprised and disgusted emerge later and are less accessible. Children initially understand emotions in terms of the broad dimensions of pleasure-displeasure and degree of arousal (Widen & Russell, 2008), and they are more likely to 'mislabel' a face with a label from a similar emotion category (Widen & Russell, 2003). For example, disgust-anger and fear-surprise confusions are the most common forms of error, even in adults (Gagnon et al., 2010). Since disgust and anger expressions share the same valence and degree of arousal, differentiation of these two emotions may be more difficult in young children. Further, when a given face fits into more than one category, the

earlier-emerging category labels are more accessible and more likely to be used because they are more practiced (Widen & Russell, 2008). In addition, some emotions share common facial features. For example, fear has more common facial features with surprise than with sadness or anger, and disgust has more common features with anger (the lowering of the inner part of the brows) than with happiness, surprise, fear, and sadness (Gagnon et al., 2010). For anger, this change is produced by the action unit Brow Lowerer while for disgust it is produced by the Nose Wrinkler.

The difficulty recognizing anger and disgust in children with ADHD may be conceptualized as a negative response bias, and this bias may be related to the negative affect typically experienced by children with ADHD, as intensity of experienced emotion was found to be inversely related to affect recognition (Rapport et al., 2002). Thus, extreme levels of experienced affect intensity may disrupt the ability to be sensitive to the emotions of others. Because children with ADHD display more negative affect, including anger, than children without ADHD (Braaten & Rosen, 2000), it is reasonable to think that they would have greater difficulty recognizing negative emotions, especially anger. It is also possible that children with ADHD are frequently exposed to negative emotions in their everyday lives, as they tend to have more conflictual relationships with family members and peers. Expressions of anger can be threatening in these situations and may place the person in a "heightened" physiological state. As a result, as predicted by the Polyvagal Theory, the individual may not be able to promote calm behavioral states, decrease negative affect, pay attention to the subtle facial expressions, and engage with others (Bazhenova et al., 2001). Consistent with the assumptions of the Polyvagal Theory, it is possible that the difficulty recognizing anger and disgust in the ADHD group may be part of a generalized adaptive hypervigilance response. Supporting this view,

Becker and Detweiler-Bedell (2009) found that threat is evaluated rapidly and results in active avoidance of, rather than overt attention towards, fearful and angry faces. In fact, in their study, the bias to avoid a fearful face occurred as early as the first eye movement post stimulus onset. Facial expressions of these negative emotions can be particularly threat-inducing for children with ADHD due to their frequent exposure to negative affect, and they may react to these emotions with a defensive mobilization strategy – fight or flee (Porges et al., 2008). This response pattern was previously demonstrated in children with high functioning autism (Bal et al., 2010; Vaughan Van Hecke et al., 2009) compared to typically developing children who increased heart rate regulation to support social interactions (Heilman et al., 2007). Thus, it may be that this mobilization strategy would impair the ADHD children's ability to accurately identify these negative, threat-inducing emotions. In the current study, RSA and heart rate were assessed as indices of physiological state. Although the findings did not indicate significant differences between the ADHD and control groups on these variables and are consistent with some of the previous work (Beauchaine et al., 2001; Crowell et al., 2006), it is important to note that the analyses were based only on data recorded during the baseline period, while the participants were in relatively stable, calm states. Due to the short and varied duration of the videos (affect videos stopped synchronous with the button press), analyzing the cardiac data for each emotion video was not possible. Further, this type of analysis perhaps would have led to carryover effects from one emotion to the other. Nonetheless, the current study provided some evidence to support above-mentioned assumptions. For example, the preliminary results suggested a possible link between calmer physiological states and emotion recognition errors (i.e., fear and surprise errors) in the ADHD-PI group, and this finding needs further investigation with a larger sample. Further, in the current study, typically developing children with high

baseline RSA displayed higher compliance, lower externalizing, and lower problem behaviors, all of which may improve social skills performance. The Polyvagal Theory suggests that regulation of heart rate may impact physiological readiness for social engagement and be linked to better social and behavioral outcomes. Our finding that higher RSA was related to better social behaviors (e.g., higher compliance, lower problem behaviors) in typically developing children supports this assumption. The lack of this significant relationship in the ADHD group is interesting and deserves attention. It is most likely that this finding represents a true phenomenon, as previous studies also demonstrated similar relationships between RSA, social behaviors, and problem behaviors (Vaughan Van Hecke et al., 2009). It is possible that the disorder itself leads to a disruption of the documented, "normal" link between RSA and prosocial or more regulated behaviors. Alternatively, it is possible that the commonly used medications to treat ADHD may indirectly disrupt this expected relationship. Despite their efficacy, there are concerns about the possible adverse cardiovascular effects of these medications in children and adolescents. Although relatively minor, stimulant-induced increases in mean blood pressure, heart rate, and QT interval have been observed in children, adolescents, and adults (Silva, Skimming, & Muniz, 2010). In the current study, medication use was not controlled, and we cannot draw any conclusions related to this matter. Further studies examining the effects of these medications on physiological state and emotion recognition in children with ADHD may provide valuable information.

The results of the current study do not support some of the previous findings on emotion recognition (Guyer et al., 2007; Singh et al., 1998; Shapiro et al., 1993). For example, Singh and colleagues (1998) found that fear was least frequently recognized emotion by children with ADHD. In the current study, ADHD children and typically developing children did not differ on

fear recognition. Although both anger and fear elicit comparable activity in similar brain regions (i.e., left amygdala, temporal cortices, and ventrolateral and dorsomedial prefrontal cortex), the perception of anger triggers activity in additional regions (i.e., anterior temporal lobe, the premotor cortex, and ventromedial prefrontal cortex). This may indicate that coping with someone's anger may require additional contextual information and more complex behavioral readjustments than dealing with someone's fear (Pichon, de Gelder, & Grèzes, 2009). Consistent with this assumption, Da Fonseca and colleagues (2009) found that in addition to emotion recognition, children with ADHD were also impaired at using contextual information to understand emotions. Other studies (Guyer et al., 2007; Shapiro et al., 1993) indicated that children with ADHD performed similarly to controls on the face-emotion labeling tasks. In one of these studies (Guyer et al., 2007), for example, children with ADHD/CD were older than 12 years of age. Similarly, Shapiro and colleagues (1993) found that younger ADHD children were more impaired than older ADHD children. In the current study, children were between the ages of 7 and 12, and there was no relationship between chronological age and children's ability to identify emotions across groups. Thus, it is possible that preadolescent children with ADHD may have greater difficulty identifying emotions than older children with ADHD. It is possible that as they mature, children develop compensatory strategies that enable them to more accurately interpret facial affect (Shapiro et al., 1993). Differences in experimental stimuli can also partly account for these inconsistent findings.

