NEUROCOGNITIVE AND PSYCHOPHYSIOLOGICAL CORRELATES OF IMPULSIVITY

by

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Abstract

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The construct of impulsivity is multidimensional as evidenced in symptoms occurring across a range of psychiatric and personality disorders. Previous studies have elucidated multiple latent factors that represent impulsive personality traits. We believe there are two divergent personality traits that give way to impulsive tendencies. The first, disinhibition, has been theorized as stemming from a weak behavioral inhibition system (BIS). Both the trait and the system have been associated with fearlessness, lack of anxiety, and a weaker inhibition. The second, sensation seeking, has been theorized to be associated with the behavioral approach system (BAS) and is correlated with goal-directed behavior, novelty seeking, and excessive reward sensitivity. Recent studies found that various behaviors and forms of psychopathology were differentiated by distinct aspects of impulsive personality, as well as impaired neurocognitive abilities. Additionally, psychophysiological measures, such as heart rate and blood pressure reactivity, have been associated with externalizing disorders associated with impulsivity. Therefore, the goal of the study was to explore the associations of sensation seeking and disinhibition with neurocognitive and psychophysiological functioning among young adults. Results indicated no significant relationships among impulsive personality traits and neurocognitive function.

Significant associations were observed among disinhibition and increased resting diabolic blood pressure as well as disinhibition and decreased cardiovascular reactivity. No relationships were observed between sensation seeking and any cardiovascular measures. Impulsive aggression was related to a decrease in cardiovascular reactivity. Although these findings suggest that disinhibition and sensation seeking are not related to cognition, additional studies are necessary to confirm this lack of relationship. The literature on the psychophysiology of externalizing disorders associated with impulsivity is conflicting. Our results are not conclusive and further research is warranted to obtain a greater understanding of the association between the trait disinhibition and autonomic function.

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INTRODUCTION

Impulsive acts and decisions are part of everyday behavior. However, in its pathological form impulsivity can lead to adverse consequences and is associated with a range of psychiatric and personality disorders, the so-called "externalizing disorders" (Hollander & Evers, 2001; Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). In particular, impulsivity is a cardinal feature of psychopathy and its associated DSM-IV (APA, 1994) diagnostic counterpart, Antisocial Personality Disorder (ASPD). The term psychopathy was originally conceptualized as a personality disorder with affective and interpersonal traits such as grandiosity, arrogance, and manipulation, and an incapacity to feel empathy, guilt or remorse (Hare, 2006).

Psychopathy has mainly been characterized by poor impulse control and destructive behavior that begins in childhood and persists into adulthood (American Psychiatric Association, 1994). The violent and aggressive consequence of psychopathy has resulted in numerous attempts to explain the causes of such maladaptive behaviors. Studies have consistently found two constructs associated with psychopathy; neurocognitive deficits (LaPierre, Braun, & Hodgins, 1995) and psychophysiological abnormalities, such as autonomic under-reactivity (e.g., Arnett, Howland, Smith, & Newman, 1993). Due to the genetic component that significantly contributes to the distinct psychopathic traits (Blonigen, Hicks, Krueger, Patrick, & Iacono, 2005), it is no surprise that symptoms are exhibited in childhood. Research in youth has been helpful in attempts to define developmental precursors to psychopathy. Children with disorders of poor impulse control are strong predictors of later having behavioral problems as evidenced by Lynam (1996), who found that children who manifest symptoms of hyperactivity-impulsivity-attention problems and conduct problems, are at the greatest risk for chronic offending. Furthermore, a subset of youths that have been identified as having psychopathic-like personality traits presented with more severe and pervasive aggressive behaviors than other youths with conduct problems (Andershed, Kerr, & Stattin, 2002), an association similar to that seen in adults (Lynam & Gudonis, 2005).

Therefore, it would follow that the study of the personality trait/temperament of impulsivity may have predictive value in understanding the etiology of psychopathy. This dissertation will examine how impulsive dimensions are associated with both deficits in neurocognitive functions (e.g., LaPierre Braun, & Hodgins, 1995) and psychophysiological abnormalities, such as autonomic under-reactivity (e.g., Arnett, Howland, Smith, & Newman, 1993), factors that are believed to be at the root of psychopathic maladaptive behaviors.

The fact that impulsivity is evidenced across a broad spectrum of psychiatric and personality disorders (Hollander & Evers, 2001; Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001), is indicative of the complexity and ambiguity of this construct. In addition, the term “impulsivity” has been used by different people to mean different things. Therefore, conceptualization of impulsivity is better understood as multidimensional. Research encompassing dimensions of impulsivity, rather than the construct as a whole, allow for study of the putative underlying neurobiology of these dimensions and thus help interpret the various presentations.

However, the nomenclature and understanding of even impulsive dimensions have been long debated among personality theorists. Therefore, a review of the prominent personality theories and their conceptualization of impulsivity is warranted, followed by a description of how we have operationalized impulsivity for the current project. Where possible, we have also described how various personality theories incorporate neuroscientific aspects.

Major Personality Theories: Consideration of Impulsivity

J.A. Gray. In the 1970's, a prominent biological theory of personality was proposed by J. A. Gray. Based on animal research, Gray delineated two systems important in the control of behavior that centered on orthogonal motivational systems (Gray, 1987). According to Gray, anxiety regulates aversive motivation, termed the behavioral inhibition system (BIS), while impulsivity regulates appetitive motivation, reflecting a behavioral approach system (BAS). The Behavioral Inhibition System (BIS) organizes responses to conditioned aversive stimuli and is composed of three specific and sequential responses: 1) ongoing behavior is brought to a halt, 2) there is increased attention to the environment, and 3) there is an increased arousal. Although Gray did not specify whether such arousal occurs in the central nervous system (CNS) versus peripherally (PNS), or both, Fowles (1980) interpreted Gray's arousal as behavioral vigor manifested in increased intensity of response, such as running speed, which cannot be attributed to greater incentive. This not only implies peripheral arousal, but also distinguishes this arousal from that seen in the BAS. Due to the fact that it is aversive stimuli that alter one's response, Gray viewed this system as the substrate for anxiety; the greater an individual's sensitivity to this system of punishment, the more prone the individual is to anxiety. Further evidence proposed by Gray that this system is associated with anxiety is that anti-anxiety drugs block all three behavioral responses associated with this system (Fowles, 1980). This system is sensitive to signals of punishment, non-reward and novelty, and is responsible for the experience of negative feelings such as fear, anxiety and sadness in response to these cues. In addition, Gray suggested that the BIS inhibits behavior that may lead to negative or painful outcome.

Gray proposed that the BIS plays a monitoring role in checking that behavior goes according to plan. First, it draws upon stored information concerning past events and compares the current situation to the previous. Second, if it matches, the system continues in its checking mode and behavior remains in 'control'. If it doesn't match, the system begins to operate in a behavioral inhibition mode by halting behavior, but continues to gather more information via increased attention and arousal in order to resolve the discrepancy (reviewed in Gonzalez, Hynd, & Martin, 1994).

Gray proposed that the major neural structures associated with this system were the septal area and the hippocampus. The subicular area of the hippocampus is thought to be associated with the comparison checking, while the prefrontal cortex processes the current event information. Noradrenergic projections from the locus coeruleus are thought to mediate the heightened arousal while serotonergic projections from the raphe nuclei mediate the behavioral inhibition (Gray, 1987). In 2000, McNaughton and Gray updated this theory as it became well accepted that the amygdala controls both fear and anxiety (Ledoux, 1994). They proposed that although individual variations depend on the action of a septohippocampal behavior inhibition system, this region then engages the amygdala to produce fear-related outputs. For example, anxiety arises from the interaction between the amygdala and the septohippocampal BIS; therefore heightened anxiety sensitivity should be associated with increased amygdala activity in fear-relevant situations. Another important aspect to this updated theory distinguished fear and anxiety as two distinct types of defensive behavior, termed by McNaughton and Gray (2000) as ‘defensive direction’. Fear-related behavior was described as a fight/flight reaction to an immediate danger, whereas anxiety-related behavior, considered ‘risk assessment’, occurs when a danger may or may not be present. The authors discussed further evidence for the distinction between these behaviors in that anxiolytic drugs were found to consistently affect anxiety-related measures of risk assessment (by reducing anxiety), but not measures of avoidance, or other ‘fear’ associated behaviors.

The Behavioral Approach System (BAS) is activated by stimuli associated with reward. Reward may be understood as providing a source for incentive motivation, as well as active avoidance; that is, relieving non-punishment or the non-occurrence of punishment when the subject has reason to expect punishment (Gray, 1987). Reward in this approach system is associated with conditioned secondary rewarding stimuli or non-punishment and triggers such states as pleasurable anticipation, elation or happiness. Activity in this system motivates the person to begin movement toward a goal. Due to the fact that it is conditioned reward stimuli (or ‘relieving non-punishment’ – that is, the non-occurrence of an expected punishment) that alter one’s response, Gray viewed this system as the substrate for incentive motivation; the greater an individual’s sensitivity to reward, the more prone the individual is to elicit approach behavior.

Gray (1987) proposed that associated neural substrates of this system include dopaminergic projections to the nucleus accumbens in the ventral striatum that relate to incentive motivation or goal-related behavior. Additionally, dopamine from the substantia nigra to the dorsal striatum may be associated with motor aspects of motivation. When discussing the brain with regard to the BAS, Gray referred to Olds and Milner (1954) who first reported that rats electrically self-stimulate, pioneering the discourse of these neural correlates associated with behavioral effects of reward. However, since that time experiments have proved complex in terms of teasing out specific approach or inhibitory systems due to inevitable interaction between the BIS and BAS. Therefore a brief discussion on Gray's interpretation of the interaction of these systems is warranted.

Due to the inherent nature of the BIS, it is plausible that BAS activity may be inhibited by the BIS (Gray, 1987). Gray posited that this effect takes place at the ventral striatum as this area is a major target for efferent fibers of the subicular cortex. Another type of interaction of the BIS affecting the BAS is described by Gray as the excitatory effect of the BIS. Here, Gray discussed arousal output in preparation for vigorous action that is mediated by noradrenergic fibers mostly originating from the locus coeruleus and distributed widely throughout the brain. Although Gray doesn't provide detailed information regarding this aspect of the interaction, he suggests that this action possibly primes the BAS, as the anxiety may enhance responding. On the other hand, during conflict situations, Gray suggested that the BAS moderates BIS activity; a decision mechanism resolves conflict between reward and punishment, with the consequences of behavior (whether reward or punishment) feeding back to comparator mechanisms (actual to expected; an aspect of BIS). Neural associations of this interaction that were discussed by Gray include two regions that are recipients of dopaminergic afferents; the lateral septal area, as well as inhibitory control over cholinergic projections from the medial septal area to the hippocampus.

The development of reliable self-report measures of BIS and BAS sensitivity has facilitated the conversion of BIS/BAS from animal models to the study of human behavior

(Amodio, Master, Yee, & Taylor, 2008). Based on Gray's descriptions of these theoretical systems, Carver and White (1994) developed self-report measures written in Likert-type format and intended to assess individual differences that reflect sensitivity to the two self-regulatory systems: aversive motivation (BIS) and appetitive motivation (BAS). Assessment of BIS and BAS sensitivities were designed to measure responses to situations rather than general affective tone (as measured by, for example, Tellegen's positive and negative emotionality [Tellegen, 1985] discussed later). The BIS scale is designed to measure sensitivity to anxiety-provoking stimuli, with statements designed to reflect a concern over the possibility of a bad occurrence such as "I worry about making mistakes" or a sensitivity to such events when they do occur, "I feel pretty worried or upset when I think or know somebody is angry at me". BAS sensitivity is measured in statements designed to reflect potentially rewarding events and assess how one would respond to them such as "I crave excitement and new sensations", and "I go out of my way to get things I want".

