PSYCHOPATHY AND RESTING STATE EEG (THETA/BETA)

IN ADOLESCENT OFFENDERS

by

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A DISSERTATION

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ABSTRACT

Psychopathy is a personality disorder that is underpinned by three factors including grandiose-manipulative, callous-unemotional, and daring-impulsive traits. Recently, researchers have turned to investigating the physiological correlates of psychopathy to more fully understand the etiology and neuronal functioning of the condition. However, few studies exist on the neurocorrelates of psychopathy within adolescent samples and little information is provided on the underlying dimensions of psychopathy. The aim of this study was to test neural functioning of 50 adolescents with varying degrees of psychopathic traits using EEG spectra analysis. Theta/beta ratio was examined in an 8-minute resting state task during which participants had their eyes-open (4 minutes) and eyes-closed (4 minutes). In addition, a go/no-go task paradigm was implemented to measure response inhibition which was indexed by percent error, mean response time, and post-error slowing. It was hypothesized that (1) total psychopathy scores and daring-impulsive (DI) subscale scores would be positively correlated with theta/beta ratio; (2) grandiose-manipulative (GM) and callous-unemotional (CU) subscale scores would be negligibly correlated with theta/beta ratio; (3) total psychopathy scores and DI subscale scores, would be negatively correlated with mean reaction time and post-error slowing on the go/no-go task; (4) GM subscale scores would be weakly positively correlated with mean reaction time and post-error slowing; and (5) CU subscale scores would be negligibly correlated with mean reaction time and post-error slowing on the go/no-go task. All study hypotheses were non-significant aside from one: total psychopathy scores were negatively correlated with post-error slowing on the go/no-go task.
Overall, the findings show that those with elevated psychopathic traits do not differ from those with low levels of psychopathic traits in terms of their neuronal functioning at least based on theta and beta waves readings during a common EEG resting state task. This is an interesting finding as the theta and beta waves have been key markers linked to other related externalizing psychiatric conditions (i.e., ADHD). These findings show a point of departure from research in ADHD literature. Rather, findings may indicate individuals higher in psychopathic traits show similar levels of regulatory behavior as non-psychopathic individuals as indexed by theta and beta waves, although they did show less behavioral modulation as evidenced by the lack of post-error slowing on the go/no-go task.
DEDICATION

“Science, my lad, is made up of mistakes, but they are mistakes which are useful to make, because they lead little by little to the truth.” -Anthony Doerr, “All the Light We Cannot See”

This dissertation is dedicated to my family, who have provided me with the support and encouragement I needed to tackle such a large project. Thank you for being my comedic relief throughout this process and instilling in me the courage and confidence to accomplish what I never thought I could. In addition, thank you to my partner, Thomas Van Dyke, for constantly giving me unconditional love and support. Last, but certainly not least, thank you to my best friends, Natalie Harrison and Marissa Stanziani, for providing me with so much love and laughter, and being there for me unconditionally through everything. I am truly blessed.
**LIST OF ABBREVIATIONS AND SYMBOLS**

<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>GM</td>
<td>Grandiose-Manipulative</td>
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<tr>
<td>CU</td>
<td>Callous-Unemotional</td>
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<td>DI</td>
<td>Daring-Impulsive</td>
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<td>RT</td>
<td>Reaction Time</td>
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<td>PE</td>
<td>Post-Error Slowing</td>
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<td>$a$</td>
<td>Cronbach’s alpha</td>
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<td>Pearson product moment correlation</td>
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<td>EEG</td>
<td>Electroencephalogram</td>
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<td>TBR</td>
<td>Theta/Beta Ratio</td>
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ACKNOWLEDGEMENTS

This research project would not have been possible without the efforts, support, and guidance of my colleagues, mentors, supervisors, friends, and family. I am pleased to have the opportunity to share my appreciation of them here. First, this project would not exist without the guidance of Dr. Randall Salekin, my committee chair and research mentor. He has encouraged me through learning new research processes and analysis techniques. In addition, he has been kind enough to indulge my debates about psychopathy and the field in general. I am very grateful to my committee members Dr. Lochman, Dr. Tomeny, Dr. Tullett, and Dr. Houser for giving me guidance and encouraging me. Thank you all for providing me with the necessary critical thinking and different perspectives to make this project a success. I would like to thank staff at the detention facility for accommodating my endless needs as data was collected.
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INTRODUCTION

Psychopathy is a serious personality disorder marked by a number of maladaptive interpersonal, affective, and behavioral traits including arrogance, superficial charm, glibness, deceitfulness, egocentricity, low remorse, shallow affect, impulsivity, and antisocial behavior (Cleckley, 1941; Hare, 1991). Psychopathy in childhood and adolescence has been associated with high-risk behavior, fearlessness, aggression, and antisocial behavior (Salekin, 2006; Salekin, 2016). Moreover, psychopathy in childhood is thought to be linked to shallow affect and attitudinal variables, such as having a low regard for others and being cold-hearted (Barker, Oliver, Viding, Salekin, & Maughan, 2011; Salekin, Leistico, Trobst, Schrum, & Lochman, 2005). Youth with psychopathic traits may have reward and punishment-processing deficits (Finger et al., 2008), may be more likely to initiate substance use (Kosson, Cyterski, Steuerwald, & Neumann, 2002), and may be more likely to experience difficulties with peers and family members (Forth & Mailloux, 2000). Because of the link between child psychopathic traits and later negative outcomes, including antisocial behavior, there is a press to increase our understanding of the etiology and treatment of psychopathy.

While there has been considerable research on the general topic of child psychopathy, there is relatively little research on the psychophysiological functioning of youth with psychopathic traits with almost all psychophysiological research conducted primarily with adult populations. Recently, researchers have turned their focus toward examining the neural performance of individuals with elevated psychopathic traits in order to better inform our understanding of the cognitive and affective processing of individuals high in psychopathic
traits. The purpose of the current study is to examine the relation between child psychopathy and EEG functioning in adolescents with psychopathic traits. Prior to outlining the current study objectives, the following sections briefly overview definitional and conceptualization issues, dominant etiological models, and past work testing the psychopathy and EEG relationship with a specific focus on spectra analyses.

**Conceptualization Issues in Child Psychopathy**

Hervey Cleckley (1941) first theorized in *Mask of Sanity* that psychopathy was a condition that affected individuals in both community and correctional settings. He provided illustrative case studies primarily of individuals housed within a psychiatric hospital. Although he delivered the clearest modern definition of psychopathy, he did not provide a systematic manner in which to assess the condition. Due to concerns regarding the accurate assessment of psychopathy, Robert Hare developed the Psychopathy Checklist and Psychopathy Checklist-Revised (PCL, Hare, 1980; PCL-R, Hare, 1991/2003). The development of the PCL was a significant stride forward with respect to our understanding of psychopathy as it allowed for the formal scientific investigation of the condition (Hare, 1980; PCL-R, 1991/2003). Shortly afterward, based on the theoretical work on psychopathy using adult populations, Forth, Hart and Hare (1990) began to adapt the PCL for scientific investigations with adolescents. Their landmark study demonstrated that psychopathy could be measured in an adolescent sample and that psychopathy scores were related to negative outcomes such as aggression. Subsequently, Frick and colleagues (1994) and Lynam (1997) developed measures of psychopathy for children.

As diagnostic measures were developed, early factor analytic research on psychopathy revealed that the condition was underpinned by two broad factors (Harpur, Hare, & Hakstian, 1989). The first factor included interpersonal/affective traits and was labeled Factor 1 (F1).
Interpersonal/affective trait items included glibness, superficial charm, grandiosity, pathological lying, manipulative, lack of remorse, shallow affect, callousness, and failure to accept responsibility for one’s actions. The second factor, labeled Factor 2 (F2) included impulsive behavior and social deviance such as need for stimulation, parasitic lifestyle, poor behavioral control, early behavioral problems, lack of goals, impulsivity, and irresponsibility (see also Hare, 1991/2003). Cooke and Michie (2001) conducted the first set of confirmatory factor analyses on the PCL, which yielded the truncated three-factor model of psychopathy. The three-factor model included Factor 1: interpersonal traits, Factor 2: affective traits, and Factor 3: behavioral/lifestyle traits (Cooke & Michie, 2001). Antisocial behavior was not included in the Cooke and Michie (2001) model. Notably, research on factor structure for psychopathy in child and adolescent samples has also shown support for a three-factor model (e.g., Dong, Wu, & Waldman, 2014; Frick, Bodin, & Barry, 2000).

The three factors measured by the Antisocial Process Screening Device include grandiose-manipulative (narcissism), callous-unemotional, and daring-impulsive (GM, CU, and DI, respectively) traits (Frick & Hare, 2001). The GM dimension includes items such as arrogance, superficial charm, lying, and manipulation (Salekin, 2016, 2017). Children high in GM traits are more likely to become involved in ringleader bullying, even more so than children high in DI or CU traits (Stellwagen & Kerig, 2013). Additionally, GM traits are positively correlated with aggressive behavior and negatively correlated with prosocial behavior, and GM traits were a predictor for delinquent and aggressive behavior but CU was not (Lau & Marsee, 2013; Lau, Marsee, Kunimatsu, & Fassnacht, 2011). The CU dimension includes factors such as being uncaring about the effects of one’s actions, shallow affect, and disregard for the feelings of others (Frick & White, 2008). Children high in CU traits are less sensitive to punishment and
often have delinquent peers (Fisher & Blair, 1998; Kimonis, Frick, & Barry, 2004).