One of the goals of the current study was to explore the possible relationship between emotion recognition and social behavior in children with ADHD. Understanding people's feelings, thoughts, and perspectives, facilitates and fosters prosocial behaviors and healthy social relationships. There is a growing body of literature on the role of empathy in children, including

children with ADHD, and its relation to social behavior. For example, children with ADHD were found to be less empathic on an empathic reasoning task than those without ADHD (Braaten & Rosen, 2000) and were rated as less empathic by their parents (Marton et al., 2009). Interestingly, these studies did not find differences between children with ADHD and controls on self-reported empathy, which may be due to their tendency to overestimate their competencies, including social skills (Evangelista, Owens, Golden, & Pelham, 2008; Stormont, 2001). The findings of the current study showed that children with ADHD had more social skills deficits and problem behaviors than typically developing children. The difficulties in emotion recognition, less empathy skills, and disparity between self-report of competence and actual competence may partly explain ADHD children's social difficulties. Supporting this view, the current study identified significant relationships between emotion recognition and some of the subscales of the social skills domain of the SSRS in both the ADHD and control groups. It was found that ADHD children who scored higher on Cooperation (e.g., helping others, sharing, complying with rules and directions, etc.) made more errors in fear and disgust. It is possible that the children with higher compliance behaviors are not exposed to negative emotions as much as less compliant children, and they do not experience negative emotions as frequently. As a result, they may be less sensitive to features of fear and disgust. It was also found that ADHD children with high Hyperactivity scores made fewer errors on anger. This may possibly suggest that children with more severe ADHD symptoms are exposed to more negative affect and develop adaptive compensatory strategies in anger recognition (e.g., heightened awareness of anger) to reduce harm. The "heightened awareness of anger" hypothesis was partly supported by the finding that ADHD children with higher levels of hyperactivity displayed shorter latencies to detect anger. On the other hand, typically developing children with higher externalizing and

problem behaviors displayed longer latencies to detect anger. Perhaps, they are not exposed to negative affect as much as children with ADHD and have not yet developed these adaptive strategies. The current study also found that ADHD children with more self-control regarding responses in conflict situations had longer detection time during surprise, perhaps indicating more thoughtful evaluation of the expression or less impulsive patterns of responding.

Overall, the current study did not identify significant differences between children with ADHD-PI and ADHD-C on the main variables examined. The groups did not differ on emotion recognition as well as on the latency to detect emotions. Similarly, no group differences were found on RSA and heart rate. The results indicated differences on eye gaze, with ADHD-C children focusing less on the EYE and more on the MOUTH regions during happiness and focusing more on the MOUTH region during fear than children with ADHD-PI, it is imperative to note that there are only 9 children in the ADHD-PI group. Thus, these findings should be interpreted with extreme caution due to very low statistical power. On the same note, it was found that children with ADHD-PI had higher internalizing behaviors than children with ADHD-C. This finding supports previous literature that mood and anxiety disorders are commonly observed in children with ADHD (Hartung et al., 2002). Previous studies showed that individuals with anxiety may display an over or under sensitivity to certain expressions of emotions. For example, Richards, French, Nash, Hadwin, and Donnelly (2007) found that children with high anxiety were less able to discriminate anger from happiness than the children with low anxiety. Thus, it may be that children with ADHD comorbid with internalizing disorder may experience more difficulties recognizing anger. Interestingly, the findings of the current study indicated that typically developing children with higher internalizing scores made fewer errors on anger and disgust. This may possibly suggest an over sensitivity to anger and

disgust expressions. In the current study, no measures of state or trait anxiety were included.

Thus, definite conclusions cannot be drawn related to anxiety. However, this interesting link

deserves more attention from future research.

The results of the current study need to be cautiously interpreted for several reasons.

First, due to small sample size, the associated statistical power is low on some of the variables.

More research studies that use a similar paradigm with more subjects and a broader age range

would allow future researchers to more closely examine the possible difficulties in emotion

recognition and social behaviors in children with different subtypes of ADHD, as well as gender

differences. Further, this may also expand the generalizability of the findings to older children.

With increased sample size and statistical power, examining the effects of psychiatric

comorbidity on emotion recognition and social behaviors may also be possible. Second, in the

current study, social behaviors were assessed only using a parent-report measure. Future studies

collecting data from other sources, such as teachers, can provide more information regarding

social behavior across different settings. What would be the most beneficial is the examination

of these behaviors in natural environments, such as interactions with familiar and unfamiliar

people and peers. Third, a number of children in the ADHD group were on medication, which

may have influenced the results for the ADHD group. Further studies examining the effects of

psychiatric medications on physiological state and emotion recognition in children may provide

valuable information. Lastly, there is a possibility that the technology used in the current study

to assess visual scanning (i.e., visual attention) was not sensitive enough to pick up the potential

weaknesses in children with ADHD. Thus, a development of more sensitive measures or the use

of multiple attention measures would be imperative. Despite these limitations, the current study

has several strengths. All of the children with ADHD were clinically referred and recruited from

the HALP clinic, which increases the generalizability of the findings to clinical populations. Most previous work evaluating emotion recognition used tasks that require higher order executive functioning (e.g., comprehension of stories, matching emotions), an area in which children with ADHD display weaknesses. In this regard, the stimuli used in the current study were not too taxing for the ADHD children. However, it is important to acknowledge that brief exposure to an affective expression lacks some ecological validity, as the person cannot gather more data using other sources, such as voice (Rapport et al., 2002).