Of further relevance to the current proposal is that although Gray considered the BIS to underlie anxiety proneness, at one end of this spectrum is *dis*inhibition, that is, the inability to halt or 'control' one's behavior to best adapt to a situation. As we describe below, some models of personality equate disinhibition with impulsivity, indicating that Gray's label for the BAS is not wholly consistent with the literature.

Eysenck; EPQ. In 1947, H. Eysenck postulated a two-dimensional model of personality that included extraversion (E) (versus introversion – I) and neuroticism (N) (Eysenck & Eysenck, 1985). Eysenck posited that E is controlled by the reticulocortical activating system that regulates the level of stimulation of the central nervous system (CNS). Extraverts seek out high stimulatory activities due to their low (basal) levels of CNS arousal in order to bring themselves to a homeostatic level of arousal. Introverts, on the other end of that dimension, have higher basal levels of CNS arousal, and therefore tend to engage in quiet, or limited stimulated activity. His theory conceptualized personality as a hierarchy of constructs such that extraversion is a higher-order concept composed of subfactors, one of which is impulsivity. On the face of this theory, it would appear that Gray's BAS would reflect extraversion and BIS would reflect introversion, however this would conflict with Gray's interpretation that these systems (BIS and BAS) are orthogonal. In terms of neuroticism, Eysenck theorized that high scorers on this dimension have a low threshold for limbic reactivity, and that the reverse is true for low-scorers. Further, Eysenck proposed the limbic system as a set of structures that determine the level of N that is exhibited and experienced by the individual. As Eysenck's theory was presented earlier historically, Gray (1970) argued that the BAS personality dimension was situated in the Extraversion × Neuroticism plane of Eysenck's personality system. He suggested that people high on the BAS dimension were neurotic extraverts. However, when Eysenck later modified his model to encompass another dimension, Psychoticism (P), he moved impulsivity to this newer dimension (P). According to Eysenck, individuals high on the psychoticism dimension tend to disregard common sense and act impulsively. This re-situation of impulsivity on another dimension places it conceptually closer to the view that impulsivity represents a failure to inhibit responding to a rewarding stimulus (i.e., a lack of constraint). A relationship between E and BAS does remain however, with regard to the motivational/approach/excitatory components. Eysenck developed a questionnaire designed to measure individuals on these three dimensions, E, N, & P, called the Eysenck Personality Questionnaire (EPQ). The EPQ has received criticism for psychometric problems on the

Psychoticism Scale such as low reliability, low range of scoring, and grossly skewed distribution of scores (Eysenck, Eysenck, & Barratt, 1977), and has been revised several times to address these problems and shorten the length of the scale. Although Eysenck's theory was provocative and groundbreaking for its time, the advent of technological methods that allow for a greater understanding of neurobiological systems has resulted in research that does not support his view of individual differences in basal CNS activity (Zuckerman, 1991).

Zuckerman; Z-SSS. By combining Eysenck's major personality dimensions and Gray's neurobiological foundations, Zuckerman created a distinctive theory of personality based on human studies (Zuckerman, 1979). Although he proposed a three-dimensional model, 1) psychoticism – impulsivity- unsocialized sensation seeking, 2) neuroticism-emotional and 3) extraversion-sociability, his work primarily focused on the first factor – sensation seeking. Zuckerman (1979) defined sensation seeking as a need for varied or novel sensations and a willingness to take risks for the sake of such an experience. This definition implies that impulsivity is a trait inherent in sensation seeking (Zuckerman, 1993) and therefore related to Gray's BAS. In comparison with Gray, Zuckerman focused on neurochemicals versus neuroanatomy, but similarly concurred that sensation seeking activities are associated with dopaminergic circuitry (Gonzalez et al., 1994). Zuckerman further proposed that high sensation seekers are sensitive to their internal sensations and choose stimuli that will maximize these sensations. This differs from Eysenck who postulated that extraverts seek stimuli due to their low levels of arousal to approach their homeostatic (or ideal) arousal level. A scale that Zuckerman created describes four distinct aspects of sensation seeking that all relate to reward and incentive motivation, further substantiating this trait as an aspect of the approach system (BAS). The Zuckerman Sensation Seeking Scale (Z-SSS) was designed with forced-choice items on four subscales. The first of these subscales is Thrill and Adventure Seeking, which measures a tendency to pursue a variety of dangerous physical activities, with examples such as, “I like to dive off the high board” vs. “I don’t like the feeling I get standing on the high board”. Next, the Experience Seeking subscale measures the tendency to pursue novel experiences. Individuals who score high on this scale report frequent exploration of new environments, meeting new people and trying new foods; “I like to explore a strange city or section of town by myself, even if it means getting lost” vs. “I prefer a guide when I am in a place I don’t know well”. The third subscale is called Disinhibition, which measures the tendency toward unrestrained behavior. Individuals who score high on this subscale report frequent partying and drinking. An example is, “I like wild uninhibited parties” vs. “I prefer quiet parties with good conversation”. Finally, the fourth subscale is Boredom Susceptibility, which measures aversion for repetitive experience of any kind such as routine work. Examples on this subscale are, “I get bored seeing the same old faces” vs. “I prefer friends who are excitingly unpredictable” (Zuckerman, 1979).

Cloninger; TPQ, TCI. According to Cloninger’s biopsychosocial model, personality consists of three orthogonal dimensions, which are represented by variation in neurotransmitter activity (Cloninger, 1987). The first is Novelty Seeking (NS), thought to be associated with the BAS as it reflects a tendency toward excitement as a response to novel stimuli. According to Cloninger, subjects high in NS tend to be more exploratory, impulsive in their decision-making, quick to lose their temper, and active in avoidance of frustration, whereas subjects low on NS tend to be rigid, stoic, and orderly. Cloninger theorized that NS as a trait is related to dopaminergic activity. Harm Avoidance (HA) is described as a BIS-related trait as it reflects the tendency to inhibit or interrupt behaviors. High scores on HA are indicative of pessimism, fatigue, worry, and shyness, while those with low scores are risk-takers, optimistic and outgoing. According to Cloninger, the HA dimension is related to serotonin, which corroborates with the putative neurochemistry of Gray's BIS. The third dimension, Reward Dependence (RD), is thought to reflect a tendency to maintain or pursue ongoing behaviors, especially with verbal indications of approval. Those who score high on RD are dependent on the approval of others, sentimental, and socially attached versus aloof and cold. Cloninger has proposed that variation in this dimension is related to variation in central norepinephrine activity due to norepinephrine's role in the learning and memory of paired associations. Verbal conditioning of social reinforcement is impaired in individuals with low reward dependence.

In order to assess these three dimensions of personality, Cloninger developed the Tridimensional Personality Questionnaire (TPQ; 1987), later revised to the Temperament and Character Inventory (TCI; 1994). The three dimensions assessed by the TPQ are harm avoidance (HA), novelty seeking (NS), and reward dependence (RD). The HA dimension resembles Gray's BIS sensitivity in that it concerns sensitivity to, and avoidance of, punishing stimuli. The NS dimension concerns a tendency toward excitement in response to cues of potential reward or relief of punishment resembling sensitivity to Gray's BAS. The RD dimension concerns a tendency toward responsiveness to unconditioned signals of reward and does not correspond directly to either of Gray's theoretical systems. The TCI represents a revision (and expansion) of the TPQ, but the main properties of the NS and HA scales remain intact in the revised version.

Tellegen; PA, NA. Tellegen and colleagues based their personality model on positive versus negative affect (Tellegen, 1985), which is comparable to Gray's association of sensitivity to punishment to negative emotions such as fear, and the association of reward sensitivity with feelings of happiness and pleasant emotion. With the intention of clarifying the organization and relationship among both mood and personality features, Tellegen and his colleagues analyzed a number of cross-sectional and longitudinal studies that used current-mood self-rating inventories (Watson, Wiese, Vaidya, & Tellegen, 1999). Positive and Negative Affect were the two dominating dimensions to emerge in orthogonal factor analyses, each with varying sets of descriptors. High Positive affect is characterized by pleasurable 'engagement', evidenced with high ratings on factors such as 'enthusiastic', 'elated' and 'active', and low ratings on 'drowsy', 'sleepy' and 'sluggish'. This relates to Gray's BAS as pleasant engagement may be interpreted as activity for reward. Low Positive Affect (i.e., low ratings for 'elated', high ratings for 'drowsy') suggests non-pleasurable disengagement. High Negative Affect, measured with high ratings on 'distressed', fearful', hostile' and low ratings on 'relaxed', 'calm', and 'placid', and reflects unpleasurable engagement; Low Negative Affect represents 'nonunpleasurable disengagement'. The Negative Affect dimension is consistent with Gray's BIS, in that it requires 'arousal', here termed 'engagement', in concert with negative feelings. Tellegen clarifies that 'engagement' not only serves to reflect arousal, but also cognitive relationships with the environment. As with other theories of personality, this model was revised by Clark and Watson (1999) to include a third dimension (Constraint), which is analogous to the aforementioned aspect of impulsiveness: disinhibition.

Costa and McCrae; NEO-PI, NEO-FFI. The Five-Factor model (Big Five) was initially developed to describe the normal range of individual differences in personality in adults and depicts five dimensions of personality: Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism (Costa & McCrae, 1997). While the dimensions of Agreeableness and Conscientiousness have some overlap with the BIS and BAS, Agreeableness and Conscientiousness are more likely part of a third dimension, perhaps similar to the earlier described Eysenck's Psychoticism dimension. Extraversion and Neuroticism have been discussed as the core domains of the Five-Factor model (FFM) due to agreement among many personality theorists that these are basic traits that influence behavior and feelings (Rolland & De Fruyt, 2003). Neuroticism (N) represents a tendency to experience psychological distress and therefore reflective of the BIS; rating low on the neuroticism scale may reflect emotionally stability (Costa & McCrae, 1992). Extraversion (E) encompasses traits such as sociability, activity and the tendency to experience positive emotions such as joy and pleasure; this scale relates to Gray's BAS as well as Tellegen's positive emotionality dimension. An inventory measuring the three facets (N, E, and O) was published in 1978 as the NEO Inventory (Costa & McCrae, 1978). In 1985, with the addition of the two new factors, Agreeableness and Conscientiousness, the NEO-Personality Inventory (PI) was published (Costa & McCrae, 1985), and the NEO Five-Factor Inventory (NEO-FFI) is a brief version of the scale (Costa & McCrae, 1989).

Summary and Conceptual Model of Impulsivity. Review of these theoretical models, as discussed above with some based on animal research, resulted in our conceptualization of impulsivity as two consistent dimensional aspects of impulsivity –

sensation seeking (Ss) and disinhibition. All of the above mentioned models include a conceptualization of impulse control, although the models differ on whether the lack of control is driven by an approach or reward seeking mechanism versus a constraint or inhibiting mechanism. Additional confirmation for these two dimensional aspects of impulsivity stems from empirical research that has elucidated latent factors of impulsivity that distinctly relate to established personality traits and measures (Swann, Bjork, Moeller, & Dougherty, 2002). Further, latent factors of impulsivity show comparable structure in normal and disordered samples thereby underscoring the dimensional conceptualization of impulsivity (Flory et al. 2006). Miller et al. (2003) found various behaviors and forms of psychopathology differentiated by these distinct aspects of impulsive personality. Specifically, results revealed that a preference for sensation seeking behaviors was a significant predictor of involvement in delinquent acts, drug and alcohol use, and risky sexual behavior, even after controlling for other forms of impulsivity. They also found that disinhibition (which the authors termed ‘urgency’) was a strong predictor of aggression, as well as symptoms of borderline personality disorder and eating problems. This separable functionality of sensation seeking and disinhibition strengthened and confirmed these two traits to be further explored as putative neurobiological underpinnings of impulsivity.