Alternatively, the DI dimension of psychopathy is made up of characteristics including risky behavior, impulsivity, and sensation seeking and can be measured early in childhood years and is related to antisocial behavior (Salekin, 2016). There is evidence that when considering all three dimensions together they are strongly related to behavior problems (Andershed, Kohler, Eno Louden, & Hinrichs, 2008; Salekin, Andershed, Batky, & Bontemps, 2018).

While most research, particularly psychophysiological research, on psychopathy has examined the broader syndrome, it may be useful to separately examine the underlying dimensions. There have been studies supporting psychophysiological and biological correlates that differ by psychopathy factor. For example, individuals high in psychopathic traits have lower skin conductance in anticipation of aversive stimuli (Cheng, Hung, & Decety, 2012). There is also some evidence of lower amygdala functioning in youth high in psychopathic traits (White et al., 2012; Salekin, 2017). At the dimension level, deficits in fear are more closely related to interpersonally callous traits than impulsive traits (Benning, Patrick, & Iacono, 2005), but aberrant reward processing is more strongly related to DI and CU traits than GM traits (Salekin, 2017). In addition, there are attention-related event-related potentials (ERPs) that are correlated more strongly in some studies with certain factors of psychopathy. For example, P300 amplitude is negatively correlated with antisocial and impulsive behavior and unsuccessful psychopathy (Gao & Raine, 2009). Alternately, GM traits and successful psychopathy appear to be positively correlated with P300 amplitude (Gao et al., 2018). Overall, these more dimension-specific findings highlight the importance of not only studying the broader construct of psychopathy, but also its underlying dimensions, particularly when considering biological processes.
Etiological Theories of Psychopathy

A number of theoretical models of psychopathy have been posited (Patrick, 2018; Patrick, 2006; Cooke & Logan, 2018). These theoretical models have included biological and environmental perspectives. Although it is beyond the scope of this project to cover all theoretical models of psychopathy, several key biological theories will be highlighted in this section. Herbert Quay (1965) provided one of the first elaborative biological accounts of psychopathy centering his model on sensation seeking. Quay (1965) hypothesized that cortical hypoarousal, which in turn influenced sensation seeking behavior including risk-taking behaviors and that the cortical underarousal was associated with elevated psychopathic traits (Quay, 1965; see also Zuckerman, Eysenck, & Eysenck, 1978). Specifically, Quay argued that psychopathic children had an abnormality in their physiological reaction to sensory input which required a higher degree of sensory stimulation in order to obtain satisfaction. Because of this physiological difference pertaining to optimal stimulation, an extremely high degree of motivation is required to compensate for the drastic underarousal. Later, Quay (1977) discussed two specific pathways which could lead to psychopathy that were affected by the environment: 1) children’s sensation seeking behavior became aversive to parents resulting in parent-child interactions that were hostile inconsistent and rejecting; or 2) Children were less able to anticipate physical pain due to an underactive nervous system and thus punishment by parents was generally ineffective. Parents also withdrew from children after higher gradients of punishment were ineffective. While Quay’s theory is no longer widely referred to, newer models have emerged suggesting cortical hypoarousal observed in individuals with psychopathy is a consequence of emotional deficits, such as low fear or affective detachment, that can be explained by neural networks or specific brain anomalies (Blair, 2010; Fowles, 1980).
In recent years, two leading etiological theories of psychopathy have emerged: the low fear model and the response modulation hypothesis (RMH) (Smith & Lilienfeld, 2015). The low fear model of psychopathy proposes that an absence of fear is the core etiological factor that influences the development of psychopathy (Lykken 1957, 1995). Lykken (1995) proposed that the inability to experience fear in the same way as individuals low in psychopathic traits led to increased antisocial behavior, lack of guilt, and aberrant punishment processing. There has been empirical support for this theory with many studies finding that individuals high in psychopathic traits demonstrate a lower fear response measured by skin conductance, exhibit diminished responses in startle tasks, and do not experience anticipation before presentation of aversive stimuli (Lykken, 1995). The region of the brain responsible for the fear deficit was purported to be the amygdala (Patrick, 1994). Similarly, the violence inhibition model (VIM) and integrative emotional systems (IES) model have been dominant in child psychopathy research. In the VIM, Blair (2001), similar to Patrick et al. (1994), hypothesized that there is under-functioning of the amygdala in individuals high in psychopathic traits, which leads to deficits in the experience of fear processing and potentially fear-based learning. While the low fear model and violence inhibition models have been empirically supported in some studies, there are studies that have found contradictory evidence. For example, some research has shown that low levels of fear are unassociated with psychopathy total scores and the factor scores of psychopathy can show differing relations (see Smith & Lilienfeld, 2015).

Another dominant etiological theory for psychopathy is the Response Modulation Hypothesis (RMH; Gorenstein & Newman, 1980). RMH was formulated using animals with septal lesions in the brain, which contributed to disinhibited behavior. It was then studied in populations of individuals with attention deficit hyperactivity disorder (ADHD) and
psychopathy, disorders that are characterized by disinhibition (Smith & Lilienfeld, 2015). RMH posits that individuals high in psychopathy have difficulty switching attention to environmental cues when a reward is present or goal-oriented behavior is occurring (Newman, 1998). Thus, individuals high in psychopathic traits, according to RMH, have difficulty adjusting behavior when a “dominant response set” is present, often cued by reward, and do not give adequate attention to punishment cues (Newman, 1998). Essentially, this model hypothesizes that the deficit in psychopathy is cognitive in nature and there is bottlenecking of attention rather than a fear of punishment). This model would suggest that the deficit might be more related to the Prefrontal cortex, or the dorsolateral prefrontal cortex which are involved in set shifting. Despite some support for the RMH, a recent review has argued that there is little evidence that the deficit for psychopathy is strictly cognitive in nature and efforts to defend this position have been weak (Newman & Baskin-Sommers, 2016; Smith & Lilienfeld, 2015).

Currently, researchers are firmly divided into either the low-fear or RMH camp; however, it might be possible that low-fear, and therefore low limbic system activity generate resting state brain differences that impact the ability to consider both reward and punishment well. Alternately, resting state brain functioning may be somehow related to Quays arousal theory. With respect to the low fear model and RMH, it is also possible that the reward-motivated behavior is correlated with more baseline neuronal activity and that punishment learning is deficient because of low fear-based learning; moreover, there are likely subscales of psychopathy that correlate with top-down behavioral control to combat this deficit. Resting state EEG analysis could potentially identify resting-state “primers” for poor reward and punishment processing and provide missing information in understanding the progression of neuronal activity in psychopathy. Below, I provide information on EEG research as it pertains to psychopathy.
providing a brief history before turning to a specific task and form of EEG analyses, namely the Go/No-go task, and spectra analyses.

**Psychopathy and EEG Assessment**

Beginning as early as the 1940’s, researchers have studied psychopathy using electroencephalogram (EEG; Hill & Waterson, 1943). In more recent years, researchers have conducted studies examining psychopathy by utilizing EEG to determine if there are differences in neural processing of psychopathic versus non-psychopathic individuals; however, these studies are variable in quality and the findings equivocal (e.g., Kiehl, Bates, Laurens, Hare, & Liddle, 2006; Jutai, Hare, & Connolly, 1987; Raine & Venables, 1988). These studies have primarily been performed with adults and have examined alpha waves or various ERP components in relation to psychopathy. One type of task often implemented in these studies is the go/no-go task. The go/no-go task paradigm is a response inhibition measure in which an individual is asked to respond and withhold responses based on condition (Kiefer, Marzinzik, Weisbrod, Scherg, & Spitzer, 1998). This has been studied in psychopathy in conjunction with impulsivity and risky decision-making and is considered to be a task that could inform RMH (Newman & Kosson, 1986). Because of its relevance to RMH it will be incorporated in this study in order to understand the relationship between psychopathic traits, response inhibition, and resting state EEG frequencies. However, most relevant to the study is the spectra analyses. Reviewed below are several of the key findings garnered from resting state EEG studies with individuals with elevated psychopathic traits. The focus of this section is primarily on spectra analyses and will focus on two specific wave frequencies (e.g., theta and beta), the ratio between the two, and how they relate to psychopathic traits. I will define the specific waveforms and
explain how the relation between the two may be significant in terms of brain function and the psychopathic condition.

**Theta/Beta Ratio**

Theta waves are brain activity occurring at a frequency of 4-7 Hz (Massar, Kenemans, & Schutter, 2014). Theta is generated in several subcortical systems. Frontal theta activity is linked to activity in the anterior cingulate cortex (ACC), medial frontal gyrus, posterior cingulate cortex, and precuneus and is best measured at frontal, midline sites (Fz, Cz, and surrounding areas) on a traditional 10-24 EEG electrode map (di Michele, Prichep, John, & Chabot, 2005; Scheeringa et al., 2008; Womelsdorf, Johnston, Vinck, & Everling, 2010). Theta that is generated in this area is related to the subcortical septal-hippocampal system which is strongly implicated in motivational reinforcement learning and punishment sensitivity (Gray & McNaughton, 2000; Mitchell, McNaughton, Flanagan, & Kirk, 2008). Motivational reinforcement learning is the ability to learn from positive reinforcement. Punishment sensitivity is the ability to recognize punishment and change behavior accordingly. Theta activity has been positively correlated with the tendency to make risky decisions (Massar et al., 2014), but has not been studied directly in conjunction with psychopathic traits. However, related traits such as impulsivity, risky decision-making, and reward-sensitivity present in antisocial behavior and psychopathy have been studied frequently in non-psychopathic populations.