The findings of the current study have important clinical implications. Documenting specific deficits in children with ADHD can aid in identifying targets for effective interventions. In this regard, assessing emotion recognition and social skills in children with ADHD can provide valuable information to clinicians in case conceptualization, as well as in designing more comprehensive treatment plans. The results of the current study suggest that social skills training with an emotion identification component may be an important adjunct to traditional behavioral interventions. Previous work also suggests that including contextual information, such as verbal statements, in these interventions may improve ADHD children's emotion recognition accuracy. Improved empathy skills may lead to less negative affect experienced by these children and result in more positive social interactions. Further, children with ADHD, who have slow processing speed, may need more time to process facial expressions, at least when the emotions are presented only visually.

CITED LITERATURE

Abikoff, H., Hechtman, L., Klein, R. G., Gallagher, R., Fleiss, K., Etcovitch, J., et al. (2004). Social functioning in children with ADHD treated with long-term methylphenidate and multimodal psychosocial treatment. *Journal of the American Academy of Child and Adolescent Psychiatry, 43,* 820-829.

Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA school-age forms and profiles.* Burlington, VT: University of Vermont, Research Center for Children, Youth and Families.

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders-text revision* (4th ed.). Washington, DC: American Psychiatric Association.

Bal, E., Harden, E., Lamb, D., Vaughan Van Hecke, A., Denver, J. W., & Porges, S.W. (2010). Emotion recognition in children with autism spectrum disorders: Relation to eye gaze and autonomic state. *Journal of Autism and Developmental Disorders, 40,* 358-370.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121,* 65-94.

Barkley, R. A. (1998). Attention-deficit hyperactivity disorder. *Scientific American, 279,* 66-71.

Barkley, R. A. (1999). Response inhibition in attention-deficit hyperactivity disorder. *Mental Retardation and Developmental Disabilities Research Reviews, 5,* 177-184.

Barkley, R. A. (2006). *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment* (3rd ed.). New York, NY: Guilford Press.

Barkley, R. A., Fischer, M., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: An 8-year prospective follow-up study. *Journal of the American Academy of Child and Adolescent Psychiatry, 29,* 546-557.

Bazhenova, O. V., Plonskaia, O., & Porges, S. W. (2001). Vagal reactivity and affective adjustment in infants during interaction challenges. *Child Development, 72,* 1314-1326.

Beauchaine, T. (2001). Vagal tone, development, and Gray's motivational theory: Toward an integrated model of autonomic nervous system functioning in psychopathology. *Development and Psychopathology, 13,* 183-214.

Beauchaine, T., Katkin, E. S., Strassberg, Z., & Snarr, J. (2001). Disinhibitory psychopathology in male adolescents: Discriminating conduct disorder from attention-deficit/hyperactivity

disorder through concurrent assessment of multiple autonomic states. *Journal of Abnormal Psychology, 110,* 610-624.

Becker, M., & Detweiler-Bedell, B. (2009). Early detection and avoidance of threatening faces during passive viewing. *The Quarterly Journal of Experimental Psychology, 62,* 1257-1264.

Blair, R. J. R., & Coles, M. (2000). Expression recognition and behavioral problems in early adolescence. *Cognitive Development, 15,* 421-434.

Boakes, J., Chapman, E., Houghton, S., & West, J. (2008). Facial affect interpretation in boys with attention deficit/hyperactivity disorder. *Child Neuropsychology, 14,* 82-96.

Börger, N., & Van der Meere, J. (2000). Motor control and state regulation in children with ADHD: A cardiac response study. *Biological Psychology, 51,* 247-267.

Börger, N., Van der Meere, J., Ronner, A., Alberts, E., Geuze, R., & Bogte, H. (1999). Heart rate variability and sustained attention in ADHD children. *Journal of Abnormal Child Psychology, 27,* 25-33.

Braaten, E. B., & Rosen, L.A. (2000). Self-regulation of affect in attention deficit-hyperactivity disorder (ADHD) and non-ADHD boys: Differences in empathic responding. *Journal of Consulting and Clinical Psychology, 68,* 315-321.

Cadesky, E. B., Mota, V. L., & Schachar, R. J. (2000). Beyond words: How do children with ADHD and/or conduct problems process nonverbal information about affect? *Journal of the American Academy of Child and Adolescent Psychiatry, 39,* 1160-1167.

Cohn, J. F., Zlochower, A. J., Lien, J., & Kanade, T. (1999). Automated face analysis by feature point tracking has high concurrent validity with manual FACS coding. *Psychophysiology, 36,* 35-43.

Conners, C. K. (1997). *Conners' rating scales-revised.* North Tonawanda, NY: Multi-Health Systems, Inc.

Conners, C. K., Sitarenios, G., Parker, J. D. A., & Epstein, J. N. (1998). The revised Conners' parent rating scale (CPRS-R): Factor structure, reliability, and criterion validity. *Journal of Abnormal Child Psychology, 26,* 257-268.

Conners, C. K. (2000). Conners' Continuous Performance Test II (Version 5) [Computer software]. North Tonawanda, NY: Multi-Health Systems, Inc.

Corbett, B., & Glidden, H. (2000). Processing affective stimuli in children with attention-deficit hyperactivity disorder. *Child Neuropsychology, 6,* 144-155.

Crowell, S. E., Beauchaine, T. P., Gatzke-Kopp, L., Sylvers, P., Mead, H., & Chipman-Chacon, J. (2006). Autonomic correlates of attention-deficit/hyperactivity disorder and oppositional defiant disorder in preschool children. *Journal of Abnormal Psychology, 115,* 174-178.

Da Fonseca, D., Seguier, V., Santos, A., Poinso, F., & Deruelle, C. (2009). Emotion understanding in children with ADHD. *Child Psychiatry and Human Development, 40,* 111-121.

Denver, J. W., Reed, S. F., & Porges, S. W. (2007). Methodological issues in the quantification of respiratory sinus arrhythmia. *Biological Psychology, 74,* 286-294.

