COMPARING PSYCHOPHYSIOLOGICAL AND SELF-REPORT MEASURES OF BIS AND BAS IN CHILDREN WITH AND WITHOUT ADHD

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ABSTRACT

Attention deficit hyperactivity disorder (ADHD) is a neurobehavioral disorder in children in which variations in reward processing and behavioral responses to reward cues are evident. The behavioral inhibition system (BIS) and behavioral approach system (BAS) are neurological motivational systems that determine goal-directed behavior. Motivated behavior can involve the need to activate behavior (to approach a potentially rewarding stimulus or escape a punishing stimulus), or inhibit behavior to cautiously evaluate the situation and make a careful decision about behavioral response. Relative function in each of these motivational systems has been proposed to underlie the psychopathology of ADHD. Research has assessed the activation of these systems through the use of questionnaires and physiological measures. Forty-five children and adolescents with and without ADHD (control, \( n = 31 \); ADHD, \( n = 14 \)) completed the BIS/BAS Scale Questionnaire (Carver & White, 1994) and a response time task. The current study examined the relationship between both child and parent report of BIS and BAS scores with changes in physiological correlates of BIS and BAS during conditions of punishment versus reward. The activation of the BAS system has been indexed by changes in cardiac pre-ejection period (PEP) that underlie sympathetic nervous system activation during reward conditions (Beauchaine, 2001; Beauchaine et al., 2001; Brenner, Beauchaine, & Sylvers, 2005). Changes in skin conductance level (SCL) have also been shown to demonstrate activity of the BIS system during conditions of punishment (Fowles, 1988; Iaboni, Douglas, & Ditto, 1997). Children with ADHD show different response patterns for these physiological indices of BIS and BAS activation and these variations in response between children with and without ADHD were examined in relation to self-report and parental report of BIS and BAS sensitivity (Fowles, 1988;
Iaboni et al., 1997). Results showed that parents were more likely to report BIS and BAS constructs independently of one another, while children reported similar increases in both BIS and BAS sensitivity based on self-report. When examining the relationship between child and parent report with physiological responding based on PEP and mean SCL measures, a significant positive correlation between parent report of BAS sensitivity and change scores in PEP during punishment conditions was evident. This indicates a decrease in behavioral approach during punishment as would be expected based on previous research (Beauchaine, 2001; Brenner et al., 2005; Iaboni et al., 1997). The results for between groups difference in parent and child report with physiological measures indicated that children with ADHD showed decreases in PEP during punishment conditions and were thus more motivated than controls during these task conditions. Correlations among the BIS/BAS scales for parents and children with physiological reactivity across task conditions indicated that parental report of BAS score was positively correlated with changes scores in PEP during punishment conditions for control children. In contrast, results for children with ADHD indicated that parents were more likely to report BAS activation with changes in mean SCL during reward conditions. These variations in self-report measures as well as physiological response patterns demonstrate differences between the ability to recognize behavioral patterns in parents and children, and also among control children versus children with ADHD. Overall, parental report of these constructs, especially BAS sensitivity for the control group, was more consistent with physiological measures assessing the activation of these systems. This demonstrates a potential area for focus in regard to parental ability to identify child behavioral tendencies. This can benefit parents of children with ADHD and be essential to treatment in regard to reinforcing appropriate behaviors through reward contingencies.
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Introduction

Attention deficit hyperactivity disorder (ADHD) is a common neurobehavioral disorder that is diagnosed in children. Children with this disorder are more likely to show developmentally inappropriate symptoms such as trouble paying attention, controlling impulsive behaviors, and also may be hyperactive (NIMH, 2008). Currently, researchers are trying to determine the etiological mechanisms of this disorder, but no one cause has been identified. The literature on ADHD identifies several plausible causes and risk factors for the disorder that include genetics, brain injuries, exposure to lead paint at early ages, exposure to alcohol and smoking in utero, and neurotransmitter imbalances among brain pathways (NCBDDD, 2009; NIMH, 2008). Based on these proposed factors, there are a variety of treatments that target specific aspects of the disorder or provide treatment for a combination of the symptoms to increase functioning in the individual. Common therapies for ADHD treatment include stimulant medications, behavioral therapy, and also cognitive behavioral therapy.

Diagnostic Criteria for ADHD in Children

According to The American Psychiatric Association's Diagnostic and Statistical Manual-IV, Text Revision (DSM-IV-TR) (2000), six or more symptoms of inattention or hyperactivity-impulsivity have to be present for at least six months, with these symptoms being inappropriate for the child’s developmental level. The symptoms evident for inattention, hyperactivity, and impulsivity are defined in Appendix A. In addition to these defining symptoms, the clinician must also determine that the symptoms of this disorder were present before 7 years of age and there must also be clear evidence of clinically significant impairment in social or school functioning (APA, 2000). The APA (2000) also states that the symptoms cannot be better accounted for by another mental disorder diagnosis, including Anxiety Disorder or Mood
Disorder. These diagnostic criteria provide a framework for diagnosis and the subtypes of the disorder can be classified accordingly.

**Subtypes of Disorder**

The three types of ADHD are combined type, predominantly inattentive type, and predominantly hyperactive-impulsive type (APA, 2000). If the criteria of at least six symptoms are met for inattention but not for hyperactivity-impulsivity, such as “is often easily distracted” or “often has trouble organizing activities,” then the child is diagnosed with ADHD, predominantly inattentive type. The APA (2000) further classifies children who display at least six symptoms of hyperactivity or impulsivity (without inattentive symptoms), such as “has difficulty awaiting turn” or “gets up from seat when remaining seated is expected,” as having a diagnosis of ADHD, predominantly hyperactive-impulsive type. The diagnosis of ADHD, combined type is used when at least six symptoms for both inattention and hyperactivity-impulsivity have been present for the past six months. These classifications based on the most evident symptoms allow the clinician to determine where a child falls within the spectrum of this disorder, ultimately benefiting the selection of treatment for the child.

**Prevalence of ADHD in Children**

ADHD is a disorder that usually manifests itself in childhood and often not diagnosed until a child has entered school. In 2006, estimates suggest that as many as 4.5 million children between the ages of 5-17 years of age had been diagnosed with ADHD (Bloom & Cohen, 2007). Research has shown that males are diagnosed more often than females with ADHD, with the male diagnosis rate at 9.5% as compared to females at 5.9% (Bloom & Cohen, 2006; Brown et al., 2001). It is also evident that boys are more likely to suffer from the predominantly hyperactive-impulsive and combined subtypes of ADHD and are three times as likely as girls to
be diagnosed during childhood due to the externalization of these behaviors (Stine, 2009). Girls are more likely to suffer from the predominantly inattentive subtype of ADHD and are also more likely to be diagnosed in young to mid-adulthood due to internalization of behaviors that eventually may lead to self-referral of treatment (Stine, 2009). The gender differences in diagnosis are important in understanding the variety of symptoms that occur in ADHD and illustrates that behaviors may manifest themselves differently based on gender.

Etiology of ADHD in Children

ADHD is a complex disorder that is believed to result from a combination of genetic, biological, and environmental risk factors. Current research does not fully support one specific mechanism that causes the symptoms of this disorder; rather, the etiology of ADHD is an integration of multiple factors that affect the expression of symptoms and severity of the disorder. It is known that relatives diagnosed with ADHD are a risk factor for the family inheritance pattern of this disorder, which is supported by evidence from twin and sibling studies (Whalen & Henker, 1998). Other recent research on genetic factors shows possible variants of neurochemical (dopamine and serotonin) transport and receptor cells in genes to be a cause of ADHD (Singh, 2008; Tripp & Wickens, in press). Multiple genes are likely to moderate the severity of ADHD symptoms; no single gene associations have been found. The idea of several polymorphisms has lead to a specific focus on genetic variations in the dopamine D4 receptor and the dopamine transports (DAT1) (Tripp & Wickens, in press). It is also hypothesized that genetic predispositions may interact with environmental risk factors such as lead and exposure to smoke in utero to exacerbate the disorder (Tripp & Wickens, in press).

This recent genetic evidence connects with the findings that there may be specific neurobiological patterns within children who have ADHD. Neurotransmitters such as dopamine
have been implicated in the causes of ADHD, with low levels or dysfunction within the system causing problems with attention and motivation (Singh, 2008; Whalen & Henker, 1998). Other research has shown differences in brain structures within children with ADHD and provides further evidence that the deficits are most likely due to a combination of factors rather than a single genetic mechanism or brain area (Nigg, 2006; Singh, 2008; Whalen & Henker, 1998).