Sensation Seeking and Disinhibition in Psychopathy

While Cleckley (1976) was the first to distinctively describe psychopathy from an ordinary criminal offender, Hare (1980) operationalized Cleckley’s criteria with the Psychopathy Checklist (PCL), now revised as the PCL-R (1991). Factor analysis of the PCL-R has consistently found divergent relationships with constructs related to sensation seeking and disinhibitory personality traits. For example, Factor 1 is inversely related to measures of anxiety, neuroticism, and negative emotionality, whereas Factor 2 is positively correlated with these same variables after controlling for their common variance (Frick, Lilienfeld, Ellis, Loney, & Silverthorn, 1999; Harpur, Hakstian, & Hare, 1988; Patrick, 1994; Verona, Patrick, & Joiner, 2001). In addition, Factor 2 has a positive relationship with sensation seeking and a negative correlation with constraint. (Harpur et al. 1988; Patrick, 1994; Verona et al. 2001). Therefore, it may be inferred that Factor 1 is associated with disinhibition and Factor 2 is associated with sensation seeking. These two factors were mapped onto Gray's BIS and BAS constructs and were found to be differentially related; that is, the BIS was related to Factor 1 and the BAS was related to Factor 2, as expected (Wallace, Malterer, & Newman, 2009).

The use of Gray's BIS/BAS constructs to explain psychopathic behavior dates back over 30 years ago when Fowles (1980) attributed psychopathy to a weak or under-active BIS, resulting in fearless temperament. In fact, the relationship between psychopathy and constructs relating to the BIS has become more precise. Psychopaths who report significantly lower anxiety have been termed *primary* psychopaths, as compared to *secondary* psychopaths (Lykken, 1995). Since that time, both the BIS and BAS have consistently been shown to be associated with these distinctive psychopathic factors. Primary psychopaths exhibit a weak BIS, and secondary psychopaths have high BAS reactivity (Lykken, 1995; Newman, MacCoon, Vaughn, & Sadeh, 2005; Skeem, Johansson, Andershed, Kerr, & Louden, 2007). The relationship has been validated with behavioral tasks too. For example, on a task similar to the Continuous Performance Test (CPT), Newman, Wallace, Schmitt, & Arnett (1997) showed that psychopathic offenders exhibited weaker inhibition with BIS-related punishment cues in comparison to nonpsychopathic controls.

According to Gray's theory, as BAS activation increases, so does the probability of goal-directed behavior (Gray & McNaughton, 2000). Theories suggest that an exaggerated craving for excitement, reflects a BAS sensitivity (Gorenstein & Newman, 1980) and has been demonstrated with psychopaths scoring higher on novelty seeking scales (Basoglu et al., 2011). Further evidence for this explanation of psychopathy is that conduct disordered children who are at high risk for psychopathy, have similar impulsive behaviors mediated by excessive reward sensitivity (Quay, Routh, & Shapiro, 1987).

Baskin-Sommers, Wallace, Maccoon, Curtin, and Newman (2010) used laboratory assessments in order to evaluate the association between task performance and BIS and BAS functioning in psychopathic individuals. Results revealed a relationship between secondary psychopathy and a bias to focus attention on the primary task that involved an opportunity to earn a monetary reward (BAS), as well as weaker BIS-related responses such as an inability to withhold a response to non-target stimuli. In order to explain these findings, they postulate that psychopaths have a limited working memory capacity and thus devote their resources to reward cues as opposed to less satisfying cues. Additional cognitive patterns have been shown to be distinctive in psychopaths and are discussed in the following section.

Alternatively, maladaptive behavior in psychopaths may be attributable to an interaction among the BIS and BAS personality constructs. For example Avila (2001) demonstrated that a heightened sensitivity to reward (BAS activation) leads to a failure to learn from punishment, an aspect of the BIS. Further, experiments conducted by Avila

(2001) suggest that individuals with impulse control problems tend to have difficulty accommodating aversive peripheral cues while engaged in goal-directed behavior. This interactive evidence is in line with the theory that dysfunctional reward reactivity may be associated with disinhibited psychopathic behavior (Gorenstein and Newman, 1980). More specifically, Gorenstein and Newman (1980) review multiple studies that propose a 'septal syndrome', produced by a lesion of the septum in animals. Consistent with Gray's research with the septal region, animal behaviors with such lesions produced deficits in avoidance learning and aversive conditioning that resemble human disinhibition. The more recent studies reviewed by Gorenstein and Newman (1980) also revealed a hypersensivity to reward and a failure to delay gratification. Together, Gorenstein and Newman (1980) suggest a diathesis model for a deficit in the septal region important in the functioning of both aversive and appetitive responding.

Impulsivity and Cognition

The construct of impulsivity is associated with distinct neurocognitive performances that typically involve poor decision-making reflective of a lack of consideration for future consequences (Bechara, 2005), impaired ability to delay a reward for greater value (Kirby, Petry, & Bickel, 1999), and an inability to inhibit a prepotent or already initiated response (behavioral inhibition; Bechara, Damasio, & Damasio, 2000; Dougherty et al. 2003). With regard to psychopathy, cognitive processes have generally been divided into two components commensurate with the two facets of psychopathy discussed above; primary and secondary (Sadeh & Verona, 2008). The literature discussing the cognitive component associated with deficiencies in interpersonal and affective or emotional features, or primary psychopathy, is based on the concept that psychopathy is a syndrome of low-fear. These individuals are characterized by deficits in aversive conditioning (Flor, Birbaumer, Hermann, Ziegler, & Patrick, 2002), and anticipation of threat (Hare, 1965) and believed to have deficits in emotional brain circuitry involving the amygdala, paralimbic system, and orbitofrontal cortex (Birbaumer et al. 2005; Blair, 2005). In contrast, the response modulation hypothesis (RMH) holds that psychopathic individuals are in fact capable of normal emotional responses but have difficulty processing affective information when it is peripheral to their primary attentional focus (Newman & Lorenz, 2003). This model posits that it is these attentional factors that determine the quality of processing emotion. Further generalized, the theory speculates that when individuals with psychopathy are focused on a primary task, they fail to use peripheral information to regulate their behavior. For example, in a series of empirical studies, Newman and Kosson (1986) administered a go/no-go discrimination learning task in which participants would earn money if they pressed a button when particular stimuli were presented on a computer monitor and were required to inhibit pressing to avoid losing money when other stimuli were presented. As predicted, in comparison to non-psychopathic controls, psychopathic participants were more likely to fail in their ability to inhibit punished responses. To assess whether this deficiency was due to a response modulation deficit or a poor response to punishment (i.e., a motivational or emotional deficit), the authors administered a slightly modified version of the task that omitted the reward contingency. Instead, participants began the task with a cash stake and lost money each time that they incorrectly responded to "no-go" stimuli or failed to respond to "go" stimuli. Under these circumstances, psychopathic participants performed as well as non-psychopathic participants when the only goal was avoiding punishment. Therefore, in this study, psychopaths were in fact able to avoid punishment when not focused on a reward goal.

Similarly, in a study conducted by Newman, Curtin, Bertsch, & Baskin-Sommers, (2009) findings revealed that psychopaths display deficient fear responses when they are engaged in threat-irrelevant goal-directed behavior, though not when their attention is focused on threat-relevant information. These findings suggest that psychopaths' deficient response to fear stimuli may reflect deficits of attention in their ability to process contextual information, consistent with Gray's theory described above. These findings have been replicated (Zeier, Maxwell, & Newman, 2009) and support the response modulation theory, which states that the poorly regulated behavior of psychopaths reflects a failure to modify their attention in order to process affective, inhibitory, and other information while engaged in goal-directed behavior. As a result, psychopaths are relatively insensitive to information when it is peripheral to their ongoing focus of attention (Patterson & Newman, 1993).

In comparison to the previous cognitive- motor task, another more cognitive task that demonstrates these attentional deficits in psychopaths is the Stroop Task. The Stroop is a test that evaluates conflict monitoring such as reconciling irrelevant information being presented in order to provide a correct response. Exaggerated Stroop interference effects have been interpreted as indicative of disinhibition (Spieler, Balota, & Faust, 1996) and suggest difficulty maintaining an attentional focus and excessive distraction from irrelevant information. Such effects have been seen in individuals with poor impulse control (Stern & Prohaska, 1996). However, psychopaths tend to demonstrate *less* Stroop interference as shown by Hiatt, Schmitt, & Newman (2004) who revealed that while psychopaths had initial difficultly maintaining their attention, once they became focused they were less distracted by irrelevant information in comparison to nonpsychopathic individuals. These results demonstrate parallel evidence toward the theory that while psychopaths have the ability to focus and attend, they lack cognitive flexibility and become 'stuck' in their track toward a particular goal.

Gray's theory of the BIS is a related model such that in a failed (psychopathic) system one would be less likely to inhibit goal-directed behavior when potential threats or inconsistent stimuli are detected in the environment. Gray's theory continues that with inhibition, one would redirect *attention* in order to process the threatening or novel stimuli. Additionally, like Gray's model, the RMH is based on the septo-hippocampal-orbitofrontal system (Gorenstein & Newman, 1980). Further relating these attentional aspects of cognition to the BIS are studies that have indicated abnormal attentional processes to be associated with primary, and not secondary, psychopathy (Newman, 1998; Hiatt et al. 2004). One difference to Gray's model, however, is that the RMH holds that individuals with psychopathy are normally responsive to threat and other emotion information within their attentional focus (Newman, 1998).

A final attention deficit theory was proposed by Kosson (1998), who postulated the Left Hemisphere Activation Hypothesis of psychopathy, whereby difficulty in processing information in the left hemisphere and shifting attention from the left to the right hemisphere may contribute to attentional abnormalities. This theory was based on Kosson's research findings that psychopaths made more errors following cues presented in the right visual field (processed initially by the left hemisphere; Kosson, 1998).

The second cognitive component associated with psychopathy is a more global deficit of higher order cognitive process (Morgan & Lilienfield, 2000) termed executive function (EF), a process that underlies self regulation and goal-directed behavior (Loring, 1999). Welsh and Pennington (1988) theorized that EF's represent 'top-down' cognitive inputs that facilitate decision making by maintaining information about possible choices in working memory and integrating knowledge with information about the current context in order to identify the optimal action for the situation. This multi-step conception of EF incorporates distinct aspects of cognition that may be represented as a variety of abilities that include decision making, planning, working memory, and cognitive flexibility. The Tower of London Task is a good model to assess executive function due to the required use of several abilities within this umbrella construct. On this task, the stated goal is for participants to move colored beads between three vertical rods of different lengths in order to match a target arrangement displayed on three similar rods using as few moves as possible. Dolan and Park (2002) demonstrated that psychopaths have a poor performance on the Tower of London Task such that they solve significantly fewer problems with the minimum number of moves than controls and had prolonged thinking times subsequent to a first move. Poor planning for this task posits deficits in spatial working memory, a construct shown to engage the dorsolateral prefrontal cortex (DLPFC; Levy & Goldman-Rakic, 2000; Barch et al. 1997) and suggests that those with psychopathy have functional deficits in this neural region.