Dimberg, U., & Petterson, M. (2000). Facial reactions to happy and angry facial expressions: Evidence for right hemisphere dominance. *Psychophysiology, 37,* 693-696.

Douglas, V. I. (1985). The response of ADD children to reinforcement: Theoretical and clinical implications. In L. M. Bloomingdale (Ed.), *Attention deficit disorder: Identification, course and rationale* (pp. 49-66). Jamaica, NY: Spectrum Publications.

Evangelista, N., Owens, J. S., Golden, C. M., & Pelham, W. E. (2008). The positive illusory bias: Do inflated self-perceptions in children with ADHD generalize to perceptions of others? *Journal of Abnormal Child Psychology, 36,* 779-791.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Fox, N. A., Henderson, H. A., Marshall, P. J., Nichols, K. E., & Ghera, M. M. (2005). Behavioral inhibition: Linking biology and behavior within a developmental framework. *Annual Review of Psychology, 56,* 235-262.

Fox, N. A., & Porges, S. W. (1985). The relation between neonatal heart period patterns and developmental outcome. *Child Development, 56,* 28-37.

Friedman, S. R., Rapport, L. J., Lumley, M., Tzelepis, A., VanVoorhis, A., Stettner, L., et al. (2003). Aspects of social and emotional competence in adult attention-deficit/hyperactivity disorder. *Neuropsychology, 17,* 50-58.

Gagnon, M., Gosselin, P., Hudon-ven der Buhs, I., Larocque, K., & Milliard, K. (2010). Children's Recognition and Discrimination of Fear and Disgust Facial Expressions *Journal of Nonverbal Behavior, 34,* 27-42.

Garaigordobil, M. (2009). A comparative analysis of empathy in childhood and adolescence: Gender differences and associated socio-emotional variables. *International Journal of Psychology and Psychological Therapy, 9,* 217-235.

Gaub, M., & Carlson, C. L. (1997). Gender differences in ADHD: A meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry, 36,* 1036-1045.

Gray, J. A. (1985). Issues in the neuropsychology of anxiety. In A. H. Tuma & J. D. Maser (Eds.), *Anxiety and the anxiety disorders* (pp.5-25). Hillsdale, NJ: Erlbaum.

Gentschel, D. A., & McLaughlin, T. F. (2000). Attention deficit hyperactivity disorder as a social disability: Characteristics and suggested methods of treatment. *Journal of Developmental and Physical Disabilities, 12,* 333-347.

Greene, R. W., Biederman, J., Faraone, S. V., Ouellette, C. A., Penn, C., & Griffin, S. M. (1996). Toward a new psychometric definition of social disability in children with attention-deficit hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 35,* 571-578.

Greene, R. W., Biederman, J., Faraone, S. V., Sienna, M., & Garcia-Jetton, J. (1997). Adolescent outcome of boys with attention-deficit/hyperactivity disorder and social disability: Results from a 4-year longitudinal follow-up study. *Journal of Consulting and Clinical Psychology, 65,* 758-767.

Gresham, F. M., & Elliot, S. N. (1990). *The social skills rating system.* Circle Pines, MN: American Guidance Systems.

Guyer, A. E., McClure, E. B., Adler, A. D., Brotman, M. A., Rich, B. A., Kimes, A. S., et al. (2007). Specificity of facial expression labeling deficits in childhood psychopathology. *Journal of Child Psychology and Psychiatry, 48,* 863-871.

Hall, J. K., Hutton, S. B., & Morgan, M. J. (2010). Sex differences in scanning faces: Does attention to the eyes explain female superiority in facial expression recognition? *Cognition and Emotion, 24,* 629-637.

Hartung, C. M., Willcutt, E. G., Lahey, B. B., Pelham, W. E., Stein, M. A., & Keenan, K. (2002). Sex differences in young children who meet criteria for attention deficit hyperactivity disorder. *Journal of Clinical Child and Adolescent Psychology, 31,* 453-464.

Heilman, K., Bal, E., Bazhenova, O., Sorokin, Y., Perlman, S., Hanley, M., & Porges, S. (2007). Physiological responses to social and physical challenges in children: Quantifying mechanisms supporting social engagement and mobilization behaviors. *Developmental Psychobiology, 50,* 171-182.

Henker, B., & Whalen, C. K. (1999). The child with attention-deficit/hyperactivity disorder in school and peer settings. In H. C. Quay & Anne E. Hogan (Eds.), *Handbook of disruptive behavior disorders* (pp. 157-178). New York, NY: Kluwer Academic/Plenum Publishers.

Hunnius, S., de Wit, T. C. J., Vrins, S., & von Hofsten, C. (2011). Facing threat: Infants' and adults' visual scanning of faces with neutral, happy, sad, angry, and fearful emotional expressions. *Cognition and Emotion, 25,* 193-205.

Iaboni, F., Douglas, V. I., & Baker, A. G. (1995). Effects of reward and response costs on inhibition in ADHD children. *Journal of Abnormal Psychology, 104,* 232-240.

Izard, C., Fine, S., Schultz, D., Mostow, A., Ackerman, B., & Youngstrom, E. (2001). Emotion knowledge as a predictor of social behavior and academic competence in children at risk. *Psychological Science, 12,* 18-23.

Jensen, P. S., Arnold, L. E., Richters, J. E., Severe, J. B., Vereen, D., Vitiello, B., et al. (1999). Moderators and mediators of treatment response for children with attention-deficit/hyperactivity disorder: The multimodal treatment study of children with attention-deficit/hyperactivity disorder. *Archives of General Psychiatry, 56,* 1088-1096.

Kats-Gold, I., Besser, A., & Priel, B. (2007). The role of simple emotion recognition skills among school aged boys at risk of ADHD. *Journal of Abnormal Child Psychology, 35,* 363-378.

Lahey, B. B., Pelham, W. E., Loney, J., Lee, S. S., & Willcutt, E. (2005). Instability of the DSM-IV subtypes of ADHD from preschool through elementary school. *Archives of General Psychiatry, 62,* 896-902.