**Literature Review**

*BIS/BAS Psychological Constructs*

A key focus area involving ADHD research deals with motivation. Motivated behavior can be defined as the actions an individual takes in response to stimuli to achieve a goal (Ernst & Fudge, 2009), and can involve the need to activate behavior (to approach a potentially rewarding stimulus or escape a punishing stimulus), or inhibit behavior to cautiously evaluate the situation and make a careful decision about behavioral response. These different responses are mediated through distinct neural systems (Gray, 1982; Gray & McNaughton, 2000; Ernst & Fudge, 2009; Nigg, 2006). These two neurobehavioral systems are termed the behavioral inhibition system (BIS) and the behavioral activation/approach system (BAS). These two physiological mechanisms that are posited to control motivation represent orthogonal dimensions within any given population (Carver & White, 1994; Gray, 1982; Gray & McNaughton, 2000); this indicates that individuals have varying combinations of low and high BIS and BAS sensitivity and that the systems modulate one another (Corr, 2002; Kambouropoulos & Staiger, 2004). Relative function in each of these systems has been theorized to contribute to a range of psychopathological behaviors, including ADHD.
The BIS is thought to control the experience of anxiety and be responsive to signals of impending punishment, non-reward, or novelty; BIS activation regulates aversive motivation and thus causes inhibition in conditions of conflict, such as reward cues that may also be paired with punishment cues, requiring contemplation prior to behavioral response (Carver & White, 1994; Corr, 2002; Gray & McNaughton, 2000; Kambouropoulos & Staiger, 2004). Children with ADHD have been proposed to be characterized by a lack of behavioral inhibition; deficits in this system have been proposed to underlie this pathology. In normally developing children for example, a child entering a room of unfamiliar peers (a novel situation) in which there is uncertainty will carefully examine the situation and suppress both emotional expression and exploration, reactions not typically observed in children with ADHD (Nigg, 2006). The main neural systems that have been found to relate to withdrawal and inhibition are the amygdala and limbic system (Nigg, 2006; Tripp & Wickens, in press). These neural systems modulate the actions of individuals when behaviors occur and may be implicated in ADHD due to the inappropriate lack of inhibition observed in children with this disorder.

A focus on behavioral inhibition or withdrawal deals with the activation of this system in response to impending punishment, rather than actual punishment. Nigg (2006) proposes that the misbehavior of children with ADHD may be due to the lack of response to cues for negative consequences that normal children show. This insensitivity to punishment, which could also be described as low anxiety, interferes with the development of self-control and results in issues with socialization that may translate into adolescence as impulsive and developmentally inappropriate behavior that is seen in ADHD (Nigg, 2006). Research has shown that perhaps externalizing behavior problems, such as those found in ADHD, may be related to low levels of
inhibition; these behaviors in connection with insensitivity to punishment that relate to the BIS system warrant future study to uncover variations within individuals.

In contrast, the BAS is believed to control appetitive motivation and respond to signals of reward and non-punishment (Carver & White, 1994; Gray, 1982; Gray & McNaughton, 2000); BAS activation causes movement toward goals. This system has also been associated with speed of reinforcement learning and it is believed that it is related to dopaminergic systems in the central nervous system that include the nucleus accumbens and ascending limbic-frontal dopaminergic pathways (Nigg, 2006; Tripp & Wickens, in press). In addition to theories regarding deficits in BIS, activation of the BAS system has also been implicated in theories of ADHD.

Research on the reward response of children with ADHD indicates that these children do not show normal responses to reward cues. Past research has shown that some ADHD participants tend to over-respond to reward cues while others under-respond. A more recent review of the findings in previous studies was conducted by Luman, Oosterlaan, and Sergeant (2005) to reveal several overall ideas that include increased weighting of immediate reward in ADHD, better response to higher-intensity reinforcement, and also under-response of physiological reactivity to reward. Based on these ideas, it has recently become important to focus on the timing of reward in ADHD such that children are more over-responsive to immediate reward while they may be under-responsive to delayed rewards (Nigg, 2006). These ideas are important to focus on in order to identify the relationship between an altered reward response and underlying mechanisms including the neurological systems of the BIS and BAS that may contribute to symptoms of ADHD in children.
Reward dysfunction may correlate with the inability of a child with ADHD to learn from previous mistakes; a new behavior that is to be learned may fail to be incorporated by the child and can fail to replace a previous behavior (Nigg, 2006). A common report from parents and teachers of children with ADHD involves the inability of the child to learn from mistakes, which may be applicable to impairment in learning behavior from delayed reward. It can also be hypothesized that a reward dysfunction for a child with ADHD may result in the hyperactive and impulsive behaviors, relevant to increased BAS sensitivity.

Gray’s (1982) reinforcement sensitivity model that includes the BIS and BAS systems is used by researchers to study child psychopathology. Self-report and parent report of BIS and BAS scales have been developed to allow researchers to easily assess the independent and concurrent strength of these subsystems within an individual. Research has shown that BAS dominance increases the risk for externalizing problems while BIS dominance increases the likelihood of internalizing problems such as depression and anxiety (Colder & O’Connor, 2004). Researchers are continually exploring these neuropsychological constructs in order to gain an understanding of the interaction of individual biological differences with contextual risk and protective factors that may lead to the outcome of disorders such as ADHD.

**Correlates of the BIS/BAS Scales**

Gray’s (1982) reinforcement sensitivity theory that originally proposed the BIS and BAS systems held that these two systems were activated separately. Recent research by Corr (2002) modified this original theory to include a joint subsystems hypothesis of BIS and BAS activation. This joint subsystem hypothesis proposes that both systems can be activated in response to various stimuli; responses to appetitive stimuli may occur in individuals with a high BAS and low BIS functioning and vice versa for punishment cues (Kambouropoulos & Staiger, 2004).
The combination of activity of these neurological systems of behavioral output resulted from inconsistencies in evidence from self-report measures with behavioral responses to reward and punishment. Kambouropoulos and Staiger (2004) assessed self-reported levels of BIS and BAS with actual behavioral tasks designed to activate these systems in response to appetitive and aversive stimuli.

The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) and the Eysenck Personality Questionnaire (EPQ-R) were utilized by Kambouropoulos and Staiger (2004) to assess BIS and BAS functioning. In order to examine behavioral responses to reward that elicit the BAS, the Card Arranging Reward Responsivity Objective Task (CARROT) was used to measure changes in speed of card-sorting when a small financial incentive is offered to participants. In contrast, the Q-TASK was administered to index aversive motivation or BIS functioning by eliciting behavioral inhibition via punishment. This is a modified version of the go/no-go task in which participants are to respond quickly when letters appear on the screen except when the letter ‘Q’ is present. Points are given based on correct responses, and false alarms of pressing the keypad when ‘Q’ is present result in the loss of points; this condition establishes the letter ‘Q’ as an aversive stimulus or cue to inhibit a response. This task was used to test the ability to inhibit behavior based on the conditioned aversive stimulus. The theory behind this task is that slower response times to the letters when a ‘Q’ is present indicate behavioral inhibition.

Kambouropoulos and Staiger (2004) found positive relationships between BIS traits derived from the EPQ-R and sensitivity to punishment (SP) to behavioral inhibition in the Q-TASK and also sensitivity to reward (SR) and reward responsiveness on the CARROT. In regard to the joint subsystems hypothesis, the relationships in the data did not indicate the
expected outcome of high anxiety (BIS) and low impulsivity (BAS) with increased behavioral inhibition. However, it was demonstrated that individuals with both high levels of anxiety and impulsivity showed increased behavioral inhibition on the Q-TASK. Support for separable subsystems was evident when an association between high anxiety (BIS) was consistently demonstrated with slower response times to the conditioned stimulus.