Executive function is specifically related to secondary psychopathy (Ross, Benning, & Adams, 2007; Sadeh & Verona, 2008) and thus the BAS. In addition, evidence suggests that secondary psychopathy is related to the externalizing spectrum of psychopathology

(Krueger et al. 2002), a spectrum of which a vast literature exists on executive dysfunction (i.e., conduct disorder, ADHD; Herba, Tranah, Rubia, & Yule, 2006; Barnett, Maruff, & Vance, 2009; Ford, Farah, Shera, & Hurt, 2007). Although aspects of executive dysfunction have been exhibited in various syndromes of disinhibition (Carter, Krener, Chaderijan, Northcutt, & Wolfe, 1995), the construct of disinhibition, also termed, behavioral inhibition, has been debated as to whether it is a separate and independent construct from executive function (Cheung et al 2004; Barkley, 1997). Nonetheless, behavioral disinhibition is an important facet of impulsivity. Measures related to rapid response have demonstrated that individuals with psychopathy had slower reaction times to commission errors than controls, suggestive of more difficulty in an ability to withhold a response (Swann, Lijffijt, Lane, Steinberg, & Moeller, 2009). In other words, individuals with psychopathy have poor inhibition of pre-potent responses (Newman & Kosson, 1986). Poor impulse control has been associated with ventromedial frontal lobe deficits (Damasio, 2000), and paralimbic areas extending to the orbitofrontal cortex (Horn, Dolan, Elliott, Deakin, & Woodruff, 2003).

The prefrontal cortex (PFC) is thought to be at the crux of executive functioning (Arnsten, 2006) and in fact there is general agreement in the field that cognitive deficits in psychopaths are associated with prefrontal dysfunction (Davidson, Putnam, & Larson, 2000). This is further substantiated with meta-analyses that demonstrated significantly reduced prefrontal structure and function associated with antisocial behavior (Yang & Raine, 2009).

Brain imaging research on psychopathic-like children (children who have callous-unemotional traits and disruptive behaviors) revealed abnormal ventromedial PFC function

(Finger et al. 2008) and reduced amygdala response to fearful expressions (Marsh et al. 2008) in comparison to a control subjects. The fact that these brain regions are consistent with those of adult psychopaths provides additional evidence for these regions to be involved in neural deficits associated with psychopathic behavior.

Further confirmation for the involvement of the PFC includes research on patients with frontal lobe damage that has brought about an ‘acquired’ psychopathic personality. Most notorious was Phineas Gage, a railway construction worker, who suffered severe damage to his prefrontal cortex and later developed a radical change to his personality that resembled psychopathy (Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994). More recent research with frontal lesion patients has also provided evidence that PFC impairment, specifically the ventromedial frontal lobe, contributes to poor impulse control (Damasio, 2000). These findings have given insight to a neurobiological model to explore such behaviors.

Impulsivity and Cardiovascular Activity (Unless otherwise noted, this summary was obtained from Berntson, Quigley, & Lozano, 2007; Rushmer, 1989.)

Background: Cardiovascular Physiology. The cardiovascular system is a complex physiological system with multiple regulatory mechanisms. An overview of the system and its central and peripheral autonomic and neuroendocrine controls will aide in understanding its susceptibility to neurobehavioral processes. In order for oxygenated blood to reach all tissues in the body, the heart pumps deoxygenated blood that is returning from previous systemic circulation via the right ventricle of the heart to the lungs for oxygenation. The blood then returns to the heart’s left ventricle where it is pumped into the aorta, a large blood vessel, from which the blood is then disseminated to the rest of the body through various sized arteries and capillaries. The time in which the heart is not pumping and is filling with blood is called the diastolic period, where as the time during which the heart is pumping the blood is called systolic, together comprising the cardiac cycle. The difference between systolic and diastolic blood pressure is called pulse pressure. The blood flow through the vessels is dependent on pressure and resistance of the vessel walls, affected by both the structure of the vessel (i.e., bumps or bends in the walls) and/or thickness of the blood in the vessel; when there is an increase in resistance, blood flow decreases. The resistance of blood flow creates the blood pressure, the force exerted by the blood against the vessel walls, which can vary across different parts of the circulatory system. Other mechanisms that affect blood flow to the heart are twofold: intrinsic and extrinsic. The primary intrinsic mechanism, called the Frank-Starling mechanism, occurs when increased stretching of the ventricles cause a stronger ventricle contraction due to a greater amount of blood returning to the heart than was pumped out on the preceding beat. This is important in order to maintain constant driving pressure in the system despite widely varying flow rates required to meet the changing requirements of various organs. Another intrinsic mechanism in the artery walls are pressure sensors, called baroreceptors that transmit impulses to the central nervous system at frequencies related to the fluctuating arterial pressure. These signals processed in the nervous system affect the extrinsic mechanisms associated with the regulatory process of blood flow, and include the autonomic and hormonal systems. The baroreceptor reflex circuit contains stretch receptor afferents from various arteries to the brainstem, specifically the nucleus tractus solitarius (NTS), a major visceral receiving station. Projections from the NTS impact sympathetic and parasympathetic neurons such that increasing blood pressure increases baroreceptor afferent action potentials, which increases parasympathetic activity, thereby decreasing heart rate.

The action of the sympathetic and parasympathetic nerve endings influence the interval between successive heart beats (see below). Acetylcholine discharged by parasympathetic vagus nerve endings increases the interval between beats thereby slowing the heart rate. Conversely, sympathetic nerve discharges of norepinephrine (noradrenaline) quicken heart rate. These autonomic influences on cardiac contraction are quite rapid, often within the interval of a single cardiac cycle.

Limbic and forebrain substrates are also involved in autonomic blood flow by regulating aforementioned reflex mechanisms. These higher neural controls are more variable and are responsive to emotions, such as stress or fear. The intercorrelations between these 'higher order' structures and the autonomic nervous system play a role within the cardiovascular system such that cognitive stressors drive predominantly stress responses from the autonomic nervous system (ANS; Lundberg & Frankenhaeuser, 1980). During a normal stress response, the heart rate increases which feeds the brain with energy via glucose and oxygen. The availability of oxygen in the blood is affected by sympathetic and para- sympathetic ANS control. Benarroch (1993) identified the central autonomic network (CAN), which is comprised of multiple higher neural structures with reciprocal interconnections and controls preganglionic sympathetic and parasympathetic neurons, among others.

Autonomic Reactivity

The autonomic nervous system (ANS) consists of two separately functioning subsystems, the parasympathetic and sympathetic nervous systems (PNS, SNS, respectively), which work together in a perpetual process of acclimating to meet individual and environmental demands (Bauer et al. 2002). The balance between these two subsystems is crucial to blood pressure stability; the PNS slows the heart through cholinergic activity and the SNS elevates heart rate and blood pressure by enhancing norepinephrine activity (Wong et al. 2007). Several decades of psychophysiological research has provided extensive data that demonstrate the association between externalizing behaviors and low autonomic arousal (Hare, 1978; Raine et al. 2000; Herpertz et al. 2001; Lorber, 2004). More recently, there is accumulating evidence for a broad externalizing vulnerability factor, conceptualized as risk for multiple disorders within the externalizing spectrum (Krueger et al. 2005), that is highly heritable (for reviews see Hare, 1978; Lorber, 2004) and associated with reduced physiological responding (Baker, 2009; Raine, 2002).

In order to understand the relationship of individual differences of the ANS and externalizing traits, several different aspects of ANS activity have been measured such as heart rate (HR), electrodermal activity (EDA), and blood pressure (BP). The use of these non-invasive measures (versus angiography for example) has allowed for examination of different classes of autonomic activity in a laboratory setting, such as resting state (basal levels), response to tasks or stressors (e.g., reactivity), as well as recovery from stress. Cardiovascular reactivity (CVR), in particular, is a response conceptualized as a trait characteristic and measures changes in cardiovascular functions (i.e., blood pressure, heart rate, heart rate variability) elicited by challenging tasks (Kamarck & Lovallo, 2003). These tasks are situations that require attentional engagement and require adaptive responding, either cognitively or motorically (Kamark and Lovallo, 2003). Further, different types of tasks have been used experimentally, from physically challenging, such as the cold pressor test whereby one's hand or foot is placed in ice water, to psychologically challenging, such as the mental arithmetic test that requires one to count backwards in 7's from a high number. Evidence has suggested that cognitive tasks tend to have more robust individual differences in cardiovascular reactivity, than physically challenging tasks (Kamarck & Lovallo (2003).

Linden, Gerin and Davidson (2003) describe the importance of studying CVR as a 'window into complex psychological and physiological processes that are involved in the development of disease'. In terms of reliability, behaviorally evoked cardiovascular reactivity has been shown to be relatively stable within an individual and consistent across time (Sherwood et al. 1995). In fact, a meta-analysis (Treiber et al. 2003) showed that CVR in the laboratory successfully predicted subsequent BP levels up to six years later with replication across tasks and time. However, the generalizability of laboratory reactivity predicting cardiovascular responses in the natural environment has been debated (Schwartz et al. 2003). Although the vast majority of the cardiovascular reactivity literature has focused on this construct as a risk marker for the development and progression of cardiovascular diseases, there is recent interest in the neural correlates of such responses (Critchley, Corfield, Chandler, Mathias, & Dolan, 2000), which suggests the construct may be applied also to the study of trait measures of personality and temperament.

Three cortical brain systems, orbitofrontal cortex, anterior cingulate cortex, and the insular cortex, have consistently been associated with cardiovascular reactions to stressors (Critchely, Corfieled, Chandler, Mathias, & Dolan, 2000). While there is scarce information regarding neural correlates of individual differences in CVR, there is one study that found the posterior cingulate cortex to be differentially associated with CVR such that individuals that had exaggerated CVR to a cognitive stressor showed an increase in posterior cingulate activation in comparison to those individuals that had an attenuated response who showed a decrease in posterior cingulate activation (Gianaros, May, Siegle, & Jennings, 2005).

In order to further understand individual differences associated with CVR, researchers have looked at trait characteristics with the idea that characteristic response style may be associated with physiological response disposition. Substantiating this concept is the temperament theory which refers to one’s personal habitual response style thought to be biologically based due to these characteristics believed to manifest from birth (Strelau, 1983). Individual perceptions and interpretations can influence hypothalamic and brainstem control centers from which cardiovascular activity may be altered (Lovallo & Gerin, 2003) in preparation for a fight or flight response (Kamarck & Lovallo, 2003). Therefore, temperament provides a plausible avenue to study the central nervous system bases for cognitive emotional tendencies (Lovallo & Gerin, 2003). More specifically, these control centers are associated with McNaughton and Gray’s (2000) fear-related behavior, termed, ‘defensive direction’, and thus related to the behavioral inhibition system.

The examination of the association between individual differences and CVR has been helpful in attempts to find preclinical markers in individuals at risk for many different types of diseases. For example, the reactivity hypothesis states that exaggerated CVR may serve as a risk marker for cardiovascular disease (Manuck, 1994). Within this model, the interpretation for a putative relationship between CVR and disease is twofold; exaggerated responses are seen as the cause of disease versus a signal for elevated risk without direct causation (Lovallo & Gerin, 2003; Linden, Gerin, & Davidson, 2003). Analogously, we can apply this paradigm in research designed to identify risk markers in psychopathy-prone individuals, which may provide opportunity for early intervention during childhood or adolescence due to the great harm and costs these individuals pose to society.