There is some psychophysiological evidence to show that individuals higher in psychopathic traits are more reward-sensitive (Wallace, Malterer & Newman, 2009). Increased theta activity has been positively correlated with reward-motivated learning, but not punishment related learning, which might contribute to impulsive behavior (Masser et al., 2014). These findings indicate that resting state theta activity may be related to the propensity to pursue
rewards, but not avoid punishments. In a study by Massar, Rossi, Schutter, and Kenemans (2012), resting state theta activity was correlated with reward/loss ERPs in the Iowa Gambling Task. Some research has found that individuals high in psychopathy tend to be reward seeking and poorer in decision-making (Glenn, Raine, Yaralian, & Yang, 2010). The above studies provide evidence that theta activity is positively correlated with risky behavior and aberrant reward processing, which is also present in psychopathy.

Aside from early studies examining alpha density, resting beta wave activity has been the only other wave activity studied in conjunction with psychopathy. Beta waves are brain activity between 12.5 and 30 Hz (Meier, Perrig, & Koenig, 2014) indicative of cortical-subcortical interactions, alertness, and brain arousal. Particularly, beta activity is thought to be indicative of activity in GABA interneurons and is cortically spread over the surface of the head in most studies (Massar, Kenemans, & Schutter, 2014). Beta activity is thought to be increased in central locations in the brain in individuals diagnosed with antisocial personality disorder compared to offenders without an ASPD diagnosis (Calzada-Reyes & Alvarez-Amador, 2009); however, to date only one study has examined beta waves in relation to psychopathic traits and these findings have not been replicated (i.e., Calzada-Reyes et al., 2013).

In addition to considering theta and beta alone, recent research has suggested that considering the ratio between theta and beta could be important in understanding clinical disorders, particularly disorders in which impulsivity is a symptom. Theta/beta ratio is computed by taking total theta power spectra and dividing that by total beta power spectra in order to create the ratio. Therefore, higher TBR indicates more theta activity combined with less beta activity occurring in the brain. Theta and beta activity are generated in separate systems in the brain, as noted in previous sections, but the link between them is unique in predicting risk-taking behavior.
(Schutter & van Honk, 2005). This means that the two frequencies considered together give different information than considered separately.

To elaborate, Schutter and van Honk (2005) hypothesized that smaller theta/beta ratios might be indicative of frontal cortical top-down regulation of subcortical structure-driven reward motivated behavior, which implies that there is better ability to regulate behavior. In the past, theta/beta ratio has been thought to be indicative of hypoarousal; however, in some recent research, theta/beta levels have been related to reward motivation. Specifically, individuals with high resting state theta/beta ratio were slower to learn and identify advantageous decks in the Iowa Gambling Task (Schutter & van Honk, 2005). These findings may indicate that high theta/beta ratio is associated with poor reward and punishment learning and positively associated with impulsive behavior. Relatedly, Schutter and van Honk (2005) found that a larger theta/beta ratio predicted increased approach-driven and less risk-aversive motivated decision-making. As can be seen, theta beta ratio is an important potential consideration in examining psychopathy.

**Go/No-go**

To measure top-down behavioral regulation, some studies have employed a go/no-go task (Newman & Kosson, 1986) and also measured EEG to the task. The Go/No-go task requires participants respond to stimuli then withhold responses on 20% of trials. For example, a participant is required to respond to “x” and “o” but withhold responses when the letters change to a checker pattern. As a measure of impulsivity, some studies have used percent error and reaction time on the Go/No-go task. However, there is also much research on post-error slowing as an indicator of behavioral regulation (Laming, 1968) although some also believe it may be related to affective processing of errors. Post-error slowing, which is slowing in reaction time after an error is made, has been purported as an effect of cognitive control. In early research,
post-error slowing was correlated with increased accuracy (Laming, 1968). Additionally, research in psychopathy examining post-error slowing has found that post-error slowing was related to unconscious error processing, much the same as Error-Related Negativity (ERN; Brazil et al., 2009), but not related to conscious error processing such as Positive Error (Pe; Brazil et al., 2009) and post-error signaling. This indicates that individuals high in psychopathy may have the same unconscious processing of errors, but differ in emotional processing of errors, particularly in emotionally-valenced trials. Therefore, in this study, accuracy, reaction time, and post-error slowing will be used as behavioral indicators of impulsivity, cognitive control, and behavioral adaptation. This type of trait impulsive behavior may be important in further understanding dimensions of psychopathy and their relationship to theta/beta (see Massar, Rossi, Schutter, & Kenemans, 2012).

A Related Disorder (ADHD)

There has been research utilizing EEG to identify subgroups of children diagnosed with ADHD. In one study (Clarke et al., 2011), four subgroups were identified within a sample of ADHD-diagnosed children. The four EEG subgroups were characterized by a) elevated beta activity, b) elevated theta with deficiencies of alpha and beta, c) elevated slow wave with less fast wave activity, d) elevated alpha (Clarke et al., 2011). While these findings have not been replicated, it is important to note that EEG mapped well onto behavioral symptoms of ADHD (Clarke et al., 2011). Since some consider psychopathy and ADHD to have some overlap, especially in terms of the lifestyle impulsivity aspect of psychopathy, the theta beta ration may have some relevance to psychopathy. This may generalize to the rationale that different subgroups of psychopathy present different neurologically. Specifically, increased theta/beta ratio is correlated with impulsive and reward-driven behavior, which maps directly onto the DI
dimension of psychopathy. Individuals high in DI traits are more likely to engage in risky behavior and to be bolder in their actions. Due to this symptomatic overlap with other externalizing disorders, such as ADHD, it could be that DI would be related to TBR much in the same way. Alternately, if DI traits are somehow different than ADHD traits this effect may not be present, but the broader construct might also be related to thee anomalies.

The Current Study

This study aims to extend the literature presented above to an adolescent offender population where psychopathic traits are more prevalent. In sum, theta/beta ratio is related to impulsivity, aberrant reward processing, the inability to modulate behavior when reward is present, and potentially deficient punishment learning in non-psychopathic samples. Because these behavioral symptoms are correlated with psychopathic symptoms, it is hypothesized that (1) total psychopathy scores will be positively correlated with theta/beta ratio and positively related to number of errors on the go/no-go task, but negatively related to mean response time and post-error slowing on the go/no-go task. At a dimension level, it is hypothesized that (2) GM traits will be negligibly correlated with theta/beta ratio and number of errors on the go/no-go task, and weakly positively correlate with mean reaction times and post-error slowing on the go/no-go task. This hypothesis is based on past research examining GM traits’ relationships with more thoughtful (planning) reward-seeking behavior. It is hypothesized that (3) there will be a negligible correlation between CU traits and theta/beta ratio and a negligible correlation to number of errors, mean reaction time, and post-error slowing on the go/no-go task. Lastly, it is hypothesized that (4) DI traits will positively correlate with theta/beta ratio and number of errors on the go/no-go task, but will negatively correlate with mean reaction time and post-error slowing on the go/no-go task. These hypotheses are based on previous research that suggests that
theta/beta ratio is higher in individuals with aberrant reward processing and punishment sensitivity deficit. The psychopathy literature suggests that those individuals high in especially DI traits demonstrate these same behaviors related to reward sensitivity. In addition, while there is an abundance of evidence that CU traits are correlated with aberrant punishment processing, there is only limited evidence that CU traits are correlated with reward-seeking behavior and those findings are not consistent. While some researchers have found CU traits are correlated with approach-motivation for reward, others have found the opposite.

*Figure 1: Map of dimensions of psychopathy and localized theta and beta analysis*

<table>
<thead>
<tr>
<th>Grandiose-manipulative dimension activation</th>
<th>Callous-unemotional dimension activation</th>
<th>Daring-impulsive dimension activation</th>
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*Note: Red: positive correlation and blue: negative correlation. All frontal activation is indicative of theta activity; central activation indicates beta activity*

In addition to localized hypotheses about the dimensions of psychopathy and theta and beta generation, theta/beta ratio will be calculated based on power density across the four-minute eyes opened and eyes closed conditions. While there are theoretical bases for theta generation being highest at frontal sites, no such theories for beta-localized generation exist. In order to combat an error in predicting sites that will have equitable beta density when compared to theta, both theta and beta sites will be chosen upon viewing power source density. As exploratory analyses, all individual sites and their relationship to psychopathic traits will be tested.
In addition, total activation across sites during the task will be computed with sLORETA. sLORETA is an analysis software that runs advanced algorithms to identify the area of the brain with the most activation based on given parameters, which in this case will be the frequencies of theta and beta. sLORETA allows for a precise and accurate identification of localization and will provide a more advanced analysis of activation than the one presented in the section above. It is hypothesized that theta will be highest at frontal sites and beta will be highest at central sites. In addition, it is tentatively hypothesized that psychopathy total scores will correlate with positively with theta/beta ratio and number of errors on the go/no-go task, but negatively with mean reaction time and post-error slowing on the go/no-go task. While it is expected that the dimensions may correlate differently from one another, the sample in which the study was conducted are inherently high in antisocial and impulsive behavior. Because of this, it is hypothesized that psychopathy total scores will positively correlate with theta/beta ratio, but that relationship will be largely driven by DI traits given its purported connection to ADHD.