Aversive responses were shown to occur in individuals who have higher levels of both approach (impulsivity) and inhibition (anxiety) systems. It has been proposed by Gray and McNaughton (2000) that an approach-avoidance conflict will initiate the BIS system and subsequently, there will be concurrent activation of both motivational processes. High anxiety and high impulsivity that resulted in behavioral inhibition for the Q-TASK (aversive motivation punishment task) can be interpreted according to this proposal. Participants exhibiting high anxiety and high impulsivity may have experienced conflict with approach to respond correctly to gain money while also demonstrating avoidance in increasing inhibition to avoid losing the money (Kambouropoulos & Staiger, 2004); both behavioral response systems would be activated during task completion, with BIS being activated at higher levels to inhibit behavior in response to the task designed to present aversive stimuli. An interaction between the BIS and BAS systems therefore can be present within individuals when displaying goal-directed behaviors. The variance in these systems within individuals ultimately leads to different behavioral responses in laboratory tasks and also in real world behaviors.

Colder and O’Connor (2004) adapted adult measures to assess the independent strength of the BIS and BAS to sensitivity to reward, punishment, and extinction in children. The researchers utilized measures to assess the children’s sensitivity to punishment and reward based on parental report on the Sensitivity to Punishment and Sensitivity to Reward Questionnaire
Two laboratory tasks were additionally used to measure reaction time and continuous performance to assess physiological reactivity to reward and punishment in relation to BIS and BAS functioning. A final caregiver report of externalizing and internalizing symptoms using the Child Behavior Checklist (CBCL) was assessed in order to evaluate the association between these reports and the SR and SP parent reports and laboratory tasks. The use of these multiple measures allowed Colder and O’Connor (2004) to make comparisons between the caregiver-reports of SR and SP to laboratory assessment techniques and also determine the relationship between caregiver-report and laboratory assessment of SR and SP with behavior problems.

Results comparing caregiver reports of SP and SR in behavioral responses to reward and punishment via the reaction time task demonstrated that high levels of reported SP were associated with greater inhibition in response to punishment cues (Colder & O’Connor, 2004). How responses to reward cues change during punishment and pre-punishment blocks indicated activation of BIS and BAS. During punishment, slower responding to a specific stimulus (a red circle) was expected because of the possibility of increased punishment; less slowing suggests greater SR and strong BAS activation. During the post-punishment condition, greater slowing of reaction time to the red circle (stimulus previously conditioned with punishment) was indicative of high SP and BIS activation. High levels of caregiver reported impulsivity/fun seeking were associated with greater BAS activation in response to reward cues during mixed incentives (Colder & O’Connor, 2004). The subdomain of impulsivity/fun seeking was the only SR scale to correlate with speed of reaction time (in milliseconds) on the reaction time task, which may indicate a pure form of behavioral expression of BAS activation (Colder & O’Connor, 2004). Overall, caregiver reports of SR and SP were consistently related to BIS and BAS assessment via this laboratory task.
Research on physiological reactivity to reward incentive has shown that heart rate reactivity is an index of BAS activity (Iaboni, Douglas & Ditto, 1997). BIS activity indices are shown to be relevant to electrodermal reactivity in the presence of punishment cues, aversive stimuli, and the nonoccurrence of expected reward (Iaboni et al., 1997). The continuous performance task studied by Colder and O’Connor (2004) that assessed physiological reactions to task conditions supported the idea that BAS activation was indexed by heart rate (HR) reactivity. However, when comparing caregiver reports of SR to HR reactivity, evidence was limited in supporting a connection between these two measures. Unexpected findings for skin conductance level (SCL) reactivity also demonstrated a decline in the children during extinction trials relative to practice, with some SCL reactivity being similar during various extinction and reward trials (Colder & O’Connor, 2004). When comparing SP reports to SCL reactivity, this measure declined for children characterized by low levels of SP. However, for children characterized by high levels of SP, SCL reactivity did not change across conditions of extinction and reward.

The comparison between caregiver reports of SR and SP in relation to problem behavior indicated that high levels of impulsivity/fun seeking, a strong BAS, were associated with increasing externalizing behavior problems (Colder & O’Connor, 2004); the only dimension of the BAS that was associated with externalizing behavior problems was for impulsivity/fun seeking. Also, high levels of SP and a strong BIS, were associated with increasing levels of internalizing behavior problems (Colder & O’Connor, 2004). Overall, the association between laboratory measures and caregiver reports of SP and SR were stronger than the patterns resulting between problem behavior and SR and SP caregiver reports. This weaker association between
problem behaviors and reports of SR and SP indicates that there are other risk factors that most likely play a larger role in the development of problem behaviors (Colder & O’Connor, 2004).

According to the findings from this study by Colder and O’Connor (2004), the BIS and BAS can be assessed to determine the effects on behavior in children. The findings are applicable to growing research that is focusing on the strength of the BIS and BAS and the relationship with problem behaviors; strong BAS has been theorized to place children at risk for externalizing behavior problems due to disinhibition of behavior (Colder & O’Connor, 2004). In contrast, children with a strong BIS may be at an increased risk for inhibition and internalizing symptoms of psychopathology (Colder & O’Connor, 2004). The ability to apply these neuropsychological constructs to behavioral disorders may allow future treatment strategies to address these systems in order to help children understand their actions and make better decisions about goal-directed behaviors.

Physiological Indices of BIS/BAS Function

Several researchers have explored biological measures of BIS and BAS activation, that may be more tightly coupled with the neural networks that underlie these behaviors than clinical self-report. In a laboratory context, incentive-based tasks where children earn rewards are often used to induce BAS motivation, while measuring autonomic indicators of neural function such as skin conductance level (SCL) and heart rate. Variations of this include the go/no-go task, which requires inhibition of a pre-potent response, where correct responses are rewarded and incorrect responses are punished; “gambling” tasks where an individual wins or loses money based on the cards selected, with a decline in probability of winning over time; and the door-opening task, which is a developmentally modified version of the gambling/card selection task for younger children (Nigg, 2006). For incentive-based go/no-go tasks, physiological measures can be
recorded during conditions of reward versus punishment. For the chance-based games, behavior can be measured in terms of the length of time the individual plays despite the shift in contingencies, reflecting an insensitivity to increasing cues of punishment. These types of tasks are used to approximate behaviors an individual would engage in to obtain rewards in the presence of impending punishment.

Physiological measures such as heart rate and skin conductance levels have been demonstrated to reflect activation of the behavioral approach and inhibition systems in children and adults. It has been proposed that increased heart rate in response to reward reflects an activation of behavioral approach while increased skin conductance in response to the removal of reward reflects activation of the behavioral inhibition system in adults (Iaboni et al., 1997). Researchers have used this information to conduct studies to compare the psychophysiological responses of children with ADHD and also use the BIS/BAS scales as a comparison to the physiological data.

Research by Iaboni et al. (1997) has investigated these psychophysiological responses in normal children as well as children with ADHD to assess the functioning of the BIS and BAS. Behavioral inhibition is indexed by changes in electrodermal responding during punishment conditions. In normal participants, skin conductance responses have been shown to increase when BIS activation is elicited by extinction of previously rewarded behaviors (Fowles, 1988). The activation of BIS reactivity has been demonstrated to reflect changes in reward contingencies, such that an expected reward (approach) has been replaced with extinction (avoidance), resulting in concurrent activation of motivational processes (Corr, 2002; Gray & McNaughton, 2000). Research by Iaboni et al. (1997) has shown that children with ADHD do not demonstrate increased skin conductance levels during extinction. The decreased levels in
electrodermal responding have been proposed to be relevant to a weak behavioral inhibition system (Iaboni et al., 1997). Also, children with ADHD showed heart rate habituation during the reward conditions which would also suggest differences from control children in regard to physiological changes that are correlated to measures of behavioral approach. These results support the idea that the motivational systems in children with ADHD, as measured by psychophysiological data, appear to be abnormal in various respects; these variations across individuals with ADHD may be important in future studies to determine the heterogeneity in symptoms that may be present.

Relation Between Physiology and Self-Report Measures

Research on assessment of BIS and BAS has demonstrated an association between self-report of BIS and BAS sensitivity to physiological indices of these behaviors. The utilization of differential measurements allows the comparison of reported sensitivity to situations in which these behaviors may be activated, to the actual activation of these motivation systems based on biological response. Self-report of these behavioral constructs may be questionable, especially when reported by children. The BIS and BAS constructs are orthogonal dimensions that result in a dichotomous behavior. Therefore, any given behavior can be explained by increases in one system or decreases in activation of the other. This can be assessed based on an example behavior in question, such as a child in the presence of a friendly dog on the sidewalk. If the child does not approach the dog, the assessment of this behavior can indicate a child may be afraid and high in behavioral inhibition, or the child may have low behavioral approach and simply not be interested in the dog. The ability for an individual, especially a child, to differentiate the balance between these two constructs in order to evaluate their own behavioral tendencies is an open question. This assessment occurs during self-report on behavior, but
further measurement through parent report allows the study of parental ability to differentiate sources of information to identify a child’s behaviors. These various sources of report can then be validated and examined in relation to established biological indices of behavioral response.