Beginning in 1957, Lykken (1957) utilized a shock paradigm and demonstrated that psychopaths exhibit poor aversive conditioning of the EDA; he attributed these results to poor fear conditioning. Since that time, electrodermal hyporeactivity has been one of the most replicated correlates in psychopathy (Fowles, 2000). Fowles (1980) proposed that psychopathy could be understood as a consequence of weak BIS functioning. He cited a range of evidence that linked psychopathy to weak skin conductance responses in anticipation of aversive events, and other BIS- related deficiencies. The fact that psychopaths have frequently demonstrated to be electrodermally unresponsive to threats of punishment is consistent with previous discussions of a psychopath's failure to learn from punishment and an inadequately developed conditioned anticipatory fear response. Due to this putative deficient fear response in psychopaths, research on autonomic responsivity in psychopaths has mainly focused on assessing their response to aversive stimuli (Arnett, 1997). Results from these studies have steadily provided evidence for hyporesponsivity in psychopathic adults (Raine, 1996; Fowles, 2000), institutionalized adults (Kruesi, 1992), as well as psychopathy-prone adolescents (Fung et al, 2005). In 1990, Raine, Venables, & Williams (1990) provided evidence to implicate underarousal in three response systems, electrodermal, cardiovascular, and cortical, in the development of criminality. Similarly, associations between psychopathy and reduced heart rate reactivity have been demonstrated (Arnett, Howland, Smith, & Newman, 1993; Raine, 1996; Osumi, Shimazaki, Imai, Sugiura, & Ohira, 2007). In contrast however, some heart rate reactivity data have shown normal or even greater heart rate reactivity in psychopaths in comparison to controls while anticipating aversive stimuli (Hare & Quinn, 1971; Ogloff & Wong, 1990; Tharp et al., 1980). While physiological arousal to aversive or stressful situations in psychopathy appears to be inconclusive, resting heart rate measures have been somewhat more reliable. Raine (2000) demonstrated that psychopathic adults have lower resting heart rate in comparison to controls. In addition, low resting heart rate is associated with violence (Farrington, 1997) and antisocial and aggressive behavior in children and adolescents (Raine, 2002). Indeed, a meta-analysis has shown that an autonomic disturbance is one of the strongest and most replicated physiological correlates of antisocial behavior in children and adolescents (Ortiz & Raine, 2004).

In concert with the vast amount of literature that describes some type of association between psychopathy and psychophysiological responses, there are competing theoretical interpretations. Two main theories (Sijtsema et al. 2010) are often given to explain the relationship between psychopathy and low arousal, both of which are related to impulsive personality traits. The first is the fearlessness theory, a general lack of anxiety and fear (Raine, 2002). This theory is associated with a disinhibited temperament and thus with the BIS trait. Consistent with the RMH model, psychopathic and non-psychopathic offenders display comparable behavioral and psychophysiological responses to threat cues when they are the focus of attention, but psychopathic individuals display significantly weaker responses when they are focused on earning rewards (Arnett, Smith & Newman, 1997). In addition, Raine (1996) reviewed a number of studies that have found prospective relationships among a disinhibited temperament and reduced autonomic activity. The second theory explaining reduced arousal is a sensation seeking theory (Eysenck, 1997; Quay, 1965) in which one's state is under constant underarousal and there is a need to behave antisocially in order to increase heart rate and approach a more comfortable and optimal state.

Yet the question remains whether either of these impulsive personality traits, disinhibition and/or sensation seeking, may be the link between autonomic response and maladaptive behavior. Of particular interest is heart rate variability (HRV), another measure of the autonomic nervous system. HRV is the variation in time between heart beats. This variation is mediated by phasic increases and decreases in neural efferent output to the heart. The greater the amplitude of variation in this rhythmic pattern, the greater the range potential for an individual's response/behavior and the healthier the individual (Porges, 1992). Porges (1992) showed that during exposure to sustained attention tasks, HRV decreased which may be explained as a stressful perception of the attention task. Furthermore, reductions in HRV have been shown to be associated with panic disorder (Friedman and Thayer, 1998) and depression (Nugent, Bain, Thayer, Sollers, & Drevets, 2011). Friedman and Thayer (1998) conclude that this HRV decrease is consistent with psychological symptoms of ineffective emotional regulation, poor attention control, and behavioral inflexibility. Thus, HRV may be associated with attention and self-regulation, including emotion. Hansen, Johnson, Thornton, Waage, & Thayer (2007) conducted a study that investigated whether psychopathy is related to cardiac function, and cognition. Results suggested that antisocial personality, as measured on the PCL-R, is positively related to baseline HRV, however, this relationship was not sustained during the computerized tasks that assessed working memory (2-back task) and attention (continuous performance test; CPT).

A ‘neurovisceral integration’ model has been proposed by Thayer and Lane (2000) and discusses a relationship between HRV and the central nervous system (CNS). Based on a review of studies, including pharmacological and neuroimaging studies, the authors provided evidence that links HRV to prefrontal neural circuits, specifically the anterior cingulate. The authors further suggest that HRV serves as an index of inhibitory control, due to their reviews of higher levels of resting HRV in association with superior performance on executive function tasks. It would follow then, that psychopathic individuals, who have lower HRV, would have deficient executive function, and thus a weak BIS. This model of neurovisceral integration may help explain why neurocognitive deficits and autonomic activity are the two most well-documented facets of psychopathy. The fact that the circuit involves prefrontal neural function substantiates this model as an explanation toward understanding psychopathy. Further corroboration for the association between prefrontal cortical functions and cardiovascular health was suggested in findings of disrupted ANS responses in patients with lesions in the prefrontal cortex (Cheung & Hachinski, 2000; Colivicchi, Bassi, Santini, & Caltagirone, 2004).

Summary and conceptual model: Cardiovascular reactivity and impulsivity. The cardiovascular processes involved in abnormal stress responses, as described earlier among individuals who exhibit impulsive or externalizing behaviors, remain somewhat elusive. At a higher cognitive level that encompasses evaluation of a particular situation, temperament and the neurophysiology of emotions may play a role in determining reactivity (Lovallo & Gerin, 2003). Further, emotional reactions are then translated into autonomic or endocrine outputs at the hypothalamus or brainstem that also contribute to and/or interact with CVR (Lovallo & Gerin, 2003). These higher order components then lead to the most obvious and simple physiological explanation of low arousal. Hence, there is an integration of multiple systems that may be active in shaping the relationship between heart rate and antisocial/aggressive behavior (Raine, 2002). Putative mechanisms to further explain such relationships include 1) low vagal tone (Raine & Venables, 1984; Mezzacappa et al., 1997) that stems from a lack of parasympathetic influences in concert with strong sympathetic underarousal, 2) reduced noradrenergic functioning (Raine, 1993; Rogeness, Javors, Mass, & Macedo,1990), which along with the locus coeruleus forms an arousal system in the brainstem that may cause underarousal of the sympathetic nervous system, and 3) right hemisphere functioning due to its dominance for control of autonomic functions (Lane & Jennings, 1995). Several human studies support the concept that the neural sympathetic activity regulating the cardiovascular system undergoes primary modulation by the right cerebral hemisphere

(Cereda, Ghika, Maeder, & Bogousslavsky, 2002; Hilz, Dutsch, Perrine, Nelson, Rauhut, & Devinsky, 2001; Meyer, Strittmatter, Fischer, Georg, & Schmitz, 2004). Lesion and stroke studies confirm that reduced heart rate is associated with decreased right hemisphere functioning (Zamrini et al., 1990; Yokoyama, Jennings, Ackles, Hood, & Boller, 1987). Additionally, poor right hemisphere functioning has been associated via fMRI with antisocial behaviors (Raine et al., 2001). Further, anterior regions of the right hemisphere have been associated with deficits in the withdrawal system, a system that stimulates a flight reaction from aversive situations (Davidson Eckman, Saron, Senulis, & Friesen, 1990).

Aims

The construct of impulsivity is multidimensional as evidenced in symptoms occurring across a range of psychiatric and personality disorders. Previous studies have elucidated multiple latent factors that represent impulsive personality traits. We believe there are two divergent personality traits that give way to impulsive tendencies. The first, disinhibition, has been theorized as stemming from a weak behavioral inhibition system (BIS). Both the trait and the system have been associated with fearlessness, lack of anxiety, and a weaker inhibition. The second, sensation seeking, has been theorized to be associated with the behavioral approach system (BAS) and is correlated with goal-directed behavior, novelty seeking, and excessive reward sensitivity. Recent studies found that various behaviors and forms of psychopathology were differentiated by distinct aspects of impulsive personality, as well as impaired neurocognitive abilities. Therefore, we set out to further explore the differential association of disinhibition versus sensation seeking with neurocognitive functioning among young adults. As reviewed above, a growing body of research has implicated impulsive personality traits in association with psychopathy. More specifically, the BIS and BAS have neatly mapped onto two divergent factors of psychopathy. Further, the current literature debates various putative cognitive deficits in an attempt to understand these patterns of psychopathic behavior. As reviewed, the literature has suggested that psychopaths have a deficit in emotional brain circuitry to explain their lack of response to aversive cues and punishment. Within that same framework, results from studies suggest that psychopaths have an attentional deficit that precludes their ability to process affective information when it is peripheral to their attentional focus. Other theorists have posited the etiology of a psychopaths behavior results from a lack of cognitive flexibility due to a goal-oriented focus. In order to better understand the underlying explanation for these varied findings, we set out to differentiate putative cognitive models associated with the well-accepted divergent factors (1 and 2) of psychopathy and their relationship to impulsivity. However, because cognitive deficits extend to several different impulsive disorders, we set out to explore the two dimensions of impulsivity; sensation seeking and disinhibition. If a dimension(s) of impulsivity is a trait for psychopathy, we should see a dimensional relationship to the normal population (Gottesman & Gould, 2003; Kendler & Neale, 2010).

Therefore, we employed the use of the two trait characteristics associated with Factors 1 (disinhibition) and 2 (sensation seeking) of psychopathy within a young adult population in order to determine if personality traits are associated with cognitive performance. These results may then be extended to aide in the understanding of cognitive differences seen in psychopathy. Due to previous studies that have found attention deficits associated with processing affective information, we hypothesize that 1) the BIS will be associated with attention, more specifically that increased BIS will be associated with increased vigilance. Due to studies that have found associations between cognitive flexibility and a goal-oriented focus, we hypothesize that 2) cognitive flexibility will be negatively associated with the BAS.

Many of the cognitive deficits described above are associated with prefrontal neural correlates that are also related to ANS function. The neurovisceral intergration model, in concert with vast literature surrounding patterns of autonomic nervous system arousal as a primary facet of psychopathy, warranted our study of psychophysiological response to stress in association with disinhibition and sensation seeking. In line with low arousal theories, we hypothesized that 3) those with increased disinhibition, that is fearlessness and weaker inhibition, would have attenuated reactivity to stress, specifically with cognitive tasks. If these two facets, neurocognitive ability and psychophysiological response to stress, are differentially associated with the proposed two trait characteristics, it would not only give us insight toward the etiology of psychopathy, but perhaps all impulsive disorders.

In sum, this experiment examined the relationships between sensation seeking and disinhibition with cognitive performance and cardiovascular reactivity among young adults.

METHOD

Participants

Participants were 76 students (31 male; 41%) who were recruited from two ongoing studies (parent studies) based at Queens College. All psychology 101 students are required to participate in a subject pool from which our participants were recruited. Participants ranged in age from 18-23, mean (sd) = 19.36 (1.28) and 96% were full time students.

Participants from the parent studies were recruited to participate in this additional experiment that included neuropsychological testing and a cardiovascular reactivity protocol. The psychophysiology protocol was added after the initiation of the study and data for that aspect of the study are available for only 58 participants. The sample was ethnically diverse with 51% describing themselves as Non-Hispanic Caucasian, 12% African American, 18% Hispanic or Latino, 11% Asian, and 8% mixed or other ancestry. Participants were compensated $20.00 for their participation in this additional protocol.

This study was approved by the Institutional Review Board of Queens College, City University of New York. Participants signed informed consent for participation in the study.

Procedures

As part of the parent protocols, participants indicated on the consent form whether they were willing to be re-contacted for a follow-up assessment. Students that gave informed consent were contacted by either phone or email; an appointment was set after a brief screening interview. Participants from the parent studies were not scheduled for this study if they regularly took medication that is associated with cardiovascular functioning (e.g., allergy medication, appetite suppressant) or if females took a birth control pill. Participants were asked to refrain from the following for two hours prior to their scheduled appointment: eating, drinking alcohol or caffeine, using tobacco, or engaging in strenuous exercise. During the consent process, all participants verbally confirmed that they had not engaged in these behaviors.