The data will be analyzed separately based on resting state condition, due to findings from Barry, Clarke, Johnstone, Magee, and Rushby (2007) found that there are significant decreases in power of beta, theta, and delta from eyes-open compared to eyes-closed conditions, while the opposite is true of alpha. There is evidence that eyes-open conditions might be more indicative of cortical baseline activation and eyes-closed conditions more indicative of cortical baseline arousal. Pribram and McGuinness (1975) differentiate baseline arousal and activation as the following: baseline arousal is the brain’s resting state in which it is preparing for incoming stimuli; baseline activation is when the brain is processing stimuli. Therefore, eyes-closed conditions are indicative of a lower baseline functioning than eyes-open, where visual stimulus is
present. While the conditions will be analyzed separately, the hypotheses above will remain the same for each condition.
METHODS

Participants

Participants for the current study were 50 male youth ranging in age from 13-18 years old, with a mean age of 15.17 (SD = 1.06) and a mean grade level of 8.98 (SD = 1.00) recruited from a juvenile correctional/residential facility in a southeastern state. The sample was 76% African-American, 16% Caucasian, 4% Multiracial, 2% Asian/Pacific Islander, and 2% Hispanic/Latino. Youth had committed a variety of index crimes ranging from more serious offenses that resulted in being held in higher security settings to less severe crimes resulting in less restrictive housing placements within the broader residential facility. Of those who reported their offense in the demographic questionnaires (n = 41), over one-third (34.1%) had violated probation, 14.6% had committed a robbery, and the remaining percentage had committed various crimes such as theft, receiving stolen property, various drug offenses, manslaughter, and murder.

For recruitment, juveniles were asked to participate, but there was no compensation given for participation. To avoid subtle coercion, it was emphasized that their participation did not affect their time at the facility in any way (i.e. shorten their sentence, treatment by staff, special privileges, etc.) and that lack of participation would not negatively affect their stay at the facility in any way. The researcher also explained in detail the confidentiality of the study in that none of their responses or results would be shared with any other person (probation officers, staff, case managers, parents, etc.). However, the participants were informed of limitations to confidentiality. If they indicated to the researcher the intent to harm themselves/someone else or
informed the researcher of any physical or sexual abuse, the researcher was legally bound to report this. In addition to assent to participate in the study, participants were given an assent form for the researcher to access their detention records to corroborate offense and days in custody. Participant assent was obtained during the first study session.

Because of the EEG component of the study, participants were excluded if they were left-handed. This is simply due to potential hemispheric differences between right and left-handed individuals. Participants were also excluded if the researchers could not accurately place the electrode on the head due to hairstyle. These were the only two exclusion criteria of the study. It should be noted that any excluded individuals were not part of those counted toward total sample size ($N = 50$); they were included in data collection per facility policy, but excluded from the current study. Participants were given several questionnaires before beginning the study. They completed a demographics questionnaire in which they indicated their age, gender, ethnicity, and current grade (or last grade completed if they were no longer enrolled in school). They were asked to indicate (in the number of days) how long they had been in custody. Participants then completed all self-report measures. For the purposes of this study, only the APSD will be overviewed, as it is the only measure specific to the data analyses.

**Measures**

**Antisocial Process Screening Device.** (APSD; Frick & Hare, 2001). The APSD was originally developed for use by parents and teachers to rate children in psychopathic traits; however, this study used the self-report version for children and adolescents. The measure has 30 items rated on a three-point scale (0 = not at all true, 1 = sometimes true, 2 = definitely true). The measure was developed based on the PCL-R (Hare, 1991) with each question directly assessing an item from the PCL-R. The APSD is composed of 3 subscales: grandiose-manipulative (GM),
daring-impulsive (DI), and callous-unemotional traits (CU). The measure was designed to assess for interpersonal, affective, and impulsivity traits of psychopathy. The APSD has been found to have generally good reliability and validity in several studies ($r = -0.38, -0.41, p < 0.01$) (Kruh, Frick, & Clements, 2005; Loney, Frick, Clements, Ellis, & Kerlin, 2003).

**Instruments**

**Electroencephalograph.** The EEG amplifier (3000 series) that was used is a product of Avatar EEG Solutions, Inc. based in Calgary, Alberta, Canada. The amplifier has eight channels, a ground channel, and a single-ended reference channel. The eight biopotential measurement channels have 500 Hz storage. The amplifier has a 24-bit sample size, gain 12, and range 750 mVpp. The recordings are stored on a removable microSDHC card. The amplifier is small and portable, which allowed the researcher to easily transport it to the juvenile detention facility. The eight sites that were recorded were the right earlobe, Fp1, F3, F4, Cz, Pz, P3, and P4. These sites are located on the frontal and parietal lobes. The reference channel was connected to the left earlobe. The ground electrode was connected at the AFz site. The data was referenced online. After recording, the data was re-referenced to the right earlobe, so that all data was referenced to an average of the two ear lobes.

**DMDX.** DMDX is a stimulus presentation program and was used to administer tasks while the EEG was recording. DMDX records the latency of the responses and the percent error of each task for each participant. The EEG tasks used for this study were a baseline measure and a go/no-go task. During the baseline measure, the participant read instructions on the screen to close or open their eyes. For the eyes opened condition, the participant was instructed to look at the center of the screen where “***” was displayed. Each condition was repeated four times, so there was a total of eight minutes of data collection. Eight minutes of data collection has been the
norm since earliest spectra analyses were conducted (Tomarken et al., 1992). Eight minutes provides adequate internal consistency reliability, and even time frames as short as two minutes are similarly reliable (Coan & Allen, 2004; Coan, Allen, & Harmon-Jones, 2001). The eyes-open and eyes-closed conditions were presented in random order.

After completing the baseline task, the participants completed a go/no-go task in which they were asked to continuously respond to stimuli. The go/no-go task is a trait impulsivity task that employs a target stimulus that overtly requires response and a non-target that requires the participant to withhold response (Kiefer, Marzinzik, Weisbrod, Sherg, & Spitzer, 1998). The go/no-go is used to measure response inhibition. In this go/no-go, a series of white x’s and o’s were presented in random order. The respondents were asked to click left shift if a white “x” was presented and right shift if a white “o” was presented. On trials where the white “x” or “o” changed to a checker pattern, the participant was asked to withhold response. Approximately 20 percent of the trials were withhold trials. The participants completed a practice round in which they were given feedback for their answers.

Procedure

The study was divided into two different sessions. Each session lasted one and a half to two hours. To begin the first session of the study, the participant completed a demographics questionnaire, a questionnaire about previous offenses, and a questionnaire about time spent in custody. They then were asked to complete the self-report measures. The researcher explained the instructions for each measure. If the participant did not understand an item on one of the assessments, the researcher explained the meaning. If a participant was unable to comprehend the questionnaires, a researcher verbally administered the questionnaires.
In the second part of the study, the EEG tasks were administered. The participant was located in a classroom in the detention facility with only the researcher and participant present. The laptop for responses on the DMDX tasks was on the participant’s desk, and the researcher sat behind the participant with a master laptop that controlled the DMDX tasks. The researcher was out of the direct line of sight of the participant. The participant was measured for cap size and the researcher then set up the electrode sites. The reference electrodes on the ear lobes were set up first. A conductance gel was used (Abralyte) to create good conductance from the skin to the electrode after the skin was degreased with alcohol and exfoliated. The researcher used a separate impedance monitor to ensure that the impedance for each site was below 10 K. This allowed each channel to get a clear reading with very limited noise. After all eight channels (the right earlobe, Fp1, F3, F4, Fz, Pz, P3, and P4) were set up, the participant was given general instructions for completing the computer tasks. The participant was asked to sit as still as possible and remain quiet during the tasks. However, they were allowed to ask questions as needed during the instructions for the tasks before recording began. To reduce distraction while the participant was completing the tasks, a white-noise machine (Dohme) was run. The participants then completed the baseline-recording task and go/no-go task as part of a larger battery of tasks.
DATA ANALYSIS

The EEG data was cleaned and reduced before data analysis took place. The data was re-referenced to the right earlobe. Following re-referencing, the data was visually inspected for artifact and all artifacts were manually removed. If more than 30 seconds (or half the trial) was contaminated with artifact, that trial was removed from the overall analyses. The data was low pass filtered at a rate of 35 Hz, a typical filter used in other theta-beta ratio research (Putnam et al., 2010). Power spectra of theta (4-7 Hz) and beta (12-30 Hz) were calculated using Fast Fourier Transforms method. Power spectrum density was calculated for each site recorded individually.