Other research has also explored the connections between psychophysiological measures and motivational systems in order to develop better methods for assessing the sensitivity of the BIS and BAS. Brenner, Beauchaine & Sylvers (2005) used data on heart rate response to a monetary incentive task to study the relationship between physiological indices of motivational drive with the self-report questionnaire often administered to individuals. It is hypothesized that in order to facilitate goal directed activity from behavioral approach, the cardiac output of an individual will increase accordingly. Heart rate is controlled by input from both the sympathetic and parasympathetic nervous system. The cardiac pre-ejection period (PEP) has been used as an index of sympathetic nervous system activity by measuring the time onset between left ventricular depolarization and the ejection of blood into the aorta in the heart during reward tasks (Beauchaine, 2001; Beauchaine, Katkin, Strassberg, & Snarr, 2001; Brenner et al., 2005). PEP reactivity marks BAS activation during appetitive motivational states which require the sympathetic nervous system to expend energy to meet the environmental demands (Beauchaine, 2001; Beauchaine et al., 2001). The sympathetic nervous system also mediates changes in the contractile force of the left ventricle during increased cardiac output for behavioral activation responses (Sherwood et al., 1986; 1990).

Brenner et al. (2005) also used respiratory sinus arrhythmia (RSA) to assess parasympathetic nervous system changes (vagal suppression) on cardiac activity in order to determine which measure would provide a better marker of behavioral activation during the reward conditions of the task. Most studies provide stronger support for PEP as better predictor
of BAS as opposed to RSA, and through the use of both of these indices, Brenner et al. (2005) were directly comparing these measures of BAS reactivity during stimulus conditions of pure reward.

Results from Brenner et al. (2005) indicated that both PEP and RSA were sensitive to reward, but only PEP was found to be specific to reward, showing no variation in response to extinction. However, significant changes in RSA were observed during extinction as well as reward, and during an emotion induction task administered separately, indicating an overall response of RSA to conditions of emotionality regardless of valence or motivational disposition. It has been concluded that PEP is a better indicator of behavioral approach because it responded only to the reward condition (Brenner et al., 2005); RSA values that change for extinction and reward could be indicative of sensitivity to both BIS and BAS that can be competing within the task condition. These measures are useful to determine if the behavior systems under study are indeed activated by the task conditions. It is important to ensure that the correct behaviors are elicited and that the physiological measures can track the changes accordingly; the ability to distinguish which motivational system(s) are active allows researchers to apply these behavioral systems to neural networks that should also be activated during the task. The correlation between behavior and neural activation can allow a better understanding about psychopathologies that may arise due to variations in response to reward tasks, such as in ADHD.
Hypotheses and Study Objectives

BIS and BAS reactivity assessment has been measured through the use of self-report and psychophysiological measures. Individual differences in BAS and BIS reactivity that are measured by self-report allow participants to identify prototypical behaviors that they may engage in during various situations. Within the design of the current study, BIS and BAS self-report measures were completed by both parent and child during laboratory testing sessions. It is of interest whether parents and children would rate behavioral tendencies similarly on BIS/BAS questionnaires. The aim of this research paper is to compare the ratings of behavior patterns between parents and children on the BIS/BAS scales.

Psychophysiological measures of BIS and BAS assess autonomic function indicative of changes in the output of the central nervous system that underlie behavioral response. Peripheral physiological measures of cardiac reactivity and impedance, as well as electrodermal responding, are assessed during appetitive responding for reward and during punishment conditions. Extensive research has documented the connection between physiological measures of behavioral approach and behavioral inhibition (Beauchaine, 2002; Beauchaine et al., 2001; Iaboni et al., 1997). Based on these findings, research has demonstrated a shortened PEP in normal children and adolescents during monetary incentive tasks (Beauchaine, 2002; Beauchaine et al., 2001). The changes in PEP values as an index of sympathetic nervous system activity will be utilized in this study as a measure of BAS activation in children and adolescents. Changes in mean skin conductance level (mean SCL) will also be used to indicate BIS activation in children and adolescents during task conditions of reward versus punishment.

To assess group differences between self-report measures as well as physiological responding, comparisons between ADHD versus control children will be conducted. Differences
in total score for BIS and BAS assessed through parent versus child report in children with and without ADHD will be examined. Changes in PEP values between group differences (control vs. ADHD) during conditions of punishment versus reward will be investigated. The current study will also assess changes in mean skin conductance level (SCL) between groups (ADHD vs. control) to assess activation of BIS and BAS during task conditions of punishment and reward.

The final objective of this study is to determine the correlation between parent and child self-report of BIS and BAS scores and changes in physiological responding during reward and punishment conditions in children with and without ADHD. The goal is to determine whether normal children and parents rate behavior more similarly to the matched physiological measures than children with ADHD and their parental reports of behavior. Variations within the activation of BIS and BAS have been related to the psychopathology of ADHD symptoms (Brenner et al., 2005; Iaboni et al., 1997). An increase in BIS sensitivity increases the likelihood of internalizing problems such as depression and anxiety (Colder & O’Connor, 2004). Research has also shown that externalizing behavior problems may be related to low levels of behavioral inhibition and the potential for higher levels of behavioral approach; increased externalization of behaviors, such as impulsivity, may be relevant to increased BAS sensitivity. By examining these relationships, it can be determined whether children with ADHD may be unable to understand behavioral response as reflected on self-report measures as compared with children without this disorder. Parents may be able to better predict the behavior of their children and be especially sensitive to behavioral patterns in children with ADHD.
Methods

Participants

Forty-five children and adolescents (30 males and 15 females) between the ages of 6 and 16 years ($M = 11.8$ years) participated in this study. The sample consisted of 31 control and 14 ADHD participants. Children with and without ADHD were recruited for this study from fliers distributed throughout the university campus, within the local school district, and the community. Children were screened prior to the study and children with ADHD were not included if they were taking non-stimulant medications. Children diagnosed with ADHD by a family practitioner attended two sessions of the experiment, an “on” and “off” medication visit. Only data from the off medication visit will be reported here. The off medication visit was identical to the single, control group, session and lasted approximately 1 ½ - 2 hours. Children with ADHD were required to discontinue use of medication 48 hours prior to testing. For this visit, the children played a response task alone to win a prize and then completed a “gambling” task with the help of a parent. Participants’ ethnicities were predominantly Caucasian ($n = 33$), with African American ($n = 3$) and other also being reported ($n = 9$).

Procedure

Participants were introduced to the research assistants and shown the laboratory facility. Assent/consent forms were reviewed and signed with the caregiver and the child. A standardized script was used to explain the task to the child. Children were told that if they “earned more points than the average child their age” they would get to select from a large display of toys worth approximately $15, or select a gift card of a $15 value if the toys did not seem appealing.
The point value to target was purposefully left vague, in the attempt to maintain a constant state of motivation toward the goal with no way to determine if and when the goal had been reached. It was explained that if the child did not do as well they would get a small prize as a thank you (e.g., jacks or small plastic farm animals). The child then filled out the BIS/BAS scale and was read aloud the questions by the research assistant.

Children washed their hands in preparation for placement of skin conductance electrodes. Alcohol wipes were used to clean the surface of the skin before placement of ECG electrodes. Three cardiac spot electrodes (pre-jelled Ag/AgCl disposable disks) were placed on the child’s chest to form a triangle. The electric current across the heart was measured from the electrode placed below the right clavicle to the left lower ribcage. The third electrode was used as a ground electrode and placed on the right lower ribcage. Cardiac impedance was measured by four additional spot electrodes. The two outer electrodes provided the constant current signal path to the subject and two inner electrodes measured voltage to reflect changes in impedance that resulted from volumetric changes in blood flood and distribution (Bernston, Quigley, & Lozano, 2007). The configuration of electrodes consisted of two inner electrodes on the chest, placed slightly left of the center/below the left clavicle and immediately below the xiphoid process of the sternum. The two outer spot electrodes on the back of the subject were then placed approximately one inch above and below the inner electrodes (Bernston, Quigley, & Lozano, 2007; Sherwood et al., 1990; Qu, Zhang, Webster, & Tompkins, 1986). The electrodermal electrodes (pre-jelled disposable Ag/AgCl with lower salinity than the ECG electrodes) were also placed on the thenar and hypothenar eminences of the non-dominant hand of the participant. The EEG cap was then placed over the child’s head and impedance was measured prior to the start of
the task. The child was then shown the keypad to respond and the experimenter read the
directions on the screen to describe the task.