Upon arrival at the laboratory, informed consent was obtained and measures of height, weight and waist–to-hip-ratio were obtained for the purpose of using these measures as covariates in psychophysiological analyses due to the relationship between waist-to-hip-ratio and cardiovascular disease (Hu, Tuomilehto, Silventoinen, Barengo, & Jousilahti, 2004). Female participants were also asked to provide the date of their last menstrual period and average cycle length so that menstrual phase could be determined and also used as potential covariates.

Cardiovascular and Subjective Reactivity to Acute Stressors. Systolic and diastolic blood pressure and heart rate were monitored while participants performed two standardized laboratory tasks designed to resemble everyday stressors. Participants were seated in a recliner chair and an automated blood pressure (BP) monitor (Datascope Corp, Mahwah, N.J.) measured BP with a cuff around the left upper arm. Systolic and diastolic measures were read with estimated beats per minute (BPM) interpreted as heart rate (HR). Inflation was set to automatically trigger during tasks. First, however, a practice reading was obtained to reassure participants of the sensation. Participants were instructed to remain relatively still during measurements. Then, during a 15-minute baseline period, heart rate and blood pressure readings were taken at 9, 11 and 13 minutes while participants sat comfortably in the chair listening to relaxing sounds on headphones. The participants were then asked to complete a Mood Rating scale to assess current mood and subjective responses to the task. The scale asks the subject to rate 8 mood states from 0-3 (0 = not at all, 1 = a little bit, 2 = some, and 3 = a lot) and is administered to ensure mood congruency with relaxed state (and later stressed states). Next, the subject was asked to complete a Serial Subtraction (mental arithmetic) test and the Speech Task (Al' Absi, Bongard, Buchanan, Pincomb, Licinio & Lovallo, 1997; order counterbalanced). Three measures of heart rate and blood pressure were simultaneously assessed at 1-minute intervals during each of the tasks, and after each task the participants were again asked to complete the Mood Rating scale**.** Between tasks, a five-minute rest period was provided with the participants listening to relaxing sounds. At the end of this period another heart-rate/blood pressure reading was measured to confirm that the participants returned close to their prior physiological relaxed state before beginning the second test.

Experimental Tasks

The Serial Subtraction test required the subject to verbally subtract 7 from a four-digit number continually for three minutes. The interviewer (RLP) remained in the room, reminding subjects of the last correct response if they made a mistake and encouraged them to go faster. During the Speech Task, participants were told to pretend that while shopping in a department store, they were falsely accused of shoplifting by a security guard. They were given 30 seconds to prepare a two-minute speech to explain why the police should not be called, that they then presented to the store manager (researcher RLP). The participants were informed that they would be videotaped so that they could be rated for poise, articulation, and personal appearance. The video camera, however, was never turned on and no video recordings were created. Participants were not debriefed in order to maintain the integrity of the study and prevent discussion among participants.

Personality Trait Assessment. As part of the parent studies, participants had already completed the Barratt Impulsivity Scale (BIS-10-R; Barratt, 1985, 1994) and the Zuckerman Sensation Seeking Scale (ZSSS V; Zuckerman, 1979). The BIS-10-R is a 30-item questionnaire with three subscales that tap self-control of thoughts and behaviors (e.g., acts without thinking, decides on the spur of the moment, does not plan ahead). Subscales include motor, cognitive and nonplanning impulsivity. The 30 items on the BIS had adequate internal consistency (alpha coefficient = .60). Internal consistency for each of the subscales was as follows: Non-planning subscale = .42; Motor subscale = .58; Cognitive = .28. The ZSSS V is a 40-item scale that measures an individual's preference to seek novel and complex experiences. The scale has four subscales, named Thrill and Adventure seeking, Experience Seeking, Boredom Susceptibility and Disinhibition. The Scale had internal consistency with alpha coefficent = .82 across our sample. Internal consistency for the subscales of the ZSSS V were as follows: Boredom Susceptibility = .42; Disinhibition = .82; Experience Seeking = .46; Thrill and Adventure Seeking = .81. These two scales were used to represent Disinhibition (e.g., our measure of the BIS) vs. Sensation-Seeking (e.g., our measure of the BAS) aspects of impulsivity.

Neuropsychological Assessment. Evaluation of participants' neuropsychological functioning was conducted in order to assess whether reward seeking versus constraint are associated with different aspects of cognitive dysfunction or whether these traits are related to overall cognitive impairment. The neuropsychological test measures examined three areas of cognitive functioning: IQ (intelligence), executive function, and memory skills.

Neuropsychological measures

Intelligence. The Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was employed to assess IQ. The two-subtest version that includes Vocabulary and Matrix Reasoning was used, yielding an estimate of general intelligence.

Executive functioning. The Stroop (Stroop, 1935) test includes three sections (color naming, word reading and interference) and is designed to establish competing response tendencies and ability to suppress the interfering stimuli, thereby inhibiting a wrong response. The Trail Making Test (Giovagnoli, et al., 1996) is a visual conceptual and visuomotor tracking task and is sensitive to the participants' ability to shift sets and process concurrent stimuli. The Digit Vigilance Task (Lewis & Rennick 1979) is a paper and pencil test that required selective attention during rapid visual tracking. Participants were asked to cross out an assigned number that is embedded among other numerical digits, and were told to do this as quickly as possible.

Memory. In order to evaluate verbal memory, the California Verbal Learning Test – Second Edition (CVLT II; Delis, Kramer, Kaplan & Ober, 2000) was conducted to assess participants' ability to learn a list of 16 nouns that are presented verbally five times. Short and long delay retrieval, recognition memory, proactive interference from a new list, and clustering are all assessed by number of nouns correctly recalled for each condition. To evaluate visual memory, Family Pictures I (immediate) and Family Pictures II (delayed 25 minutes) sub-tests of the Wechsler Memory Scale –Third Edition (WMS-III; Wechsler & Stone, 1945) were employed during which participants were asked to memorize as many details as they can from four different cartoon-like family scenes. After the four scenes were displayed for 10 s each, the examinees were prompted to describe which characters were in each scene, where they were positioned, and what they were doing. After a delay (25 minutes), the participants were asked the same questions as in Family Pictures I.

Data Analyses

Gender differences were tested with a t-test for equality of means with regard to trait scores, IQ scores, cardiovascular data, and neuropsychological tests. Note that given the restricted age range (18-23 years), associations between age and the above mentioned measures were not tested. Pearson correlations were conducted to reveal the relationships among the subscales of the personality questionnaires, the cardiovascular variables, and the neuropsychological test scores.

Neuropsychological data analysis. A series of linear regression analyses was conducted to evaluate the association of reward-seeking and constraint with measures of cognitive functioning including executive function and memory; each measure was assessed separately (i.e., Stroop, Trails, CVLT short term memory). In the first step of these analyses, we entered gender and IQ. In the second step, we included the two dimensional measures of impulsiveness.

Cardiovascular data analyses. Mean values of each physiological measure (systolic blood pressure [SBP], diastolic blood pressure [DBP], and HR) derived from the three readings for the baseline and each experimental period (serial subtraction and speech task) were calculated. As a measurement of cardiovascular response during stress, delta (reactivity) scores for each cardiovascular variable (SBP, DBP, HR) were created by subtracting the mean baseline from the mean of each experimental period. Pearson correlations were used to assess the relationship between personality traits and cardiovascular reactivity variables. The experimental tasks were presented in a counterbalanced order to neutralize order effects and repeated measures analysis of variance (ANOVA) was performed assessing task-order as a between subjects factor for the cardiovascular reactivity variables, to determine that there was no order effect for the tasks (F = 0.05; df = 1; p = 0.82).

A series of regression analyses was conducted to evaluate the association of sensation-seeking and disinhibition with cardiovascular reactivity variables including baseline, serial subtraction and speech. In the first step of these analyses, we entered any resultant confounding variables (i.e., gender, baseline cardiovascular measure) and in the second step, we included the two dimensional measures of impulsiveness.

RESULTS

Impulsivity

Disinhibition for the 76 participants, as measured by Barratt Impulsivity Scale total score, had a mean (sd) = 66.51 (9.79), while the sensation seeking personality trait, as measured by Zuckerman Sensation Seeking Scale total score, had a mean(sd) = 57.20 (6.39). There were no gender differences with regard to trait scores, and race and IQ were not correlated with either trait scale (see Tables 1 and 2).

Table 1

Impulsive Personality Trait Means by Gender

	Gender			
	Male	Female	*t*	*p*
Barratt Impulsivity Scale				
Total Score	66.97 (11.01)	66.20 (8.97)	0.33	0.74
Non Planning Subscale	26.03 (4.93)	25.24 (4.57)	0.72	0.48
Motor Subscale	21.65 (4.77)	21.27 (3.67)	0.39	0.70
Cognitive Subscale	19.29 (3.92)	19.69 (3.57)	-0.46	0.65
Zuckerman Sensation Seeking Scale				
Total Scale	58.16 (6.06)	56.53 (6.60)	1.09	0.28
Thrill and Adventure Seeking Subscale	16.81 (2.79)	15.76 (2.87)	1.59	0.12
Experience Seeking Subscale	14.10 (2.01)	14.38 (2.15)	-0.58	0.57
Disinhibition Subscale	14.52 (2.66)	14.13 (2.50)	0.64	0.53
Boredom Susceptibility Subscale	12.74 (1.51)	12.27 (1.83)	1.20	0.24

Note: Standard Deviations appear in parentheses below means.

Table 2

Impulsive Personality Trait Correlations with IQ and Race

	Barratt Impulsivity Scale Total Score	Zuckerman Sensation Seeking Scale Total Score
IQ	.08	.16
Race	-.08	-.09

Note. IQ estimate according to the Wechsler Abbreviated Scale of Intelligence.

Cognitive, Motor, and Nonplanning, as measured on the Barratt Impulsivity Scale subscales, were all significantly intercorrelated as were the subscales of the Zuckerman Sensation Seeking Scale, Thrill and Adventure seeking, Experience Seeking, Boredom Susceptibility and Disinhibition. On a global level, disinhibition was correlated with sensation seeking with regard to total scores (see Table 3).

Table 3

Impulsive Personality Trait Correlations

	Barratt Impulsivity Scale Total Score	NonPlanning Subscale	Motor Subscale	Cognitive Subscale
Zuckerman Sensation Seeking Scale Total Score	.26*	.19	.14	.27*
Thrill and Adventure Seeking Subscale	-.09	-.08	-.06	-.08
Experience Seeking Subscale	.25*	.26*	.11	.22
Disinhibition Subscale	.30**	.26*	.12	.32**
Boredom Susceptibility Subscale	. 36**	.15	.32**	.39**

Note: ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

At the factor level, while subscales of the Barratt Impulsivity Scale were mostly correlated with the subscales on the Zuckerman Sensation Seeking Scale, the Thrill and Adventure Seeking subscale on the Zuckerman Sensation Seeking Scale was not related to any subscale on the Barratt Impulsivity Scale, indicative of the independence of the Thrill and Adventure Seeking Scale from disinhibition.

Neuropsychological Performance

Gender differences. A t-test of equality of means revealed a significant difference between men and women on the digit vigilance task, $t(74) = -2.16$, $p = .03$. Women made more omission errors than men (mean errors = 9.4:6.0, respectively) suggesting mild attention differences between men and women. There were no other gender differences for the neuropsychological performance measures, including IQ (see Table 4 for mean scores).