Any participants with missing EEG data were not included in analyses (missing data could be due to equipment malfunction, problems with transferring data, or problems with participant completion, etc.). Missing items on self-report measures were left blank during analysis; however, if more than a one third of items were missing, that participant was excluded from analysis. These exclusion criteria resulted in the following analyses being conducted with a subsample \( n = 38 \). Total psychopathy scores and dimension scores were calculated. Total number of errors, reaction time, and post-error slowing from the go/no-go task were also calculated. Post-error slowing has been traditionally defined as “Post-Error Slowing = Post-Error Mean RT – Post-Correct Mean RT” (Rabbitt & Rogers, 1977). This is the formula that was used in the current study. The data was examined for skew and kurtosis before the main analyses were conducted.
Following the preparation of the data, statistical analyses were conducted under the following plan. First, descriptive statistics were run for all the study variables. Second, after power spectrum density was calculated, each site was correlated with psychopathy dimension scores in order to conduct a preliminary site localization analysis. This helped in determining whether different areas of the brain were implicated in the different dimensions. Third, total scores and dimensions scores were correlated with the theta and beta band activity. Fourth, after preliminary site analyses, a sLORETA analysis was conducted to understand broad activation patterns across the eyes open and eyes closed conditions. sLORETA was used to identify which sites were most dense in the power spectra analysis. This type of analysis is a statistical inference for localization of brain activity based upon images of standardized current density (Pascual-Marqui, 2002). This is much further advanced than previous EEG localization methods and has a zero-localization error (Pascual-Marqui, 2002). Essentially, sLORETA analyzes activity at each site on the scalp and pictorially generates the highest activation map depending on the parameters of activation. The site-level activation was computed for theta and beta activity separately. Because theta is frontally generated by frontal subcortical structures such as the anterior cingulate cortex, and beta is more spatially variable in its generation, the localization of the two power spectra were identified separately.

In addition to theta and beta activity, the ratio of theta activity to beta activity was computed for each participant by dividing slow wave density by fast wave density (theta/beta). Total theta and beta were analyzed separately based on condition of eyes-open or eyes-closed (Arns, Conners, & Kraemer, 2011). There is evidence that eyes-closed conditions may be more indicative of baseline arousal, while eyes-open conditions are indicative of cortical baseline activation (Barry et al., 2007). There is evidence that power spectra change based on whether the
eyes are open or closed, and that the two conditions are not equivalent measures of baseline activity; therefore, it is recommended to analyze both if available, but to do so separately in order to fully understand differences in baseline arousal and activation (Barry et al., 2007). Therefore, for the purposes of this study, both eyes-open and eyes-closed conditions were analyzed separately.

In order to be sure that there was enough variance in psychopathy scores in our sample to be useful in conducting further analyses, preliminary analyses were conducted in order to calculate the range and distribution of the traits. For total psychopathy scores, the $M = 16.85$ ($SD = 5.00$; Range = 9.00 – 32.00); for GM dimension scores, the $M = 5.12$ (SD = 2.49, Range = 1.00 – 13.00); for CU dimension scores, $M = 5.63$ ($SD = 2.54$; Range = 2.00 – 13.00); for DI dimension scores, $M = 5.98$ ($SD = 1.82$; Range = 2.00 – 10.00). In addition, normality was tested for psychopathy total scores using Shapiro-Wilk Test. The Shapiro-Wilk test was insignificant, meaning that the data was normally distributed. The means for total psychopathy and subscale scores are similar to other research with samples consisting of juvenile offenders (Lee, Vincent, Hart, and Corrado, 2003; Vitacco, Rogers, and Neumann, 2003).
RESULTS

Descriptive Statistics

The Means (M) and Standard Deviations (SDs) were calculated for all study variables. See above Data Analysis Plan or Table 1 below for total psychopathy scores and dimension means and standard deviations. For the go/no-go task, mean percent accurate was 92.74 (SD = 10.58), mean reaction time was 937.66 ms (SD = 336.78 ms), and mean post-error slowing was 23.85 ms (SD = 230.48 ms).

For theta activity, the mean total theta power spectral density for the eyes open condition was -52.18 (SD = 1.36) and was -51.91 for the eyes closed condition (SD = 1.57). For beta activity, the mean total beta power spectral density was -45.24 (SD = 1.75) for the eyes open condition and -44.93 (SD = 1.69) for the eyes closed condition. The mean TBR for eyes open condition was 1.15 (SD = 0.02) and mean TBR for eyes closed condition was 1.16 (SD = 0.02).

Table 1: Descriptive Statistics for Study Variables

<table>
<thead>
<tr>
<th>Study Variable</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>APSD Total</td>
<td>9.00</td>
<td>32.00</td>
<td>16.85</td>
<td>5.00</td>
</tr>
<tr>
<td>GM Subscale</td>
<td>1.00</td>
<td>13.00</td>
<td>5.12</td>
<td>2.49</td>
</tr>
<tr>
<td>CU Subscale</td>
<td>2.00</td>
<td>13.00</td>
<td>5.63</td>
<td>2.54</td>
</tr>
<tr>
<td>DI Subscale</td>
<td>2.00</td>
<td>10.00</td>
<td>5.98</td>
<td>1.82</td>
</tr>
<tr>
<td>Go/NoGo Percent Accuracy</td>
<td>43.23</td>
<td>100.00</td>
<td>92.74</td>
<td>10.58</td>
</tr>
<tr>
<td>Go/NoGo Reaction Time</td>
<td>359.82</td>
<td>1909.66</td>
<td>937.64</td>
<td>336.78</td>
</tr>
<tr>
<td>Go/NoGo Post-Error Slowing</td>
<td>-612.96</td>
<td>980.34</td>
<td>23.85</td>
<td>230.48</td>
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<td>-54.59</td>
<td>-48.67</td>
<td>-52.18</td>
<td>1.36</td>
</tr>
<tr>
<td>Theta (eyes closed)</td>
<td>-55.29</td>
<td>-48.98</td>
<td>-51.91</td>
<td>1.57</td>
</tr>
<tr>
<td>Beta (eyes open)</td>
<td>-48.24</td>
<td>-40.57</td>
<td>-45.24</td>
<td>1.75</td>
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<tr>
<td>Beta (eyes closed)</td>
<td>-48.35</td>
<td>-41.50</td>
<td>-44.93</td>
<td>1.69</td>
</tr>
<tr>
<td>TBR (eyes open)</td>
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<td>1.20</td>
<td>1.15</td>
<td>0.02</td>
</tr>
<tr>
<td>TBR (eyes closed)</td>
<td>1.11</td>
<td>1.19</td>
<td>1.16</td>
<td>0.02</td>
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</table>
Mean power spectral density for theta and beta was calculated by site location and condition. Mean theta activity in the eyes open condition at F4 was -53.37 ($SD = 2.00$), Fz was -51.70 ($SD = 2.04$), P4 was -51.83 ($SD = 2.10$), Pz was -52.43 ($SD = 2.06$), and P3 was -51.58 ($SD = 2.02$). Mean theta activity in the eyes closed condition at F4 was -53.53 ($SD = 1.99$), Fz was -51.93 ($SD = 2.31$), P4 was -51.25 ($SD = 2.31$), Pz was -51.84 ($SD = 2.06$), and P3 was -50.98 ($SD = 2.13$). Mean beta activity in the eyes open condition at F4 was -46.78 ($SD = 2.08$), Fz was -45.11 ($SD = 2.10$), P4 was -44.68 ($SD = 2.33$), Pz was -45.26 ($SD = 2.23$), and P3 was -44.35 ($SD = 2.36$). Mean beta activity in the eyes closed condition at F4 was -46.76 ($SD = 1.91$), Fz was -45.13 ($SD = 2.27$), P4 was -44.09 ($SD = 2.01$), Pz was -44.85 ($SD = 2.08$), and P3 was -43.84 ($SD = 2.18$).

After examining mean power spectral density for theta and beta activity by site, sites Fz and P3 were chosen to calculate total theta power source density and theta/beta ratio. Additionally, sites P3 and P4 were chosen to calculate total beta power source density and theta/beta ratio.

**Total Psychopathy**

It was hypothesized that total psychopathy scores would be positively correlated with theta/beta ratio and positively related to number of errors on the go/no-go task, but negatively related to mean response time and post-error slowing on the go/no-go task. Total psychopathy scores were not significantly correlated with total theta activity in the eyes open or eyes closed conditions ($r = -0.10, p = 0.57; r = 0.05, p = 0.77$). Total psychopathy scores were not significantly correlated with total beta activity in the eyes open or eyes closed conditions ($r = -0.03, p = 0.85; r = 0.01, p = 0.95$). Total psychopathy scores were not significantly correlated with TBR eyes open or eyes closed conditions ($r = 0.02, p = 0.91; r = -0.03, p = 0.84$). Total
psychopathy scores were not significantly correlated with percent accuracy on the go/no-go task ($r = 0.02, p = 0.93$) or reaction time on the go/no-go task ($r = 0.01, p = 0.98$). Total psychopathy scores were significantly negatively correlated with post-error slowing on the go/no-go task ($r = -0.37, p = 0.04$).