The “critter” response time task consisted of images of a “Little Miss” or “Mr. Men”
character (based on the children’s book series) displayed on the computer screen and requiring
the child to respond by pushing a button on the keypad. The child was instructed to push the
button as fast as they could after viewing the image of the cartoon character. They were also told
to not respond (not hit the button) if the character was displayed twice in a row. If the child
pushed the button incorrectly or not fast enough, a red box would appear on the screen to
indicate a mistake. After several character images were displayed, the amount of points won or
lost was displayed to indicate to the child how they were doing while playing the game. After
these instructions were explained, the child was also told that there were several instances
between blocks where a crosshair would appear on the screen to look at and sit still. The child
was then allowed to practice the critter task before actually winning or losing points.

The practice round enabled the experimenter to set the speed (in milliseconds) of stimuli
presentation depending on the child’s age and response pattern while the child was able to
practice the task. The speed was set so that the child obtained an error rate between 40 and 60
percent before beginning the actual blocks. This allowed for an approximately equal number of
correct and incorrect responses to facilitate examination of error processing, not relevant to the
current manuscript. The critter task consists of six baseline measures and five task blocks. An
initial baseline was obtained followed by a reward and frustration block. The pattern of baseline,
reward block, baseline, and then frustration block was repeated so that there were three reward
blocks and two frustration blocks (task pattern, B = baseline, A= reward block, F = frustration
block: B1, A1, B2, F1, B3, A2, B4, F2, B5, A3, B6). Task performance rate was adjusted for
throughout the task and stayed relatively constant due to automatic adjustment of speed by the computer program according to the responses of the participant. Throughout the game, the point awarding algorithm was automatically changed based on the block the participant was completing. A child would win more points during the reward blocks and lose more points during the frustration blocks. The child could not adjust performance based on block, but would generally lose most points during the two punishment blocks and gain more points during reward blocks.

While the child was completing this task, the caregiver filled out various questionnaires including: a demographics form, the Conners Rating Scales- Conners 3rd Edition to assess ADHD and comorbid problems and disorders in children and adolescents (Conners, 2008), and the BIS and BAS Scale parent report form (Carver & White, 1994).

Questionnaires

*BIS/BAS Scales*

The Carver and White (1994) BIS/BAS Scales were administered to the parent and child at the beginning of the session. This questionnaire consists of 20 questions scored on a 7-point Likert scale to assess the activation of these systems within individuals when engaging in goal-directed behavior. The BIS scale includes seven items assessing anxiety sensitivity to external events that are referenced through potential punishment and the behavioral response to punishment cues. Sample BIS scale items include: “I worry if I have done poorly at something” or “Criticism or scolding hurts me a lot”. The BAS scale includes 13 items that reflect the potential for reward and assess behavioral responses of the child. Three subscales have been developed to assess BAS sensitivity to reflect the following: pursuit of an appetitive goal,
response to reward, seeking out rewarding experiences, and also acting to pursue a desired goal (Carver & White, 1994). The Drive subscale is used to assess the persistent pursuit of desired goals by individuals (“When I want something, I go all out to get it”). The Fun Seeking scale utilizes questions to reflect a desire for new reward potential and willingness to approach these events quickly (“I crave excitement and new sensations”). The Reward Responsiveness subscale focuses on positive responses to the occurrence or anticipation of reward (“When I get something that I want, I feel energized”). The design of the BAS subscales was developed due to an incomplete consensus on how BAS sensitivity would manifest in behavior; hypotheses relate BAS sensitivity to the potential for impulsive and antisocial behaviors (Carver & White, 1994). Internal consistencies for the scales showed accepted levels at \( \alpha = 0.745 \) for child BIS/BAS questionnaire and \( \alpha = 0.731 \) for parent questionnaire of BIS/BAS. See Appendices B and C for BIS/BAS Scale questionnaires.

Physiological Measures

**PEP**

The time interval between left ventricular depolarization and ejection of blood into the aorta was used as a measure of cardiac pre-ejection period (PEP) (Bernston, Quigley, & Lozano, 2007). This assessment was utilized as a measure of sympathetic influence on fluctuations in heart rate during goal-directed activity. Greater changes in sympathetic nervous system activity are represented by shorter intervals (Sherwood et al., 1986). Impedance cardiography information combined with the ECG trace determines the pre-ejection period. The PEP value can be defined as the difference in milliseconds between the Q point on the ECG trace and the B point on the IMP wave (Bernston, Quigley, & Lozano, 2007). PEP values were determined from
ensemble-averaging data in 60-s epochs for baseline measures and 30-s epochs for task conditions using Mindware software, version 3.0.3. The cardiac impedance data was scored and cleaned by undergraduate research assistants working in the lab and trained to use the Mindware programs. Baselines were scored in 60-s intervals and each block was scored in 30-s epochs. Data that had high impedance was not scored, and segments that could be salvaged were edited to retain as much data as possible. Due to equipment issues and data that was unable to be scored, only seven of the fourteen ADHD children and twenty-three of thirty control children have physiological data reported.

Average PEP values were calculated for each block and among baseline, reward, and punishment conditions. To investigate the effects of the reward and punishment conditions on PEP, the average values observed during 60-s periods immediately preceding each block were used as baseline values. Change scores for each condition were calculated by subtracting average PEP values observed during the 60-s periods (baselines) from the average of the values observed during reward and punishment conditions.

EDA

Skin conductance level was measured by changes in electrical conductivity on the hands throughout the task conditions. EDA output data included skin conductance responses (SCR’s) such as mean skin conductance level (mean SCL). Mean SCL measures the mean level of skin conductance (in microsiemens) on average, across the segment. The threshold level for skin conductance response was 0.05 μs. Average EDA values were determined from 60-s epochs of baseline measures and 30-s epochs of task condition using Mindware software, version 3.0.3. The cardiac impedance data was also scored and cleaned by undergraduate research assistants.
trained to use the Mindware programs. Data that was not useable was not scored, and segments that could be salvaged were edited to retain as much data as possible. Due to equipment issues and data that was unable to be scored, only six of the fourteen ADHD children and twenty-six of the control children have physiological data reported.

Average mean EDA values were calculated for each block and among baseline, reward, and punishment conditions. To investigate the effects of the reward and punishment conditions on EDA, the values observed 60-s periods immediately preceding each block were used as baseline values. Change scores for each condition were calculated by subtracting average EDA values observed during the 60-s periods (baselines) from average values observed during reward and punishment conditions.

Data Analyses

Total score values for the BIS and BAS scales were calculated for both parent and child self-report questionnaires. Correlation values were used to analyze the relationship between parent and child report scores for BIS and BAS reactivity for all participants. The correlation between physiological response and self-report scores of all participants was examined by determining relationships between parent and child self-report BIS and BAS totals and change scores of PEP and change scores of mean SCL during reward and punishment conditions.

Based on group status (ADHD vs. control), between groups differences in reports between parents and children on the BIS and BAS scales were analyzed using a one-way ANOVA. Between groups differences for physiological measures were analyzed using one-way ANOVAs for change scores in PEP and EDA during each task block and total change scores for reward versus punishment conditions.
Correlations between parent and child self-report of total BIS/BAS scores and change scores in PEP and EDA during reward and punishment conditions were examined to evaluate the convergent validity of self-report and psychophysiological measures. The significance level for all analyses was $p = 0.05$.