Lahey, B. B., Pelham, W. E., Schaughency, E. A., Atkins, M. S., Murphy, H. A., Hynd, G., et al. (1988). Dimensions and types of attention deficit disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 27,* 330-335.

Landau, S., & Moore, L. A. (1991). Social skill deficits in children with attention-deficit hyperactivity disorder. *School Psychology Review, 20,* 235-251.

Marsh, P. J., Lazzaro, I., Manor, B. R., Harris, A. W. F., Williams, L. M., Gordon, E., et al. (2000). Facial expressions of emotion and visual scanpaths in attention-deficit hyperactivity disorder and first-episode psychosis. *Schizophrenia Research, 41,* 288.

Marsh, P. J., & Williams, L. M. (2006). ADHD and schizophrenia phenomenology: Visual scanpaths to emotional faces as a potential psychophysiological marker? *Neuroscience and Biobehavioral reviews, 30,* 651-665.

Marshal, M. P., Molina, B. S. G., & Pelham, W. E. (2003). Childhood ADHD and adolescent substance use: An examination of deviant peer group affiliation as a risk factor. *Psychology of Addictive Behaviors, 17,* 293-302.

Marton, I., Wiener, J., Rogers, M., Moore, C., & Tannock, R. (2009). Empathy and social perspective taking in children with Attention-Deficit/Hyperactivity Disorder. *Journal of Abnormal Child Psychology, 37,* 107-118.

Matthys, W., Cuperus, J. M., Van Engeland, M. (1999). Deficient social problem-solving in boys with ODD/CD, with ADHD, and with both disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 38,* 311-321.

Merrell, K. W., & Boelter, E. (2001). An investigation of relationships between social behavior and ADHD in children and youth: Construct validity of the home and community social behavior scales. *Journal of Emotional and Behavioral Disorders, 9,* 260-269.

Molina, B. S. G., & Pelham, W. E. (2003). Childhood predictors of adolescent substance use in a longitudinal study of children with ADHD. *Journal of Abnormal Psychology, 112,* 497-507.

Morrison, R. L., & Bellack, A. S. (1981). The role of social perception in social skills. *Behavior Therapy, 12,* 69-79.

Mostow, A. J., Izard, C. E., Fine, S., & Trentacosta, C. J. (2002). Modeling emotional, cognitive, and behavioral predictors of peer acceptance. *Child Development, 73,* 1775-1787.

Newcorn, J. H., Halperin, J. M., Jensen, P. S., Abikoff, H. B., Arnold, L. E., Cantwell, D. P., et al. (2001). Symptom profiles in children with ADHD: Effects of comorbidity and gender. *Journal of the American Academy of Child and Adolescent Psychiatry, 40,* 137-146.

Nigg, J. T. (2006). *What causes ADHD? Understanding what goes wrong and why.* New York, NY: Guilford Press.

Nigg, J. T., & Casey, B. J. (2005). An integrative theory of attention-deficit/hyperactivity disorder based on the cognitive and affective neurosciences. *Development and Psychopathology, 17,* 785-806.

Nijmeijer, J. S., Minderaa, R. B., Buitelaar, J. K., Mulligan, A., Hartman, C. A., & Hoekstra, P. J. (2008). Attention-deficit/hyperactivity disorder and social dysfunctioning. *Clinical Psychology Review, 28,* 692-708.

Nowicki, S., & Duke, M. P. (1994). Individual differences in the nonverbal communication of affect: The diagnostic analysis of nonverbal accuracy scale. *Journal of Nonverbal Behavior, 18,* 9-35.

Ostrander, R. Crystal, D. S., & August, G. (2006). Attention deficit-hyperactivity disorder, depression, and self- and other-assessments of social competence: A developmental study. *Journal of Abnormal Child Psychology, 34,* 773-787.

Parent, A. (1996). *Carpenter's human neuroanatomy* (9th ed.). Baltimore, MD: Mosby-Williams and Wilkins.

Pelc, K., Kornreich, C., Foisy, M. L., & Dan, B. (2006). Recognition of emotional facial expressions in attention-deficit hyperactivity disorder. *Pediatric Neurology, 35,* 93-97.

Pelham, W. E., & Gnagy, E. M. (1999). Psychosocial and combined treatments for ADHD. *Mental Retardation and Developmental Disabilities Research Reviews, 5,* 225-236.

Pelham, W. E., Wheeler, T., & Chronis, A. (1998). Empirically supported psychosocial treatments for attention deficit hyperactivity disorder. *Journal of Clinical Child Psychology, 27,* 190-205.

Pichon, S., de Gelder, B., & Grèzes, J. (2009). Two different faces of threat: Comparing the neural systems for recognizing fear and anger in dynamic body expressions. *NeuroImage,* 1873-1883.

Polanczyk, G., de Lima, M. S., Horta, B. L., Biederman, J., & Rohde, L. A. (2007). The worldwide prevalence of ADHD: A systematic review and metaregression analysis. *American Journal of Psychiatry, 164,* 942-948.

Porges, S.W. (1985). Method and apparatus for evaluating rhythmic oscillations in aperodic physiological response systems [Abstract]. *United States Patent. No: 4, 510, 944.*

Porges, S. W. (1995). Orienting in a defensive world: Mammalian modifications of our evolutionary heritage. A Polyvagal Theory. *Psychophysiology, 32,* 301-318.

Porges, S. W. (1997). Emotion: An evolutionary by-product of the neural regulation of the autonomic nervous system. *Integrative Neurobiology of Affiliation, Annals of the New York Academy of Sciences, 807,* 62-77.

Porges, S. W. (1998). Love: An emergent property of the mammalian autonomic nervous system. *Psychoneuroendocrinology, 23,* 837-861.

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology, 42,* 123-146.

Porges, S. W. (2003). Social engagement and attachment: A phylogenetic perspective. *Roots of Mental Illness in Children, Annals of the New York Academy of Sciences, 1008,* 31-47.

Porges, S. W., & Byrne, E. A. (1992). Research methods for measurement of heart rate and respiration. *Biological Psychology, 34,* 93-130.