Table 2: Descriptive Statistics for Theta and Beta Activity by Site Location

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Theta Eyes Open</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_z$</td>
<td>-57.14</td>
<td>-48.51</td>
<td>-53.3733</td>
<td>1.99854</td>
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<tr>
<td>$F_3$</td>
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<td>-45.93</td>
<td>-51.7045</td>
<td>2.03550</td>
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<tr>
<td>$P_4$</td>
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<td>-46.92</td>
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<tr>
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<tr>
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<td>-45.83</td>
<td>-51.5811</td>
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<tr>
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<td>-41.06</td>
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<tr>
<td>$F_3$</td>
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<tr>
<td>$P_4$</td>
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<td><strong>Theta Eyes Closed</strong></td>
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<tr>
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<td><strong>Beta Eyes Closed</strong></td>
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<tr>
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<tr>
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<td>-37.57</td>
<td>-43.8430</td>
<td>2.17953</td>
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</table>

Grandiose-Manipulative Traits

It was hypothesized that GM traits would be negligibly correlated with theta/beta ratio and number of errors on the go/no-go task, and weakly positively correlate with mean reaction
times and post-error slowing on the go/no-go task. Grandiose-Manipulative Traits subscale scores were not significantly correlated with total theta activity in the eyes open or eyes closed conditions ($r = -0.17, p = 0.33; r = -0.09, p = 0.60$). GM subscale scores were not significantly correlated with total beta activity in the eyes open or eyes closed conditions ($r = -0.11, p = 0.54; r = -0.05, p = 0.78$). GM subscale scores were not significantly correlated with TBR eyes open or eyes closed conditions ($r = -0.04, p = 0.83; r = 0.03, p = 0.88$). Grandiose-Manipulative Traits subscale scores were not significantly correlated with percent accuracy on the go/no-go task ($r = -0.14, p = 0.45$), reaction time on the go/no-go task ($r = -0.11, p = 0.56$), and post-error slowing on the go/no-go task ($r = -0.18, p = 0.32$).

**Callous-Unemotional Traits**

It was hypothesized that there would be a negligible correlation between CU traits and theta/beta ratio and a negligible correlation to number of errors, mean reaction time, and post-error slowing on the go/no-go task. Callous-Unemotional Traits subscale scores were not significantly correlated with total theta activity in the eyes open or eyes closed conditions ($r = 0.03, p = 0.88; r = 0.17, p = 0.31$). CU subscale scores were not significantly correlated with total beta activity in the eyes open or eyes closed conditions ($r = 0.07, p = 0.68; r = 0.14, p = 0.40$). CU subscale scores were not significantly correlated with TBR eyes open or eyes closed conditions ($r = 0.09, p = 0.58; r = 0.04, p = 0.81$). Callous-Unemotional Traits subscale scores were not significantly correlated with percent accuracy on the go/no-go task ($r = 0.17, p = 0.35$), reaction time on the go/no-go task ($r = 0.16, p = 0.38$), and post-error slowing on the go/no-go task ($r = -0.33, p = 0.06$).
**Daring-Impulsive Traits**

It was hypothesized that DI traits would positively correlate with theta/beta ratio and number of errors on the go/no-go task, but would negatively correlate with mean reaction time and post-error slowing on the go/no-go task. Daring-Impulsive Traits subscale scores were not significantly correlated with total theta activity in the eyes open or eyes closed conditions ($r = -0.07, p = 0.67; r = -0.004, p = 0.98$). DI subscale scores were not significantly correlated with total beta activity in the eyes open or eyes closed conditions ($r = -0.05, p = 0.78; r = -0.11, p = 0.51$). DI subscale scores were not significantly correlated with TBR eyes open or eyes closed conditions ($r = -0.04, p = 0.84; r = -0.17, p = 0.31$). Daring-Impulsive Traits subscale scores were not significantly correlated with percent accuracy on the go/no-go task ($r = -0.04, p = 0.81$), reaction time on the go/no-go task ($r = -0.10, p = 0.60$), and post-error slowing on the go/no-go task ($r = -0.24, p = 0.18$).

To further explore sensation-seeking and their relationship to neural correlates, the DI subscale was broken down further into impulsive and sensation seeking items. Items included in the daring/sensation-seeking were items 1, 9, and 13 which stated “I blame others for my mistakes,” “I get bored easily,” and “I do risky or dangerous things.” The daring variable was not correlated with total theta activity in the eyes open or eyes closed condition ($r = 0.13, p = 0.45; r = 0.18, p = 0.29$). The daring variables were also not correlated with total beta activity in the eyes open or eyes closed condition ($r = 0.13, p = 0.45; r = 0.09, p = 0.59$). The daring variables were also not correlated percent accuracy ($r = -0.14, p = 0.45$), reaction time ($r = -0.04, p = 0.83$), or post-error slowing on the go/no-go task ($r = -0.05, p = 0.80$).
Table 3: Pearson Correlations among Psychopathy, Go/No Go, and Spectra Activation

<table>
<thead>
<tr>
<th></th>
<th>APSD Total</th>
<th>GM</th>
<th>CU</th>
<th>DI</th>
<th>Daring Items</th>
<th>SS RT</th>
<th>SS Acc</th>
<th>SS PES</th>
<th>Theta¹</th>
<th>Beta¹</th>
<th>TBR¹</th>
<th>Theta²</th>
<th>Beta²</th>
<th>TBR²</th>
</tr>
</thead>
<tbody>
<tr>
<td>APSD Total</td>
<td>--</td>
<td>0.69**</td>
<td>0.71**</td>
<td>0.63**</td>
<td>0.44**</td>
<td>0.01</td>
<td>0.02</td>
<td>-0.37*</td>
<td>-0.10</td>
<td>-0.03</td>
<td>0.02</td>
<td>0.05</td>
<td>0.01</td>
<td>-0.03</td>
</tr>
<tr>
<td>GM</td>
<td>0.69**</td>
<td>--</td>
<td>0.18</td>
<td>0.24</td>
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*Note: Theta¹ indicates theta activity during eyes open condition; Theta² indicates theta in eyes closed condition, etc.; SS RT: Stop Signal Average Reaction Time; SS ACC: Stop Signal Percent Accuracy; SS PES: Stop Signal Post-Error Slowing.

**Note: ** indicates significance at the p < 0.01 level; * indicates significance at the p < 0.05 level; + indicates approaching significance at p < 0.10.
Site Analyses

Psychopathy total scores and subscale scores were correlated with theta and beta power spectral density at each site by condition. In the eyes open condition, theta activity at F4 was not significantly correlated with psychopathy total score \((r = 0.03, p = 0.86)\), GM subscale scores \((r = 0.001, p = 0.10)\), CU subscale scores \((r = 0.11, p = 0.53)\), or DI subscale scores \((r = -0.07, p = 0.67)\). Theta activity at Fz with eyes open was not significantly correlated with psychopathy total scores \((r = -0.03, p = 0.85)\), GM subscale scores \((r = -0.04, p = 0.84)\), CU subscale scores \((r = -0.04, p = 0.82)\), or DI subscale scores \((r = 0.02, p = 0.93)\). Theta activity at P4 with eyes open was not significantly correlated with psychopathy total scores \((r = -0.12, p = 0.46)\), GM subscale scores \((r = -0.14, p = 0.42)\), CU subscale scores \((r = -0.04, p = 0.82)\), or DI subscale scores \((r = -0.09, p = 0.60)\). Theta activity at Pz with eyes open was not significantly correlated with total psychopathy scores \((r = -0.003, p = 0.98)\), GM subscale scores \((r = -0.14, p = 0.40)\), CU subscale scores \((r = 0.11, p = 0.51)\), or DI subscale scores \((r = 0.01, p = 0.94)\). Theta activity at P3 with eyes open was not significantly correlated with total psychopathy scores \((r = -0.10, p = 0.56)\), GM subscale scores \((r = -0.20, p = 0.25)\), CU subscale scores \((r = 0.08, p = 0.66)\), or DI subscale scores \((r = -0.12, p = 0.50)\).

In the eyes closed condition, theta activity at F4 was not significantly correlated with psychopathy total scores \((r = 0.18, p = 0.28)\), GM subscale scores \((r = 0.14, p = 0.43)\), CU subscale scores \((r = 0.19, p = 0.27)\), or DI subscale scores \((r = 0.03, p = 0.85)\). Theta activity at Fz with eyes closed was not significantly correlated with psychopathy total scores \((r = 0.10, p = 0.58)\), GM subscale scores \((r = -0.02, p = 0.93)\), CU subscale scores \((r = 0.11, p = 0.54)\), or DI subscale scores \((r = 0.11, p = 0.50)\). Theta activity at P4 with eyes closed was not significantly correlated with psychopathy total scores \((r = 0.00, p = 0.999)\), GM subscale scores \((r = -0.03, p = 0.86)\), GM subscale scores \((r = -0.04, p = 0.84)\), CU subscale scores \((r = -0.04, p = 0.82)\), or DI subscale scores \((r = 0.02, p = 0.93)\).
Theta activity at Pz with eyes closed was not significantly correlated with psychopathy total scores ($r = 0.11, p = 0.50$), GM subscale scores ($r = -0.07, p = 0.67$), CU subscale scores ($r = 0.23, p = 0.18$), or DI subscale scores ($r = 0.07, p = 0.70$). Theta activity at P3 with eyes closed was not significantly correlated with psychopathy total scores ($r = -0.02, p = 0.89$), GM subscale scores ($r = -0.13, p = 0.46$), CU subscale scores ($r = 0.16, p = 0.34$), or DI subscale scores ($r = -0.13, p = 0.45$).