Table 4

Neuropsychological Performance Means by Gender

	Gender			
	Men	Women	*t*	*p*
IQ	102.40 (11.77)	98.69 (10.02)	1.47	.15
Wechsler Memory I	45.87 (8.76)	45.78 (10.16)	.04	.97
Wechsler Memory II	44.61 (8.91)	46.51 (9.64)	-.87	.39
California Verbal Learning Test - Trials 1-5	55.00 (8.23)	56.02 (6.63)	-.60	.55
California Verbal Learning Test - Short Delay	11.55 (2.94)	11.42 (2.93)	.18	.85
California Verbal Learning Test - Long Delay	11.77 (2.72)	12.16 (2.35)	-.65	.52
California Verbal Learning Test – Recognition	15.42 (.85)	15.33 (.98)	.40	.69
Stroop	.94 (8.06)	1.09 (7.67)	-.84	.93
Digit Vigilance Test Total Time	5.80 (1.11)	5.39 (.88)	1.78	.08
Digit Vigilance Test Omission Errors	6.03 (5.06)	9.44 (7.70)	-2.16	.03*
Trails	31.48 (13.93)	29.98 (15.28)	.44	.66

Note: Standard Deviations appear in parentheses below means. IQ estimate according to Wechsler Abbreviated Scale of Intelligence (WASI); Trials = Trails B score – Trails A score; *p < .05.

Cognitive performance. IQ was positively correlated with CVLT trials 1-5 (r(74) = 0.36, $p < 0.001$), indicating that one's learning skills are associated with general intelligence. Extending this association such that one's intelligence is also associated with ability to consolidate and retrieve the learned information, IQ was also positively correlated with CVLT short delay (r(74) = 0.28, p = 0.02) and CVLT long delay (r(74) = 0.31, p = 0.01). Performance on the Trail Making Test was negatively correlated with CVLT trials 1-5 (r(74) = -0.24, p = 0.03) suggesting that better executive function is associated with learning. In line with what one might intuit, DVT omission errors were negatively correlated with DVT total time (r(74)= -0.32, p = 0.01) indicating that the more time one spent on the task, the fewer errors he or she made. Visual attention was consistent between timed and un-timed visual tasks such that DVT omission errors was negatively correlated with WMS (visual acuity) for both short delay (r(74) = -0.32, p = 0.01) and long delay (r(74) = -0.32, p = 0.01). Short and long term memory functions were consistent within verbal and visual domains; WMS short and long delays were both positively correlated with each other (r(74) = 0.92, $p < 0.00$) as well as CVLT trials 1-5, CVLT short delay and CVLT long delay (all p values < 0.01).

Impulsivity and cognitive performance. In terms of impulsivity, the Barratt Impulsivity Scale scores were not significantly correlated with any of the results from the neuropsychological tests. The Zuckerman Sensation Seeking Scale scores were positively correlated with DVT total time (r(74) = 0.26, p=0.03). Additional significant findings in hierarchical regression analyses that included gender and IQ in step one and Barratt Impulsivity Scale (Disinhibition) and Zuckerman Sensation Seeking Scale (Sensation seeking) in step two, revealed a significant relationship between impulsivity and DVT total time (F (2, 74) = 2.45, p = 0.03). This relationship may indicate that the vigilance task was perceived as rewarding with incentive motivation, perhaps for the monetary compensation or simply for the novel sensation experienced by the task. See Table 5 for cognitive correlations with impulsive personality traits.

Table 5

Correlations Among Impulsive Personality Traits and Neuropsychological Performance

	IQ	Trails	Stroop	DVT Total Time	DVT Omit Errors	WMS I	WMS II	CVLT Trials 1-5	CVLT Short Delay	CVLT Long Delay	CVLT Recognition	BIS	ZSSS
IQ	1.00	-.20	.07	.14	-.12	.16	.21	.36**	.28*	.31**	.09	.08	.16
Trails		1.00	-.09	.13	.02	-.17	-.21	-.25*	-.09	-.14	-.07	-.11	.11
Stroop			1.00	.08	.06	-.15	-.10	.05	.07	.09	-.01	-.07	-.14
DVT Total Time				1.00	-.32**	.02	.03	-.07	-.02	-.05	-.001	-.11	.25*
DVT Omission Errors					1.00	-.32**	-.32**	-.04	-.02	-.08	-.11	-.14	-.14
WMS I						1.00	.92**	.26*	.27*	.33**	.11	.03	.20+
WMS II							1.00	.30**	.34**	.39**	.18	.06	.14
CVLT Trials 1-5								1.00	.59**	.72**	.28*	.06	.05
CVLT Short Delay									1.00	.77**	.50**	.02	.12
CVLT Long Delay										1.00	.51**	.06	.03
CVLT Recognition											1.00	.10	-.04

Note: BIS = Barrett Impulsivity Scale total score; ZSSS = Zuckerman Sensation Seeking Scale total score; IQ = IQ estimate according to the Wechsler Abbreviated Scale of Intelligence; Trails = Trails B score – Trails A score; DVT = Digit Vigilance Task; CVLT = California Verbal Learning Test; *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed); + trend – correlation below 0.085

Cardiovascular activity

While participants were at rest, listening to relaxing music for 15 minutes, heart rate and blood pressure were assessed for the purpose of establishing baseline. Mean measures of systolic blood pressure, diastolic pressure, and heart rate for the sample as a whole during this baseline period, as well as during the two stressful tasks (speech and serial subtraction) are presented in Table 6.

Table 6

Mean Cardiovascular Measures Among Participants

	Systolic Blood Pressure	Diastolic Blood Pressure	Heart Rate
Baseline	109.26 (9.15)	64.06 (6.31)	68.47 (9.43)
Speech Task	125.77** (13.25)	75.36** (9.05)	82.22** (11.32)
Serial Subtraction Task	121.10 ** (12.39)	72.46** (7.12)	79.82** (10.16)

Note: Standard Deviations appear in parentheses below means; * indicates significant change from baseline at the p < .05; ** indicates significant change from baseline at the p < .01.

Mood Ratings. Perceived stress levels (mood ratings) increased during each of the tasks such that a change in stress as reported on a likert scale (0-3) for eight separate items from baseline to serial subtraction task was reported with a total mean (sd) = 5.52 (3.4) and the change in perceived stress level from baseline to speech task was reported as total mean (sd) = 5.57 (3.45). Paired sample t-tests showed that stress level changes from baseline to each task were significant (serial subtraction: t(57) = -11.25; p < .001; speech: t(57) = -10.50; p < .001) yet stress level changes between the two tasks was not significant (t(57) = .258; p = .81).

Gender differences. There were significant gender differences during cardiovascular activity such that mean (sd) baseline systolic blood pressure values were higher in men in comparison to women (t(56) = 3.65; p= 0.001; see Table 7). Similarly, gender differences were observed during the speech task and serial subtraction task such that men had higher mean systolic blood pressure values than women (t(56) = 2.64; p = .01; t(56) = 3.78; p < 0.001, respectively).

Table 7

Cardiovascular Activity Means by Gender

	Gender			
	Men	Women	t	*p*
Baseline				
Systolic Blood Pressure	114.00 (8.52)	105.92 (8.13)	3.65	<.01**
Diastolic Blood Pressure	64.17 (6.50)	63.98 (6.27)	.11	.91
Heart Rate	70.31 (9.27)	67.18 (9.47)	1.25	.22
Speech Task				
Systolic Blood Pressure	130.97 (14.15)	122.10 (11.41)	2.64	.01*
Diastolic Blood Pressure	75.39 (11.30)	75.33 (7.25)	.02	.98
Heart Rate	83.03 (11.77)	81.66 (11.14)	.45	.65
Serial Subtraction Task				
Systolic Blood Pressure	127.69 (12.07)	116.45 (10.47)	3.78	<.01**
Diastolic Blood Pressure	73.36 (7.69)	71.82 (6.73)	.81	.42
Heart Rate	80.69 (9.76)	79.20 (10.53)	.55	.56

Note: Standard Deviations appear in parentheses below means. *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).

Changes from baseline. Repeated measures ANOVA revealed that mean blood pressure (both systolic and diastolic) and mean heart rate differed statistically significantly from the baseline period to each of the two stress tasks (see Table 6). Mean *change* from baseline to serial subtraction readings for the sample as a whole was as follows: systolic blood pressure = 11.84 (7.22), diastolic blood pressure = 8.4 (6.17), and Heart Rate = 11.34 (7.76). Mean change from baseline to speech readings for the sample as a whole was as follows: systolic blood pressure = 16.34 (10.14), diastolic blood pressure = 11.28 (8.49), and Heart Rate = 13.75 (8.65). Significant differences were also observed between the math task and the speech task with higher mean values observed during the speech task for all cardiac measures (mean systolic blood pressure; (F (1, 57) = 166.96, $p < .001$), mean diastolic blood pressure; (F (1, 57) = 104.38, $p = .02$), and mean heart rate; (F (1, 57) = 146.59, $p = .03$). No gender differences were revealed with regard to any reactivity changes from baseline (all p's > 0.1). See Figures 1, 2, and 3.

Figure 1

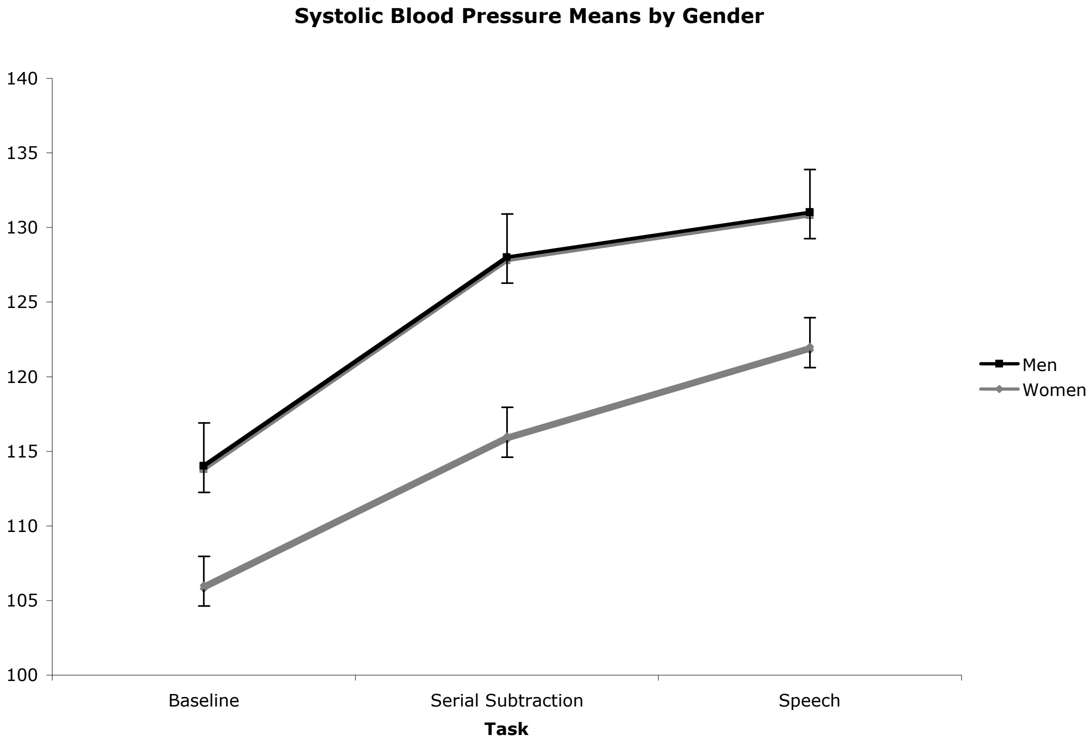

Systolic Blood Pressure Means by Gender
140
135
130
125
120
115
110
105
100
Baseline
Serial Subtraction
Speech
Task
Men
Women