Porges, S. W., Cohn, J. F., Bal, E., & Lamb, D. (2007). The Dynamic Affect Recognition Evaluation [Computer software]. Chicago, IL: Brain-Body Center, University of Illinois at Chicago.

Porges, S. W., Doussard-Roosevelt, J. A., Portales, A. L., & Greenspan, S. I. (1996). Infant regulation of the vagal "brake" predicts child behavior problems: A psychobiological model of social behavior. *Developmental Psychobiology, 29,* 697-712.

Porges, S.W., Heilman, K., Doussard-Roosevelt, J., Bazhenova, O., & Koledin, M. (2008). Quantifying the "vagal brake" in preschool children: A new metric for assessing cardiac reactivity profiles. Unpublished manuscript.

Quay, H. C. (1997). Inhibition and attention deficit hyperactivity disorder. *Journal of Abnormal Child Psychology, 25,* 7-13.

Rapport, L. J., Friedman, S. L., Tzelepis, A., & Van Voorhis, A. (2002). Experienced emotion and affect recognition in adult attention-deficit hyperactivity disorder. *Neuropsychology, 16,* 102-110.

Richards, A., French, C. C., Nash, G., Hadwin, J. A., & Donnelly, N. (2007). A comparison of selective attention and facial processing biases in typically developing children who are high and low in self-reported trait anxiety. *Development and Psychopathology, 19,* 481-495.

Shapiro, E. G., Hughes, S. J., August, G. J., & Bloomquist, M. L. (1993). Processing of emotional information in children with attention-deficit hyperactivity disorder. *Developmental Neuropsychology, 9,* 207-224.

Silva, R. R., Skimming, J. W., & Muniz, R. (2010). Cardiovascular safety of stimulant medications for pediatric attention-deficit hyperactivity disorder. *Clinical Pediatrics, 49,* 840-851.

Singh, S. D., Ellis, C. R., Winton, A. S. W., Singh, N. N., Leung, J. P., & Oswald, D. P. (1998). Recognition of facial expressions of emotion by children with attention-deficit hyperactivity disorder. *Behavior Modification, 22,* 128-142.

Slusarek, M., Velling, S., Bunk, D., & Eggers, C. (2001). Motivational effects on inhibitory control in children with ADHD. *Journal of the American Academy of Child and Adolescent Psychiatry, 40,* 355-363.

Stifter, C. A., Fox, N. A., & Porges, S. W. (1989). Facial expressivity and vagal tone in 5-month-old and 10-month-old infants. *Infant Behavior and Development, 12,* 127-137
.
Stormont, M. (2001). Social outcomes of children with AD/HD: Contributing factors and implications for practice. *Psychology in the Schools, 38,* 521-531.

Suess, P. E., Porges, S. W., & Plude, D. J. (1994). Cardiac vagal tone and sustained attention in school-age children. *Psychophysiology, 31,* 17-22.

Van der Meere, J., Shalev, R., Börger, N., & Gross-Tsur, V. (1995). Sustained attention, activation, and MPH in ADHD: A research note. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 36,* 697-703.

Van der Meere, J., Wekking, E., & Sergeant, J. (1991). Sustained attention and pervasive hyperactivity. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 32,* 275-284.

Van der Oord, S., Van der Meulen, E. M., Prins, P. J. M., Oosterlaan, L., Buitelaar, J. K., & Emmelkamp, P. M. G. (2005). A psychometric evaluation of the social skills rating system in children with attention deficit hyperactivity disorder. *Behavior Research and Therapy, 43,* 733-746.

Vaughan Van Hecke, A., Porges, S. W., Lebow, J., Bal, E., Lamb, D., Harden, E., et al. (2009). EEG and heart rate regulation to familiar and unfamiliar people in children with autism spectrum disorders. *Child Development, 80,* 1118-1133.

Wechsler, D. (2003). *Wechsler intelligence scale for children-4th edition (WISC-IV®).* San Antonio, TX: Harcourt Assessment.

Whalen, C. K., & Henker, B. (1985). The social worlds of hyperactive (ADHD) children. *Clinical Psychology Review, 5,* 447-478.

Wheeler, J., & Carlson, C. L. (1994). The social functioning of children with ADD with hyperactivity and ADD without hyperactivity: A comparison of their peer relations and social deficits. *Journal of Emotional and Behavioral Disorders, 2,* 2-12.

Widen, S. C., & Russell, J. A. (2003). A closer look at preschoolers' freely produced labels for facial expressions. *Developmental Psychology, 39,* 114–128.

Widen, S. C., & Russell, J. A. (2008). Children acquire emotion categories gradually. *Cognitive Development, 23,* 291-312.

Yuill, N., & Lyon, J. (2007). Selective difficulty in recognizing facial expressions of emotion in boys with ADHD: General performance impairments or specific problems in social cognition? *European Child and Adolescent Psychiatry, 16,* 398-404.

APPENDIX

U N I V E R S I T Y   O F   I L L I N O I S
AT   C H I C A G O

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

Approval Notice
Initial Review (Response To Modifications)

August 25, 2008

Stephen W. Porges, PhD
Psychiatry
1601 W. Taylor St.
449 P.I., M/C 912
Chicago, IL 60612
Phone: (312) 355-1557 / Fax: (312) 996-7658

RE: **Protocol # 2008-0608**
        "Emotion Recognition and Social Behaviors in Children with Attention-
        Deficit/Hyperactivy Disorder"

Dear Dr. Porges:

Your Initial Review application (Response To Modifications) was reviewed and approved by the
Expedited review process on August 7, 2008. You may now begin your research.