In the eyes open condition, beta activity at F4 was not significantly correlated with psychopathy total scores ($r = 0.16, p = 0.33$), GM subscale scores ($r = 0.08, p = 0.63$), CU subscale scores ($r = 0.16, p = 0.36$), or DI subscale scores ($r = 0.10, p = 0.56$). Beta activity at Fz in the eyes open condition was not significantly correlated with total psychopathy scores ($r = 0.03, p = 0.84$), GM subscale scores ($r = 0.02, p = 0.91$), CU subscale scores ($r = 0.06, p = 0.73$), or DI subscale scores ($r = -0.02, p = 0.90$). Beta activity at P4 in the eyes open condition was not significantly correlated with total psychopathy scores ($r = -0.06, p = 0.71$), GM subscale scores ($r = -0.13, p = 0.46$), CU subscale scores ($r = 0.03, p = 0.86$), or DI subscale scores ($r = -0.04, p = 0.80$). Beta activity at Pz in the eyes open condition was not significantly correlated with total psychopathy scores ($r = 0.01, p = 0.98$), GM subscale scores ($r = -0.11, p = 0.51$), CU subscale scores ($r = 0.11, p = 0.53$), or DI subscale scores ($r = 0.003, p = 0.99$). Beta activity at P3 in the eyes open condition was not significantly correlated with total psychopathy scores ($r = 0.001, p = 0.998$), GM subscale scores ($r = -0.08, p = 0.64$), CU subscale scores ($r = 0.11, p = 0.53$), or DI subscale scores ($r = -0.05, p = 0.77$).

In the eyes closed condition, beta activity at F4 was not significantly correlated with psychopathy total scores ($r = 0.29, p = 0.08$), GM subscale scores ($r = 0.22, p = 0.19$), CU
subscale scores \( (r = 0.24, p = 0.16) \), or DI subscale scores \( (r = 0.13, p = 0.44) \). Beta activity at Fz with eyes closed was not significantly correlated with psychopathy total scores \( (r = 0.16, p = 0.35) \), GM subscale scores \( (r = 0.07, p = 0.67) \), CU subscale scores \( (r = 0.17, p = 0.32) \), or DI subscale scores \( (r = 0.07, p = 0.67) \). Beta activity at P4 with eyes closed was not significantly correlated with psychopathy total scores \( (r = -0.03, p = 0.88) \), GM subscale scores \( (r = -0.06, p = 0.71) \), CU subscale scores \( (r = 0.07, p = 0.66) \), or DI subscale scores \( (r = -0.09, p = 0.59) \). Beta activity at Pz with eyes closed was not significantly correlated with psychopathy total scores \( (r = 0.06, p = 0.71) \), GM subscale scores \( (r = -0.09, p = 0.61) \), CU subscale scores \( (r = 0.19, p = 0.26) \), or DI subscale scores \( (r = 0.000, p = 0.999) \). Beta activity at P3 with eyes closed was not significantly correlated with psychopathy total scores \( (r = 0.05, p = 0.79) \), GM subscale scores \( (r = -0.03, p = 0.86) \), CU subscale scores \( (r = 0.20, p = 0.25) \), or DI subscale scores \( (r = -0.12, p = 0.47) \).

**sLoreta**

After conducting sLoreta analysis to further understand which areas of the brain were activated during the resting state task, it was found that for both theta and beta activity, Brodmann area 46 was activated. Brodmann area (along with Brodmann area 9) is equivalent to activity in the dorsolateral prefrontal cortex (Transcranial Technology, 2012). The dorsolateral prefrontal cortex is associated with executive functioning such as working memory, experiencing and processing emotional stimuli, and behavioral inhibition (Transcranial Technology, 2012). Therefore, activation of this area of the brain during the resting state task could have been associated with the cognitive demand of following directions as well as behavioral inhibition required to sit still and complete the trials of the task. Below are diagrams of activity generated
using sLoreta. In these diagrams, different angles were used in order to view the brain from all sides during the task.

**Figure 2: sLoreta Activation during Resting State Task**

*Note: a.) superior view (top of brain); b.) dorsolateral view (left side of brain); c.) ventralateral view (right side of brain); d.) inferior view (bottom of brain)

**Note: Yellow indicates greater activation**

**Figure 3: sLoreta Activation by Slices**

*Note: Yellow indicates greater activation*
DISCUSSION

Resting state correlates are thought to be representative of electrophysiological underpinnings of human behavior (Allen, Iacono, Depue, & Arbisi, 1993; Coan & Allen, 2004; Davidson, 1992; Harmon-Jones & Allen, 1997; Hofman & Schutter, 2012; Sutton & Davidson, 2000). The biological factors that contribute to development of psychopathy are not well understood and further understanding how psychopathic traits are related to brain functioning would contribute to a more robust understanding of how to treat the disorder in the future. This study significantly contributes to the conceptualization of the biological underpinnings of psychopathy by providing more information about how psychopathic traits are related to cortical functioning as well as behavioral indicators of cognitive control and behavioral adaptation.

Overall, TBR was not correlated with total psychopathy scores or subscale scores. In addition, total theta and beta activity were not correlated with psychopathy total or subscale scores. Particularly, individuals’ total TBR power spectra did not differ based on the level of psychopathic traits or by subscale scores. Therefore, in this population, it is likely that TBR is not related to psychopathic traits, including daring and impulsive behavior. This is a significant departure from evidence found in other TBR studies in which externalizing behavior was posited to be related to TBR. Moreover, other researchers have examined disorders with overlapping symptomology, such as ADHD and Autism Spectrum Disorder, both characterized by broader executive functioning deficits.

For ADHD, impulsive behavior has been found to be strongly correlated with TBR, so much so that TBR is being used as a biomarker for ADHD; however, the same effect was not
found in the sample of adolescent offenders in the current study. It is possible that ADHD and psychopathy are characterized by different “impulsive styles” with individuals higher in psychopathy being more calculating, ignoring risk and punishment, and acting daringly. Bink, van Boxtel, Popma, Bongers, Denissen, and van Nieuwenhuizen (2014) found that adolescents with ADHD displayed more absolute theta activity than adolescents with ASD and ADHD. This suggests that while behavioral symptoms may overlap, there could be different neural processes underlying those behaviors. The same is entirely possible in psychopathy: individuals high in psychopathy may have different psychophysiological mechanisms contributing to cognitive and socioemotional processing, particularly when related to affective stimuli, reward, or punishment.

The lack of correlation among theta and beta power source density, theta/beta ratio, and psychopathic traits, while not significant, still offers important information about the brain’s functioning at resting state and its relationship to personality traits in adolescents. Specifically, considering previous research, it may be possible that the aberrant reward and punishment processing is not primed by baseline functioning as was hypothesized in this study. Specifically, some research has examined TBR in relation to modulation of response inhibition in an emotion-invoking go/no-go task (Putnam, van Peer, Maimari, and van der Werff, 2010). In one study, the researchers stated that higher TBR is actually a “function of reduced frontal cortical control over subcortical affective approach drive.” Considering this, TBR may not be indicative of trait impulsivity as much as it rather indicates behavioral modulation when a reward/punishment is present. Because our study did not invoke emotions through stimuli or elicit reward or punishment, it may be that our baseline TBR would differ from in-task TBR in the same sample. Schutter and van Honk (2005) found that TBR was related to imbalance in motivation during Iowa Gambling Task and predicted advantageous versus disadvantageous choices, further
supporting the idea that TBR may be more effectively measured during a task rather than at resting state.

It is also possible that in our study, the null findings support the idea that individuals high in psychopathy have an emotion-processing deficit rather than a fully cognitive-processing deficit, as suggested by RMH. Although there are three dominant theories for psychopathy, each posing a singular cause for the disorder, the TBR data and the go/no-go task results do not offer strong support for RMH. Similarly, arousal also may not be supported given these findings. Information regarding low fear may require a different set of analyses. While the correlation between psychopathic traits and post-error slowing indicates some dysfunction of cognitive control, individuals high in psychopathic dimensions may experience more difficulty with cognitive control when the limbic system is activated, which would lend support to the theory that low fear, and therefore, low limbic system activation, is contributing more significantly to psychopathic behavioral traits. If this is the case, it would be expected that individuals high in psychopathic traits, while experiencing some difficulty at baseline with cognitive control and behavioral adaptation, is more likely to experience difficulty when engaged and/or motivated by a task in which the limbic system is activated. This study supports the idea that low fear may be a likely contributor to psychopathic trait expression.

While psychopathic traits were not significantly correlated with mean reaction time or number of errors in the stop signal task, they were significantly negatively correlated with post-error slowing in that task. Also, the negative correlation between CU traits and post-error slowing was approaching significance ($r = -0.33, p = 0.06$). Because post-error slowing is typically indicative of top-down behavioral regulation, this finding may indicate that individuals higher in psychopathy, and particularly CU traits, have less ability to regulate cognitive control.
Alternately, researchers have begun to believe that post-error slowing may also reflect more of an affective component whereby the errors mean very little to those high in psychopathic traits perhaps especially those with CU traits. Thus, they recognize the error, can even control, but may have little affective response to it. There may be some merit for this explanation in that the RT and accuracy did not differ between the groups. If post error-slowning was beneficial to those with low levels of psychopathic traits, it did not seem to matter for those with elevated psychopathic traits in terms of their accuracy across the task. Additionally, the sLoreta analysis indicated that, on average, all study participants had more brain activation in the dorsolateral prefrontal cortex, which is important in decision-making and behavioral control in the brain.

**Future Research**

In order to continue to explore neuromarkers of psychopathy, future studies should concentrate upon finding differences in processing, cortical activation, and personality traits. For instance, it may be that if a reward or punishment set was present, we would see difference in theta and beta power source density in individuals higher in psychopathic traits. To test this theory, theta and beta should be measured during tasks in which there is reward for performance or effort or punishment for poor performance or effort. Future research should also examiner whether either cognitive or emotional response behavior and neural correlates change over the developmental course, particularly considering imaging studies and results that the anterior cingulate cortex does not function in psychopathy as it does in individuals low in psychopathic traits.