Results

Parent and Child Report of BIS/BAS and Physiological Responding

Parent and Child Report of BIS and BAS

Correlations among the total scores on the BIS/BAS scales for both parent and child report were assessed for all participants. A significant positive correlation ($r = 0.40, p < 0.05$) was found for parent and child report on total BIS scale score. The negative correlation between parent and child report of total BAS scores ($r = -0.009, p > 0.05$) resulted in a small, nonsignificant value. Results showed that child report of BIS score ($M = 30.6, SD = 5.3$) was significantly positively correlated ($r = 0.34, p < 0.05$) with child report of total BAS score ($M = 66.1, SD = 8.3$), indicating that when children identified increase in BIS sensitivity they were also more likely to report increases in BAS sensitivity. No significant correlations were found between parent reports of total BIS ($M = 32.3, SD = 7.2$) and total BAS ($M = 69.8, SD = 8.6$), suggesting that parents consider these facets independently of one another.

Self-Report versus Physiological Indices of BIS/BAS

Physiological changes in PEP and EDA have been utilized to measure BAS and BIS reactivity, respectively. A significant positive correlation ($r = 0.37, p < 0.05$) was found for a
high parent report of total BAS with change scores in PEP during punishment conditions. This indicates that a high total score of BAS as reported by the parent was associated with an increase in PEP during conditions of punishment. Child report of BAS did not correlate with change scores in PEP or change scores in mean SCL during either condition (punishment versus reward). No significant correlations were evident between parent report of BIS total score or child report of BIS total score and mean change scores in SCL during reward or punishment conditions.

Between Groups Differences on Self-Report and Physiological Measurement

Self-Report Measures

To compare the scores of ADHD versus control children on parent and child report of BIS and BAS totals, a one-way (group) ANOVA was performed. This analysis did not reveal a significant group difference for child total BIS score, $F(1,42) = 0.184, p > 0.05$, or parent total BIS score, $F(1,43) = 0.530, p > 0.05$. For comparison of between group BAS totals, no significant group differences were reported for child total BAS score $F(1,42) = 0.401, p > 0.05$ or parent report of total BAS score $F(1,43) = 0.027, p > 0.05$. Thus neither parent nor child self-report of BIS/BAS sensitivity appears to be associated with likelihood of ADHD diagnosis.

Physiological Measures

PEP

A one-way ANOVA was used to analyze comparisons between groups (control = 25 and ADHD = 7) for change scores in PEP during reward versus punishment conditions. PEP reactivity change scores assessed by each punishment block revealed a significant between groups difference for control children ($n = 23, M = 1.04, SD = 5.72$) versus children with ADHD ($n = 7, M = -11.81, SD = 18.24$) for only the second punishment block during the task, $F(1,28) =$
9.144, \( p < 0.05 \). PEP reactivity changes assessed for each of the three reward blocks revealed a
significant between groups difference for control children (\( n = 24, M = 1.64, SD = 5.93 \)) versus
children with ADHD (\( n = 6, M = -8.70, SD = 20.10 \)) during the third reward block only, \( F(1,28) = 5.080, p < 0.05 \). Overall among the two punishment blocks, a significant difference between
groups was found for change scores of PEP during conditions of punishment (versus reward),
\( F(1,30) = 6.168, p < 0.05 \). However, change scores in PEP among all three reward conditions,
did not reveal significant differences between groups, \( F(1,31) = 0.637, p > 0.05 \).

**EDA**

A one-way ANOVA was used to analyze comparisons between groups (control = 27 and
ADHD = 6) for change scores in mean SCL during reward versus punishment conditions. No
significant differences between groups were found for changes in mean SCL for all three reward
blocks, \( F(1,31) = 3.517, p > 0.05 \), as well as no significant changes in mean SCL for both
punishment blocks together, \( F(1,31) = 0.254, p > 0.05 \). No significant differences were reported
for change scores in mean SCL in each of the two punishment blocks or each of the three reward
blocks of the task.

**Correlations between Self-Report and Physiological Measures by Group Status**

Correlations among the BIS/BAS scales for parent and child report and
psychophysiological reactivity changes across task conditions among control children and
children with ADHD are presented in Table 1 and Table 2 below.
Table 1. Correlations among BIS/BAS Scales Reported by Parent and Child and Physiological Change Scores for Control Children.

<table>
<thead>
<tr>
<th>Measure</th>
<th>BIS Parent</th>
<th>BIS Child</th>
<th>BAS Parent</th>
<th>BAS Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Reward</td>
<td>0.26</td>
<td>-0.18</td>
<td>0.39</td>
<td>-0.09</td>
</tr>
<tr>
<td>Δ Punishment</td>
<td>0.21</td>
<td>-0.33</td>
<td>0.39*</td>
<td>-0.07</td>
</tr>
<tr>
<td>SCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Reward</td>
<td>-0.05</td>
<td>0.01</td>
<td>-0.05</td>
<td>0.35</td>
</tr>
<tr>
<td>Δ Punishment</td>
<td>0.01</td>
<td>0.002</td>
<td>0.16</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Notes: PEP: pre-ejection period; EDA: electrodermal activity; BIS: behavioral inhibition system; BAS: behavioral activation system.
*p ≤ 0.05

Table 2. Correlations among BIS/BAS Scales Reported by Parent and Child and Physiological Change Scores for ADHD Children.

<table>
<thead>
<tr>
<th>Measure</th>
<th>BIS Parent</th>
<th>BIS Child</th>
<th>BAS Parent</th>
<th>BAS Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Reward</td>
<td>-0.03</td>
<td>-0.15</td>
<td>0.19</td>
<td>-0.43</td>
</tr>
<tr>
<td>Δ Punishment</td>
<td>-0.18</td>
<td>0.02</td>
<td>0.39</td>
<td>-0.42</td>
</tr>
<tr>
<td>SCL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Reward</td>
<td>0.61</td>
<td>-0.21</td>
<td>0.82*</td>
<td>-0.79</td>
</tr>
<tr>
<td>Δ Punishment</td>
<td>0.75</td>
<td>-0.47</td>
<td>0.73</td>
<td>-0.63</td>
</tr>
</tbody>
</table>

Notes: PEP: pre-ejection period; EDA: electrodermal activity; BIS: behavioral inhibition system; BAS: behavioral activation system.
*p ≤ 0.05
Control Children

Results showed a positive correlation \( (r = 0.39, p \leq 0.05) \) between change scores in PEP for punishment conditions and parent report of total BAS. These results indicate as parental report of BAS total score increased, change scores of PEP were also likely to increase during reward and punishment conditions.

No significant correlations were found for parent or child report of BIS or BAS total scores and change score of mean SCL during overall reward or punishment blocks.

ADHD Children

A significant positive correlation \( (r = 0.82, p \leq 0.05) \) was found for parent report of BAS total score and change score in mean SCL during reward conditions.

There were no significant correlations between change scores in PEP during punishment or reward conditions and parent or child report of BIS and BAS total scores.

Discussion

The main objectives of this study were to compare parent versus child ratings on the BIS and BAS scales, assess the relationship between physiological measures and self-report data, and finally examine the differences in self-report and physiological response between children with and without ADHD. Initial analyses between all parents and children showed a positive correlation for parent and child report of total BIS. This indicates that parents and children are both likely to report similar increases in BIS activation when rating behavioral response. In
contrast, there was very small and negative correlation between parent and child report of BAS. Low correlation of parent and child response on this measure demonstrates that report of this construct occurs independently between the two reporters. When examining the correlations of BIS and BAS in children on self-report measures, a significant positive correlation between the two constructs was observed. Children’s identification of BIS sensitivity on the self-report measure was also more likely to be reported with increases in BAS sensitivity as well. High correlation between the total score reports of these two measures may indicate that children are unable to differentiate between these two constructs when assessing their own behavioral response patterns. The inability to differentiate the likelihood of a behavior may cause children to be inclined to report that they will show both behavioral inhibition and behavioral approach.

The reliability of the ability of a child to self-report behaviors may be questionable based upon this finding. It could also indicate that children do not fully understand the questions being asked or how they would act in the prototypical situation. The additional assessment of behavioral approach and behavioral inhibition by parent report was utilized in this study to compare total score report of these constructs. It is interesting that although parent report alone shows no correlation between report of these two behavioral tendencies, there is a high correlation between parent and child report of BIS sensitivity. Based on this finding, it is apparent that both parent and child recognize these behavior patterns and are more likely to report them similarly. However, parent report of these constructs independently of one another, by a nonsignificant correlation between the total scores of BIS and BAS, exposes the ability to distinguish between these behavioral responses in their children. Further measurement of behavioral approach and behavioral inhibition in all children in this study was utilized to assess actual sensitivity of these systems through changes in physiological response to task conditions.
Physiological response can be utilized as an assessment technique in order to map parent and child report of BIS and BAS sensitivities with actual neural correlates that control biological changes during these behaviors. The two physiological indices of behavioral approach and behavioral inhibition assessed in this study were PEP and mean SCL, respectively. No correlations resulted from parent or child report of BIS total score and change scores in mean SCL during reward versus punishment conditions. However, change scores in PEP during punishment showed a significant correlation with increased total score report of BAS sensitivity by parents.