Please note the following information about your approved research protocol:

Protocol Approval Period: August 7, 2008 - August 6, 2009
Approved Subject Enrollment #:   200
Additional Determinations for Research Involving Minors: The Board determined that this
research satisfies 45CFR46.404, research not involving greater than minimal risk. Therefore, in
accordance with 45CFR46.408, the IRB determined that only one parent's/legal guardian's
permission/signature is needed.
Performance Site: UIC
Sponsor: Department
PAF#:   Not applicable
Research Protocol:

a) No separate protocol submitted

Recruitment Materials:

a) Emotion Recognition, ADHD; Version 1; 07/01/2008

b) Emotion Recognition, Control; Version 1; 07/01/2008

c) Flyer with Tabs, Emotion Recognition, Control; Version 1; 07/01/2008

d) Internet Ad, Emotional Recognition, Control; Version 2; 08/01/2008

e) Brochure, Control Grp; Version 2

f) Brochure, ADHD Grp; Version 2

Assents:

a) Assent, Emotion Recognition, ADHD; Version 1; 07/01/2008

b) Assent, Emotion Recognition, Control; Version 1; 07/01/2008

Parental Permissions:

a) Permission, Emotion Recognition, Control; Version 1; 07/01/2008

b) Permission, Emotion Recognition, ADHD; Version 1; 07/01/2008

c) A waiver of parental permission has been granted for identification and recruitment purposes only

HIPAA Authorizations:

a) Authorization, Emotion Recognition; Version 1; 07/01/2008

b) A waiver of authorization has been granted for identification and recruitment purposes only

Your research meets the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific categories:

(4) Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving X-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)

Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual,

(5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis),

(6) Collection of data from voice, video, digital, or image recordings made for research purposes., (7) Research on individual or group characteristics or behavior (including but not

limited to research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Please note the Review History of this submission:

Receipt Date	Submission Type	Review Process	Review Date	Review Action
07/16/2008	Initial Review	Expedited	07/23/2008	Modifications Required
08/01/2008	Response To Modifications	Expedited	08/07/2008	Approved

Please remember to:

→ Use your **research protocol number** (2008-0608) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the enclosure,
 "**UIC Investigator Responsibilities, Protection of Human Research Subjects**"

Please note that the UIC IRB has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 996-2014. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Sandra Costello
Assistant Director, IRB # 2
Office for the Protection of Research

Subjects

Enclosures:
       1. UIC Investigator Responsibilities, Protection of Human Research Subjects
       2. Assent Documents:
          a) Assent, Emotion Recognition, ADHD; Version 1; 07/01/2008
          b) Assent, Emotion Recognition, Control; Version 1; 07/01/2008
       3. Parental Permissions:
          a) Permission, Emotion Recognition, Control; Version 1; 07/01/2008

b) Permission, Emotion Recognition, ADHD; Version 1; 07/01/2008

4. **HIPAA Authorization:**
   a) Authorization, Emotion Recognition; Version 1; 07/01/2008

5. **Recruiting Materials:**
   a) Emotion Recognition, ADHD; Version 1; 07/01/2008
   b) Emotion Recognition, Control; Version 1; 07/01/2008
   c) Flyer with Tabs, Emotion Recognition, Control; Version 1; 07/01/2008
   d) Internet Ad, Emotional Recognition, Control; Version 2; 08/01/2008
   e) Brochure, Control Grp; Version 2
   f) Brochure, ADHD Grp; Version 2

cc: Henry W. Dove, Psychiatry, M/C 912

VITA

NAME: Elgiz Bal

EDUCATION: B.A., Psychology, University of Istanbul, Istanbul, Turkey, 2000

M.A., Clinical Psychology, University of Illinois at Chicago, Chicago, IL, 2006

Ph.D., Clinical Psychology, University of Illinois at Chicago, Chicago, IL, 2011

AWARDS: Third place, University of Illinois at Chicago Research Forum for Graduate Students, 2007

University of Illinois at Chicago Graduate College Travel Award, 2007

International Society for Autism Research Student Travel Award for IMFAR, 2007

Autism Diagnostic Observation Schedule Clinical & Research Training Scholarship, 2006

Autism Diagnostic Interview-Revised Research Training Scholarship, 2006

PROFESSIONAL
MEMBERSHIPS: American Psychological Association

PUBLICATIONS: Bal, E., Harden, E., Lamb, D., Vaughan Van Hecke, A., Denver, J. W. & Porges, S.W. (2010). Emotion recognition in children with autism spectrum disorders: Relation to eye gaze and autonomic state. *Journal of Autism and Developmental Disorders, 40,* 358-370.

Vaughan Van Hecke, A., Lebow, J., Bal E., Lamb, D., Harden, E., Kramer, A., Denver, J., Bazhenova, O., & Porges, S.W. (in press). EEG and heart rate regulation to familiar and unfamiliar people in children with autism spectrum disorders. *Child Development.*

Heilman, K., Bal, E., Bazhenova, O., Sorokin, Y., Perlman, S., Hanley, K., Porges, S. W. (2008). Physiological responses to physical and social challenges in children: Quantifying mechanisms supporting social

engagement and mobilization behaviors. *Developmental Psychobiology, 50 (2),* 171-182.

Heilman, K. J., Bal, E., Bazhenova, O. V., & Porges, S. W. (2007). Respiratory sinus arrhythmia and tympanic membrane compliance predict spontaneous eye gaze behaviors in young children: A Pilot Study. *Developmental Psychobiology, 49 (5),* 531-542.

Porges, S. W., Heilman, K. J., Bazhenova, O. V., Bal, E., Doussard-Roosevelt, J. A., & Koledin, M. (2007). Does motor activity during psychophysiological paradigms confound the quantification and interpretation of heart rate and heart rate variability measures in young children? *Developmental Psychobiology, 49 (5),* 485-494.

Ayçiçegi, A., Göçmen, M., Bal, E. (1999). The effectiveness of loci method when time is limited (*translated title*). *Journal of Istanbul Studies in Experimental Psychology, 21,* 203-213.

PUBLISHED ABSTRACTS:

Heilman, K. J., Bazhenova, O. V., Bal, E., Sorokin, Y., Perlman, S., Denver, J. W., & Porges, S. W. (2003). RSA, heart period, and cortisol in children during social and physical challenges. *Psychophysiology, 40, S46-46.*

Denver, J. W., Heilman, K. J., Sorokin, Y., Bal, E., Perlman, S., Bazhenova, O. V., & Porges, S. W. (2003). Eye gaze and auditory processing differences in individuals with language and social communication difficulties. *Psychophysiology, 40, S36-36.*

SOFTWARE:

Porges, S. W., Cohn, J. F., Bal, E., & Lamb, D. (2007). The Dynamic Affect Recognition Evaluation [Computer software]. Chicago, IL: Brain-Body Center, University of Illinois at Chicago.