**Limitations**

There were several limitations of the current study. First, the sample is relatively small and the study did not contain a control group with which to compare the adolescent offenders.
However, it can be argued that this study’s aim was to view psychopathic traits on a spectrum and that this sample afforded us this ability to view psychopathy dimensionally. Second, the residential facility used in the current study housed only males, and thus, the results are not generalizable to female offender populations. Third, this study was conducted in a detention facility where resources available were limited and complete isolation was not possible, which can lead to some noise and distraction. A classroom with a shut door or a room separate from the general population was used to set up the EEG equipment and run participants in order to minimize the effects of these limitations. Fourth, the current study used only self-report measures. Although there is evidence that self-report measures of psychopathy are effective (Lilienfeld, Fowler, & Patrick, 2006), use of self-report relies on the young offenders’ opinions of themselves and while on the one hand that can be a potential strength, future studies may want to incorporate a clinician-based interview format to further determine if the current findings hold across raters. Despite a number of limitations, the current study finds intriguing results in that brains of those with elevated psychopathic traits, even DI traits, do not appear to differ substantively from those with low levels of psychopathic traits, at least in terms of theta beta ratio.
REFERENCES


Transcranial Technology (2012).


UNIVERSITY OF ALABAMA
INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS
REQUEST FOR APPROVAL OF RESEARCH INVOLVING HUMAN SUBJECTS

I. Identifying Information
   Principal Investigator Second Investigator Third Investigator
   Name: Randy Salekin, PhD
   Department: Psychology
   College: Arts & Sciences
   University: University of Alabama
   Address:
   Telephone: (205) 348-6619
   FAX:
   E-mail: rsalekin@as.ua.edu
   Title of Research Project: Treatment of Conduct Problem Youth
   Date Submitted: 9/15/2015
   Funding Source: Department of Youth Service (DYS)

Type of Proposal: □ New □ Revision □ Renewal □ Completed □ Exempt

Please attach a renewal application
Please attach a continuing review of studies form
Please enter the original IRB # at the top of the page

UA faculty or staff member signature:

1
II. NOTIFICATION OF IRB ACTION (to be completed by IRB):
Type of Review: ___ Full board ___ Expedited

IRB Action:
___ Rejected Date: ______
___ Tabled Pending Revisions Date: ______
___ Approved Pending Revisions Date: ______

Approved—this proposal complies with University and federal regulations for the protection of human subjects.
Approval is effective until the following date: 10/15/2015

Items approved: Research protocol (dated_______)
Informed consent (dated_______)
Recruitment materials (dated_______)
Other (date): ______

Approval signature: [Redacted] Date: 11/9/2015
THE UNIVERSITY OF ALABAMA
Informed Assent for a Research Study

Dear DYS student:

A researcher from the University of Alabama would like to ask to have permission to use information from the treatment you are about to take part in. This is because the researcher would like to know more about treatment here and how it works. The researcher would also like to know how much how youth change over time in treatment and whether kids think it helps to discuss their problems with treatment staff. This study will help psychologists and other mental health professionals understand what life is like for kids your age in detention facilities and what aspects might best help them gain a better life for themselves. Maybe we can learn some new ways to help kids make good choices about taking care of themselves in society and getting the best out of life.

A DYS legal representative gave the researcher your name in response to a request to examine the information that comes from treatment here at the Vacca Campus. The DYS legal representative and the DYS staff know we are asking you to be in this study. It is OK with them. I am asking approximately 200 other DYS youth in this facility to be in this study.

If you decide to be in the study, you will be providing us with the opportunity to examine the information that you will be routinely completing as part of your treatment here at DYS. The questions that you will be filling out ask about conduct problems, your mood, anxiety, and about how you feel that treatment is going. At the end of the treatment, you will be interviewed and researchers would also like to be at the interview to answer any questions you may have. Researchers would also like to use information from the interview to assess how youth at DYS liked the treatment.

Researchers will not tell anyone outside the study what you or any other particular person said. We will write a report on the study that just talks about what the group said or didn’t say, but no one will be able to recognize you (there are no names attached). We will not tell your parents or teachers about any of your responses on questions or interviews as this will be all examined as a group.

You are a volunteer. You are helping us, but, you do not have to unless you want to. This is your free choice. If you start the study and decide you do not want to continue, just let me know. No one will be mad at you. If you do not want to answer or discuss a certain topic, you do not have to.

The researchers of this study do not think there are any risks or harm to you in this study except for the potential loss of confidentiality. There is a very small possibility that your name could be connected to the study, although we work very hard to keep this from happening. You may find the treatment helpful and the interview at the end of the study helpful. It may feel good to know you are helping us to help other kids that may have conduct problems and are having difficulties getting their life started. You will not be
treated badly or differently if you decide not to participate in this study. Also, your
decision to participate or not participate will have no effect on your time in detention.
Although the treatment is part of your program, participation in this study is voluntary.

If you have any questions about this study, please ask me now. If you have questions
later, you can ask one of the DYS staff to contact me immediately at the University of
Alabama. My telephone number is 205-348-8610 or 1 can be reached by email at
raeekind@ua.edu. You can also ask the legal representative at DYS questions if you
wish by asking a staff member if you can speak with him. If you have questions or
concerns about your rights in a research study, you can contact Ms. Tanta Myles at the
University of Alabama. Her telephone numbers are (256) 348-8461 or toll free at 1-877-
820-3066. Her email address is tmyles@ua.edu. Her mailing address is:

University of Alabama Office of Research
Attn: Ms. Tanta Myles - Participant Concern
Box 870104
Tuscaloosa, AL 35487-0104

Also, you may also ask questions, make suggestions, or file complaints and concerns
through the IRB Outreach website at
http://osp.ua.edu/site/PRCO_Welcome.html or email us at
participantoutreach@bama.ua.edu. After you participate, you are encouraged to
complete the survey for research participants that is online at the outreach website or
you may ask the investigator for a copy of it and mail it to the University Office for
Research Compliance, Box 8701277, 358 Rose Administration Building, Tuscaloosa, AL
35487-0127.

If you agree to be in this study, please sign your name on this letter below. You can have
a copy of the letter to keep.

Thank you very much for your interest.

Sincerely,
Randy Salekin, PhD.

Name of Participant __________________________ Date ______________

Person Obtaining Assent ______________________ Date ______________

UA IRB Approved Document
Approval date: 11/1/15
Expiration date: 11/1/15
THE UNIVERSITY OF ALABAMA

Youth Assent to Collect Records

This study also would like to gather information about my contact with the police over the next 4 years. This information is from records at DYS, Juvenile Courts, and probation office. I agree that this information can be collected even if I choose not to take part over the next 4 years. If you decide you no longer want to be part of this aspect of the study just contact Randy Salekin at 205-348-6619 and we will not include you in further study assessments.

_________________________  ___________________________  ____________
Name                        Signature                     Date

_________________________  ____________
Person Obtaining Assent                              Date

UA IRB Approved Document  39
Approval date: 11/19/15
Expiration date: 12/31/16
THE UNIVERSITY OF ALABAMA

Informed Assent for a Research Study

Dear DYS student:

This study also would like to gather information about your brain functioning using an EEG measure. The measurement of brain waves includes wearing a cap where eight electrodes will be attached to your head. This information helps us to understand what regions of the brain are being used for completing tasks. The tasks are in some ways similar to computer games, but, admittedly are likely not as fun as some games. They do help us understand what regions of your brain are most active during the tasks.

The DYS legal representative and the DYS staff know we are asking you to be in this study. It is OK with them. I am asking approximately 200 other DYS youth in this facility to be in this study.

What are the risks to you in this study? There is the possibility of a loss of confidentiality although we work very hard to maintain confidentiality. There is a very small possibility that you may have a small reaction to the gel used in attaching the sensors to the head. This attachment procedure can cause a slight reddening of the skin. Except for this, there are no risks in the experiment beyond those in everyday life.

What are my rights as a participant? Taking part in this aspect of the study (or any aspect of the study) is voluntary. It is your free choice. Whether or not you participate is completely up to you and whether or not you participate will not affect your placement at DYS, length or stay, or how you are treated. A decision to participate will not affect your status in the facility. If you start the study, you can stop at any time. There is no penalty for withdrawing. If you decide you want to stop the study at any time just let one of the researchers know and we will discontinue the study.

Who do I call if I have questions or problems? If you have questions about the study right now, please ask them. If you have questions later, please call Randy Salekin at 205-348-6619. If you have questions or concerns about your rights in a research study, you can contact Ms. Tanta Myles, the Research Compliance Officer at the University of Alabama. Her telephone numbers are (205) 348-8461 or toll free at 1-877-820-3066. Also, you may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach website at http://osp.ua.edu/site/PRCO_Welcome.html or email us at

UA IRB Approved Document

Approval Date: 11/11/15
Expiration Date: 11/11/16
participantoutreach@bama.ua.edu. After you participate, you are encouraged to complete the survey for research participants that is online at the outreach website or you may ask the investigator for a copy of it and mail it to the University Office for Research Compliance, Box 8701277, 358 Rose Administration Building, Tuscaloosa, AL 35487-0127.

If you agree to be in this study, please sign your name on this letter below. You can have a copy of the letter to keep.

Thank you very much for your interest.

Sincerely,

Randy Salekin, PhD.

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Name of Participant          Date

__________________________  _________________________
Person Obtaining Assent      Date