An increase in the change scores of PEP values illustrates a decrease in sympathetic nervous system activation during punishment conditions. Children demonstrating these changes in sympathetic activity on the heart during punishment conditions would be characterized as being less motivated during the punishment blocks. A decrease in behavioral activation during punishment would be expected based on previous research confirming decreases in PEP values for conditions of reward used to elicit behavioral activation (Beauchaine, 2001; Beauchaine et al., 2001; Brenner et al., 2005). This finding further supports the idea that parents may be better reporters of BAS activation. The report of sensitivity to BAS in their children is correlated to changes in the physiological index used to determine activation of these constructs within varying task conditions. Child report of behavioral response patterns did not correlate with either physiological measure. The physiological changes in mean SCL used to correlate with BIS activation did not correlate with parent or child report or among task conditions of punishment versus reward as expected. A lack of correlation may demonstrate that the skin conductance measure of choice did not index BIS sensitivity, and a different index may have been better suited to measure changes within this sample.
The comparison of ADHD versus control group children was assessed by examining between groups differences on self-report and physiological measures. The self-report results did not demonstrate between group significance for parent and child report of BIS and BAS sensitivity. This finding indicates that the report of BIS and BAS by parents and children on these questionnaires is not associated with the likelihood of ADHD diagnosis.

The group status comparison for the physiological measures of PEP and mean SCL indicated several interesting findings. For values of change scores in PEP, there was a significant difference between groups for punishment conditions versus reward. When these differences were examined by block, PEP reactivity change scores showed significant group differences during the second punishment block. For this second punishment block, the ADHD children showed a large drop in PEP change scores ($M = -11.81, SD = 18.24$) versus control children change scores of PEP reactivity ($M = 1.04, SD = 5.72$). These large group differences indicate that children with ADHD appear more motivated during this punishment condition due to decrease in PEP values, as calculated from a change in baseline reactivity, that link to an increase in sympathetic nervous system activation. A decrease in PEP values has been demonstrated to index behavioral activation during conditions of reward for normal children. The ADHD children in this study also demonstrated significant changes in PEP reactivity for the third reward block, which would be expected during the condition of reward in which behavioral approach is activated.

The skin conductance level data did not reach significance for between group differences. However, a trend toward significance was apparent for change in mean SCL for the first reward block and also for the total change in mean SCL for all three reward conditions. This reveals that the skin conductance measure used is not reading BIS sensitivity in punishment conditions.
as demonstrated in previous research (Iaboni et al., 1997); varying responses between control and ADHD children were not evident. Overall, these findings on between groups differences for physiological responding or lack of differences in regard to self-report measures, do not match the expected predictions based on previous research results assessing convergent validity of self-report and physiological measurement of BIS and BAS behavioral constructs.

The correlations among the BIS/BAS scales for parent and child report and psychophysiological reactivity scores across task conditions among control children and children with ADHD were examined to evaluate differential effects based on group status. Based on group status, correlation analyses revealed a significant positive correlation between changes scores in PEP during punishment conditions and parental report of total BAS score for control children. An increased parental report score of BAS for control children was likely to be associated with increases in change scores of PEP during punishment when engaging in the task. As an increase in PEP values occurs, there is less input from the sympathetic nervous system, which indicates a less activated state of motivation for the child. This occurrence in control children during conditions of punishment shows a relationship to parent report of BAS such that parents of control children are able to identify approach behaviors in their children. The parent report of their child as having higher behavioral approach patterns does correlate with the child’s physiological reactions during task conditions. This further demonstrates the ability of parents to recognize behavioral responses of their children, even though the self-report measures from the child did not significantly correlate with their physiological responses during task conditions. This findings supports the idea that parents may be better able to report child behaviors than the children themselves, especially among the control group participants.
The results for group status based on children with ADHD reveals different findings from control children. Changes in PEP reactivity during conditions of punishment were not correlated with parent report of BAS sensitivity. For the children with ADHD, parent report of BAS was correlated with changes in mean SCL for reward conditions. Parents of children with ADHD are reporting this behavior as activation of BAS but the data from physiological responding demonstrated changes in mean SCL during conditions of reward. Parental report of this construct is associated with a different physiological measure in comparison to children without ADHD. The association of this construct with a different physiological measure by parents of children with ADHD was unexpected. Parents of children with ADHD may not be attuned their child’s behavior as indexed by physiological measurement. This difference from control children may have resulted from the small sample size of ADHD participants with useable physiological responding data. The differences may also be accounted for by the physiological measures used, and perhaps different variables may be better attuned to detecting underlying group differences.

The results support the overall idea that parental report of child behavior in relation to BIS and BAS was more accurate when judged against physiological measurement. Group differences between children with ADHD and children without ADHD were evident for results of physiological measurement. Children with ADHD showed increased behavioral activation during punishment conditions in addition to one of the reward blocks as indexed by decreases in change scores of PEP. When the relationship between self-report and physiological responding was further assessed by group status, control children and ADHD showed differing correlations between the measures. The correlation between parent report of BAS sensitivity and increases in changes scores in PEP during punishment was only evident for control children. This correlation
was not evident for children with ADHD because parent report of BAS sensitivity was correlated with a different physiological measure altogether. Parents of children with ADHD were more likely to report BAS sensitivity with increased mean SCL during reward conditions. This supports the idea that parent report of behavior was more closely related in control children when assessed through both self-report and physiological measures. These results demonstrate that differential report of behavior is important to consider in study design. Children within this sample did not report the assessed constructs as measured by changes in physiological response when these behaviors were elicited. Parents and children did not appear to report behaviors similarly and differences were found among control children and children with ADHD for the reporter of BIS and BAS in relation to physiological measurement of response among task condition.

Limitations and Future Directions

A major limitation of this study was sample size. The majority of participants were control subjects and a major focus on this study was around differences between children with ADHD and peers. The relatively small number of children with ADHD in comparison to controls may not provide conclusive evidence that cannot be generalized to all children and adolescents with ADHD. Also, in comparison to the amount of BIS/BAS questionnaire data, there was missing physiological data for the ADHD participants. The sample size of children with ADHD was further reduced for these analyses and does not provide strong evidence for comparison between groups. Also, the correlation coefficients appear to be significant when in fact they are not for the sample. This is most likely a product of reduction in data values to be analyzed for the ADHD sample. This lack of sufficient data may account for inconsistent and unexpected findings relative to the literature reviewed.
Self-report questionnaires were utilized as a major predictor of BIS and BAS reactivity and as a comparison measure to physiological responding during task conditions. When using self-report measures, respondent bias is a consideration to account for in the results. In this study, BIS and BAS measures were completed by two reporters and investigating the correlation between these scores was an aim of this study. By obtaining multiple response assessments among two different reporters, it was of interest whether parent and child report would be similar overall and between groups. The ability to assess the behavior of the child from multiple perspectives can help to provide more accurate information about BIS and BAS reactivity.

The ability of parents to identify child behavior is important for daily interaction and throughout development, presenting implications for parents and children with ADHD. It has been proposed that deficits in the BIS and BAS systems are relevant to the psychopathology of ADHD in terms of externalizing and internalizing symptomology. The heterogeneity in symptoms for children with ADHD can create issues for parents when interacting with a child with this disorder. Parents who are aware of their child’s behavioral tendencies, by recognizing BIS and BAS sensitivity in actual behavioral responses, will be better adept at addressing the needs of their child and be able to help them in various daily contexts. The ability to identify a child’s behavior can benefit parents of children with ADHD and be essential to the process of treatment in regard to reinforcing appropriate behaviors through reward contingencies.
References


Appendix A

DSM-IV Diagnostic Criteria for ADHD

I. Either A or B:

A. Six or more of the following symptoms of inattention have been present for at least 6 months to a point that is inappropriate for developmental level:

Inattention

1. Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities.
2. Often has trouble keeping attention on tasks or play activities.
3. Often does not seem to listen when spoken to directly.
4. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions).
5. Often has trouble organizing activities.
6. Often avoids, dislikes, or doesn't want to do things that take a lot of mental effort for a long period of time (such as schoolwork or homework).
7. Often loses things needed for tasks and activities (e.g. toys, school assignments, pencils, books, or tools).
8. Is often easily distracted.
9. Is often forgetful in daily activities.