POSTERS:

Bal, E., Vaughan Van Hecke, A., Harden, E., Lamb, D., Denver, J., Lebow, J., Kramer, A., Heilman, K., & Porges, S.W. (November, 2007). Accuracy and response rates of children with autism in affect recognition: Relation to autonomic state. ABCT 41st Annual Convention, Philadelphia, PA.

Bal, E., Vaughan Van Hecke, A., Lamb, D., Denver, J., Bazhenova, O., Harden, E., Lebow, J., Kramer, A., Heilman, K., & Porges, S.W. (May, 2007). Emotion recognition and its relation to RSA and eye gaze in children with autism. 4th International Meeting for Autism Research, Seattle, WA.

Vaughan Van Hecke, A., Lebow, J., Bal, E., Bazhenova, O., Denver, J., Harden, E., Kramer, A., Lamb, D., Marczyk, K., McCool, M., Padilla, W., Plaut, A., Wrzosek, M., & Porges, S.W. (May, 2007). EEG and heart rate responses to familiar and unfamiliar people in children with autism. 4th International Meeting for Autism Research, Seattle, WA.

Bal, E., Vaughan Van Hecke, A., Harden, E., Lamb, D., Denver, J., Lebow, J., Kramer, A., Heilman, K., & Porges, S.W. (April, 2007). Emotion recognition and autonomic state in children with autism spectrum disorders. University of Illinois at Chicago Research Forum 2007, Chicago, IL.

Vaughan Van Hecke, A., Lebow, J., Harden, E.R., McCool, M., Kramer, A., Bazhenova, O., Marczyk, K.D., Bal, E., Lamb, D., & Porges, S.W. (March, 2007). Heart rate regulation in response to familiar and unfamiliar people in children with autism. Society for Research in Child Development biannual conference, Boston, MA.

Porges, S. W., Bazhenova, O. V., Denver, J. W., Bal, E., & Heilman, K. (2006, June). The Polyvagal Theory: A new approach to autism research. 5th International Meeting for Autism Research, Montreal, Canada.

Bono, K., Bazhenova, O., Faria, A., Bal, E., Footer, S., Hughes, C., & Kaiser, M. Y. (2006, June). Priming: Language intervention for children prenatally exposed to cocaine. Institute of Education Sciences Research conference, Washington, DC.

Bal, E., Denver, J., Lamb, D., Vaughan Van Hecke, A., Harden, E., Heilman, K., Plaut, A., Wrzosek, M. I., Padilla, W., Bazhenova, O., & Porges, S. W. (2006, May). Atypical eye gaze, affect recognition, and autonomic state in children with autism spectrum disorders: Demonstration of a compromised social engagement system. Midwestern Psychological Association conference, Chicago, IL.

Harden, E., Heilman, K., Bal, E., Vaughan Van Hecke, A., Bazhenova, O., Denver, J., & Porges, S. W. (2006, May). Social engagement behaviors in Fragile X syndrome. Midwestern Psychological Association conference, Chicago, IL.

Vaughan Van Hecke, A., Porges, S. W., Lamb, D., Harden, E., Bal, E., Heilman, K., Bazhenova, O., Denver, J., Marczyk, K., Wrzosek, M. I., Padilla, W., & Plaut, A. (2006, May). EEG alpha activity, heart rate, and blood pressure during postural changes. Midwestern Psychological Association conference, Chicago, IL.

Heilman, K., Connolly, S., Graczyk, P., Bazhenova, O., Padilla, W., Wrzosek, M., Plaut, A., Harden, E., Vaughan Van Hecke, A., Bal, E., & S.W. Porges (2006, May). Neurobiology of social behavior in individuals with selective mutism. Midwestern Psychological Association conference, Chicago, IL.

Plaut, A. J., Denver, J. W., Bal, E., Heilman, K. J., & Porges, S. W. (2006, February). The effect of an acoustic intervention on social behavior in individuals with autism spectrum disorders. University of Illinois at Chicago College of Medicine Student Research Forum, Chicago, IL.

Wrzosek, M. I., Denver, J. W., Bal, E., Harden, E., Heilman, K. J., & Porges, S. W. (2006, February). Eye gaze and vagal tone in individuals with autism spectrum disorders. University of Illinois at Chicago College of Medicine Student Research Forum, Chicago, IL.

Sorokin, Y., Bal, E., Heilman, K. J., Bazhenova, O. V., & Porges, S. W. (2003, April). The Communication Coding Scale. Society for Research in Child Development biannual conference, Tampa, FL.

INVITED TALKS:

Vaughan Van Hecke, A., & Bal, E. (October, 2006). Foundations of social behavior: Interactions between the brain and the body in students with autism spectrum disorders. Invited lecture for the North Suburban Special Education District (NSSED) meeting, Northfield, IL.

END NOTES

---

[1] Based on the previous research studies (e.g., Cadesky et al., 2000; Corbett & Glidden, 2000), effect sizes were calculated to determine the adequate sample size for the study. For a moderate effect size of .5, sufficient sample size was estimated (N=30 for each group) using the G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007) to detect differences in emotion recognition between the groups with power of 80%.

[2] Due to an experimenter error, a score for Letter-Number Sequencing for one child in the control group could not be calculated, which resulted in missing scores for Working Memory Index and FSIQ. Data from this subject were included in the data analyses, as the rest of his subtest and index scores are within the average range.

[3] Final frames of the image sequences that included similar action units for six basic emotions were chosen and each of the frames in image sequences was morphed so that there were 8 new frames between each of the originals.

[4] Data from 3 children in the control group are missing.

[5] The expression of happiness was excluded from the analyses because there were only 2 errors across all trials.