B. Six or more of the following symptoms of hyperactivity-impulsivity have been present for at least 6 months to an extent that is disruptive and inappropriate for developmental level:

Hyperactivity

1. Often fidgets with hands or feet or squirms in seat when sitting still is expected.
2. Often gets up from seat when remaining in seat is expected.
3. Often excessively runs about or climbs when and where it is not appropriate (adolescents or adults may feel very restless).
4. Often has trouble playing or doing leisure activities quietly.
5. Is often "on the go" or often acts as if "driven by a motor".
6. Often talks excessively.
Impulsivity

7. Often blurts out answers before questions have been finished.
8. Often has trouble waiting one's turn.
9. Often interrupts or intrudes on others (e.g., butts into conversations or games).

II. Some symptoms that cause impairment were present before age 7 years.

III. Some impairment from the symptoms is present in two or more settings (e.g. at school/work and at home).

IV. There must be clear evidence of clinically significant impairment in social, school, or work functioning.

V. The symptoms do not happen only during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder. The symptoms are not better accounted for by another mental disorder (e.g. Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder).

Based on these criteria, three types of ADHD are identified:

IA. ADHD, Combined Type: if both criteria IA and IB are met for the past 6 months

IB. ADHD, Predominantly Inattentive Type: if criterion IA is met but criterion IB is not met for the past six months

IC. ADHD, Predominantly Hyperactive-Impulsive Type: if Criterion IB is met but Criterion IA is not met for the past six months.
Appendix B

BIS/BAS Questionnaire for Child

For each statement below, please answer how true that statement is of you.

1 2 3 4 5 6 7
extremely quite slightly neither slightly quite extremely
untrue untrue untrue true nor true true true untrue

1. If I think something unpleasant is going to happen I usually get pretty worked up.

1 2 3 4 5 6 7

2. When good things happen to me, it affects me strongly.

1 2 3 4 5 6 7

3. When I see an opportunity for something, I get excited right away.

1 2 3 4 5 6 7

4. Even if something bad is about to happen, I am rarely nervous or fearful.

1 2 3 4 5 6 7

5. I worry if I think that I have done poorly at something.

1 2 3 4 5 6 7
6. I have few fears compared to my friends.

   1  2  3  4  5  6  7

7. When I want something, I go all out to get it.

   1  2  3  4  5  6  7

8. I feel pretty worried or upset when I think or know that somebody is angry at me.

   1  2  3  4  5  6  7

9. When I get something that I want, I feel energized.

   1  2  3  4  5  6  7

10. I act on the spur of the moment.

    1  2  3  4  5  6  7

11. When I am doing well at something, I love to keep at it.

    1  2  3  4  5  6  7

12. It would excite me very much to win a prize.

    1  2  3  4  5  6  7

13. Criticism or scolding hurts me quite a lot.

    1  2  3  4  5  6  7
14. When I want something, I rarely take no for an answer.

1 2 3 4 5 6 7

15. I will often do things for no reason other than that they might be fun.

1 2 3 4 5 6 7

16. I worry a lot about making mistakes.

1 2 3 4 5 6 7

17. I crave excitement and new sensations.

1 2 3 4 5 6 7

18. I am always willing to try something new if I think it will be fun.

1 2 3 4 5 6 7

19. I go out of my way to get something I want.

1 2 3 4 5 6 7

20. When I see something I want, I move on it right away.

1 2 3 4 5 6 7
### Appendix C

**BIS/BAS Questionnaire for Parent**

Please read each statement below and answer how true it is of your child.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
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<td>quite</td>
<td>slightly</td>
<td>neither</td>
<td>slightly</td>
<td>quite</td>
<td>extremely</td>
<td></td>
</tr>
<tr>
<td><strong>untrue</strong></td>
<td>untrue</td>
<td>untrue</td>
<td>untrue</td>
<td>true nor</td>
<td>true</td>
<td>true</td>
<td>true</td>
</tr>
</tbody>
</table>

1. If my child thinks something unpleasant is going to happen he/she usually gets pretty worked up.

   1 2 3 4 5 6 7

2. When good things happen to my child, it affects him/her strongly.

   1 2 3 4 5 6 7

3. When my child sees an opportunity for something, he/she gets excited right away.

   1 2 3 4 5 6 7

4. Even if something bad is about to happen, my child rarely seems to be nervous or fearful.

   1 2 3 4 5 6 7

5. My child worries if he/she thinks that he/she has done poorly at something.

   1 2 3 4 5 6 7
6. My child has few fears compared to his/her friends.

1 2 3 4 5 6 7

7. When my child wants something, he/she goes all out to get it.

1 2 3 4 5 6 7

8. My child feels pretty worried or upset when he/she thinks or knows that somebody is angry at him/her.

1 2 3 4 5 6 7

9. When my child gets something that he/she wants, he/she feels energized.

1 2 3 4 5 6 7

10. My child acts on the spur of the moment.

1 2 3 4 5 6 7

11. When my child is doing well at something, he/she loves to keep at it.

1 2 3 4 5 6 7

12. It would excite my child very much to win a prize.

1 2 3 4 5 6 7
13. Criticism or scolding hurts my child quite a lot.
   
   1 2 3 4 5 6 7

14. When my child wants something, he/she rarely takes no for an answer.
   
   1 2 3 4 5 6 7

15. My child will often do things for no reason other than that they might be fun.
   
   1 2 3 4 5 6 7

16. My child worries a lot about making mistakes.
   
   1 2 3 4 5 6 7

17. My child craves excitement and new sensations.
   
   1 2 3 4 5 6 7

18. My child is always willing to try something new if he/she thinks it will be fun.
   
   1 2 3 4 5 6 7

19. My child goes out of his/her way to get something he/she wants.
   
   1 2 3 4 5 6 7

20. When my child sees something he/she wants, he/she moves on it right away.
   
   1 2 3 4 5 6 7

BIS/BAS scales for children_parent version
Theresa H. McKim  
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Education:
B.S., Biobehavioral Health, The Pennsylvania State University, University Park, PA, 2010  
Minor in Psychology  
Honors in Biobehavioral Health  
Thesis Title: Comparing Psychophysiological and Self-Report Measures of BIS and BAS in Children With and Without ADHD  
Thesis Supervisor: Dr. Lisa Gatzke-Kopp

Research Experience:
Research Assistant in the Child Brain Development Lab, University Park, PA, 5/09- Present.  
• Assist Dr. Lisa Kopp with EEG, ECG, and EDA data collection
Research Assistant in the Human Electrophysiology Facility, University Park, PA, 1/09-5/09.  
• Assisted with collection EEG data.  
• Trained to apply the EEG net and run Netstation Program

Honors and Awards:
Health and Human Development College Marshal, The Pennsylvania State University, 05/10.
Evan Pugh Senior Scholar Award, The Pennsylvania State University, 04/10.
Dean’s List, The Pennsylvania State University, 12/06-Present.
The President’s Freshman Award, The Pennsylvania State University, 12/06- 5/07.
Professional Experience:

Centre Region Parks and Recreation Kid Venture Camp, State College, PA, 6/09-8/09.

- Worked as a summer camp counselor for kids ages 6 – 11.
- Planned and organized indoor and outdoor activities/games for small groups as well as for all campers according to weekly themes.

Marc A. Hirsh, MD P.C., Hanover, PA, 5/08-8/08.
- Worked in the doctor’s office filing medical records and answering the phone.
- Performed transcription of the dictation by the doctor.

Activities:

Secretary, Biobehavioral Health (BBH) Society, 1/09- Present.

Alumni Panel Group Liaison
- Work with alumni to learn more information about career options and develop networking skills.

Vice President, National Society of Collegiate Scholars (NSCS), 5/09-Present.

- Plan and organize the new member Induction Ceremony.
- Coordinate with the other officers to plan THON activities and promote new volunteer service opportunities.

Penn State Dance Marathon, 9/07-2/10.
- Raised money for pediatric cancer research.
- Helped to plan weekend Canning trips to raise money through our organization and promote involvement in THON.