Figure 2

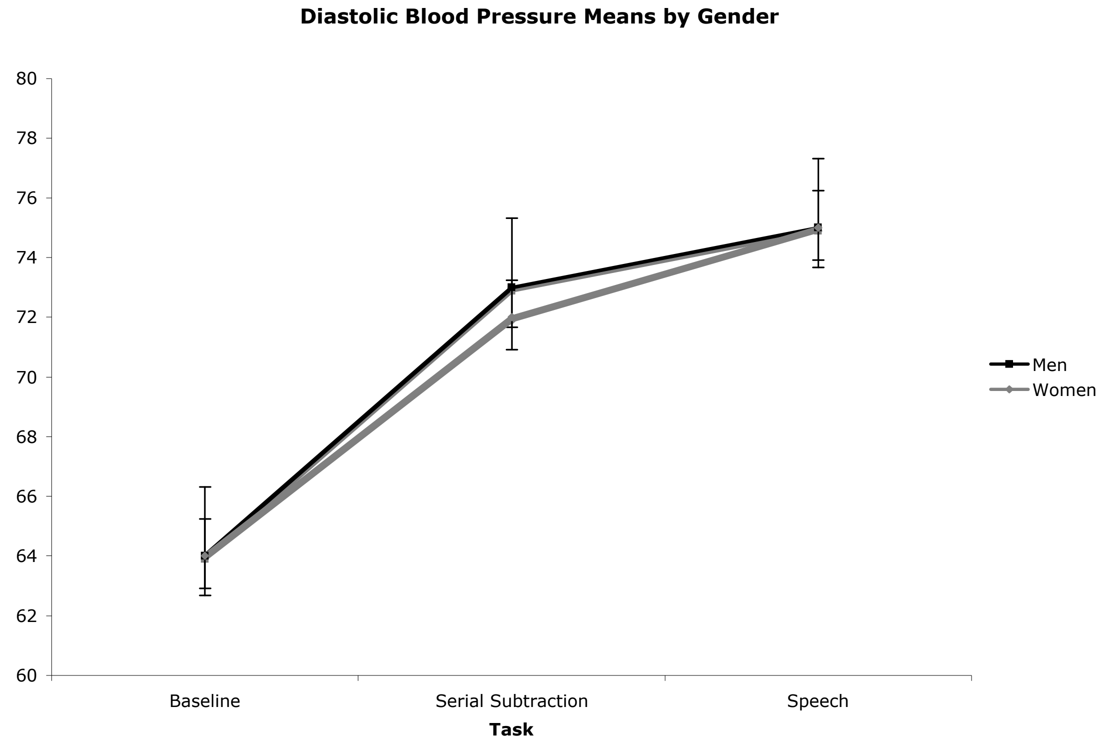
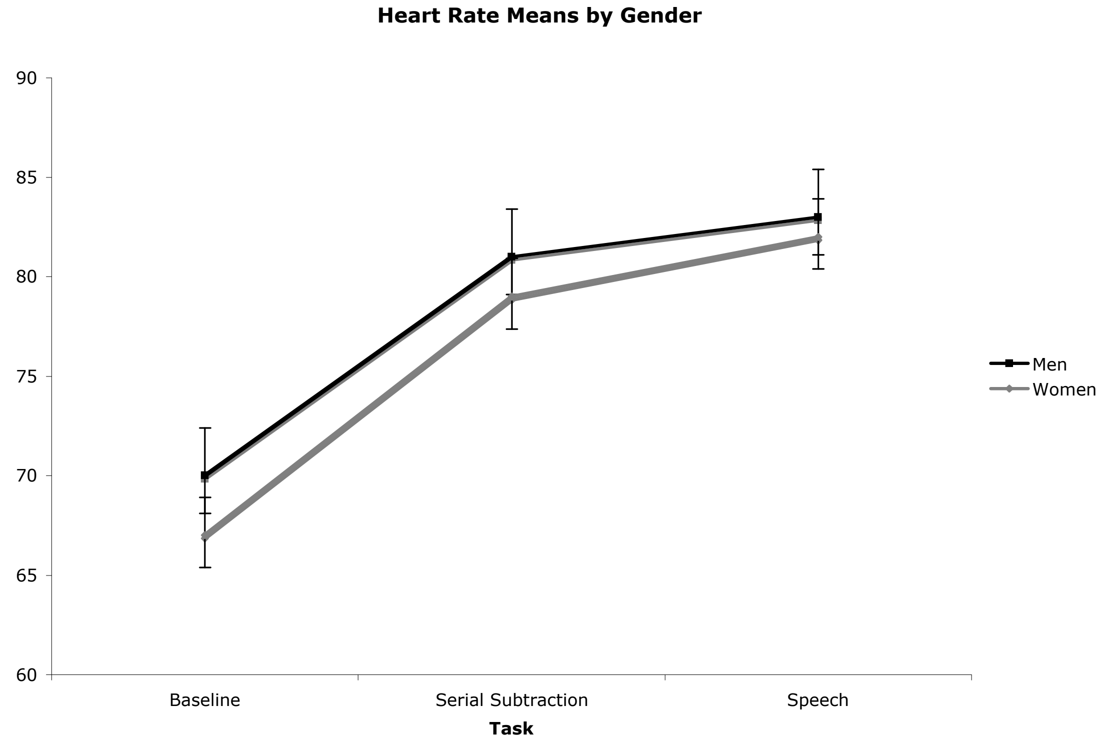


Figure 3



Cardiovascular reactivity. Correlations between cardiovascular measures at baseline and change during stress tasks are presented in Table 8.

Table 8.

Cardiovascular Correlations Between Baseline and Task Change Scores

	Speech Task		
	Δ Systolic Blood Pressure	Δ Diastolic Blood Pressure	Δ Heart Rate
Baseline Systolic Blood Pressure	-.38**	---	---
Baseline Diastolic Blood Pressure	---	-.27*	---
Baseline Heart Rate	---	---	-.22

	Serial Subtraction Task		
	Δ Systolic Blood Pressure	Δ Diastolic Blood Pressure	Δ Heart Rate
Baseline Systolic Blood Pressure	.14	---	---
Baseline Diastolic Blood Pressure	---	-.35**	---
Baseline Heart Rate	---	---	-.31*

Note: ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Significant negative correlations were revealed between baseline diastolic blood pressure and change in serial subtraction diastolic blood pressure (r (56) = -0.35, p = 0.01), between baseline diastolic blood pressure and change in speech diastolic blood pressure (r (56) = -0.27, p = 0.04), and between baseline Heart Rate and change in serial subtraction Heart Rate (r (56) = -0.31, p = 0.02).

Impulsivity and cardiovascular activity associations. Barratt Impulsivity Scale total score was positively correlated with baseline diastolic blood pressure (r (56) = 0.28, p = 0.04) and negatively correlated with change in serial subtraction from baseline to diastolic blood pressure (r (56) = -0.29, p = 0.03). Therefore higher disinhibition is associated with higher diastolic blood pressure at baseline, which may influence the negative association between disinhibition and diastolic blood pressure reactivity to stress. Although the Zuckerman Sensation Seeking Scale total score was not significantly correlated with baseline or reactivity measures, the Zuckerman Sensation Scale total score tended to be associated with baseline diastolic blood pressure (r (56) = -0.22; p = 0.09; see Table 9).

Table 9

Correlations between Cardiovascular Activity and Impulsivity Personality Trait

	Barratt Impulsivity Scale Total Score	Zuckerman Sensation Seeking Scale Total Score
Baseline Systolic Blood Pressure	.09	-.15
Baseline Diastolic Blood Pressure	.28*	-.22
Baseline Heart Rate	.02	-.17
Δ Speech Systolic Blood Pressure	-.20	-.07
Δ Speech Diastolic Blood Pressure	-.15	.09
Δ Speech Heart Rate	-.16	-.06
Δ Serial Subtraction Systolic Blood Pressure	-.15	-.05
Δ Serial Subtraction Diastolic Blood Pressure	-.29*	-.11
Δ Serial Subtraction Heart Rate	-.01	-.04

Note: ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Impulsivity and cardiovascular reactivity to stress. Due to the fact that men tended to have higher systolic blood pressure readings, gender was used as a covariate in the following regression analyses. Hierarchical linear regression analyses were conducted with gender and baseline values entered in step one and Barratt Impulsivity Scale (Disinhibition) and Zuckerman Sensation Seeking Scale (Sensation seeking) entered in step two. Results showed no significant associations with respect to the speech and serial subtraction values (see Tables 10 and 11).

Table 10

Impulsive Personality Trait Predictors of Cardiovascular Reactivity to Serial Subtraction Task

Δ Systolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.05
Gender (1=male; 2=female)	-2.85	-.20	-1.34	.19	
Baseline Systolic Blood Pressure	3.85	0.05	.33	.74	
Step 2					.08
Disinhibition	-0.12	-.16	-1.17	.25	
Sensation Seeking	-4.32	-.04	-0.25	.81	

Δ Diastolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.14
Gender (1=male; 2=female)	-1.41	-.11	-.91	.37	
Baseline Systolic Blood Pressure	-.35	-.35	-2.81	.01*	
Step 2					.20
Disinhibition	-.11	-.16	-1.22	.23	
Sensation Seeking	-.18	-.17	-1.25	.22	

Δ Heart Rate

	B	β	*t*	p	r^2
Step 1					.10
Gender (1=male; 2=female)	.85	.05	.42	.68	
Baseline Heart Rate	-.25	-.31	-2.35	.02*	
Step 2					.11
Disinhibition	1.32	.02	.12	.91	
Sensation Seeking	-.12	-.09	-.67	.51	

Note: **p < .001; *p < .05

Table 11

Impulsive Personality Trait Predictors of Cardiovascular Reactivity to Speech Task

Δ Systolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.00
Gender (1=male; 2=female)	-.93	-.05	-.30	.76	
Baseline Systolic Blood Pressure	-6.46	-.06	-.39	.70	
Step 2					.04
Disinhibition	-.20	-.19	-1.34	.19	
Sensation Seeking	-6.75	-.04	-.27	.79	

Δ Diastolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.07
Gender (1=male; 2=female)	.10	.01	.05	.96	
Baseline Diastolic Blood Pressure	-.37	-.27	-2.09	.04*	
Step 2					.08
Disinhibition	-8.51	-.10	-.66	.52	
Sensation Seeking	8.24	.06	.40	.69	

Δ Heart Rate

	B	β	*t*	p	r^2
Step 1					.05
Gender (1=male; 2=female)	1.16	.07	.50	.62	
Baseline Heart Rate	-.19	-.21	-1.56	.13	
Step 2					.08
Disinhibition	-.13	-.14	-1.05	.30	
Sensation Seeking	-8.01	-.05	-.39	.70	

Note: **p < .001; *p < .05

Post-Hoc Analysis

Due to the overall null results of this study, follow-up analyses with several additional factors were conducted. We further investigated the relationships between impulsivity and cognitive performance by looking at each impulsivity personality trait separately with regression analyses (i.e, gender and IQ as step one and Barratt Impulsivity Scale [Disinihibition] as step two). Disinhibition did not significantly predict cognitive performance. (Trails:$\beta = -1.46$, $t(72) = -0.85$, $p = 0.40$; Stroop: $\beta = -5.46$, $t(72) = -0.59$, $p = 0.56$; DVT time: $\beta = -0.74$, $t(72) = -1.06$, $p = 0.29$; WMI: $\beta = 2.35$, $t(72) = 0.21$, $p = 0.84$; WMII: $\beta = 4.44$, $t(72) = 0.41$, $p = 0.68$; CVLT trials 1-5: $\beta = 3.23$, $t(72) = 0.40$, $p = 0.69$; CVLT Short Delay: $\beta = 1.88$, $t(72) = 0.06$, $p = 0.96$; CVLT Long Delay: $\beta = 1.17$, $t(72) = 0.42$, $p = 0.68$). Sensation Seeking also did not predict cognitive performance. (Trails:$\beta = 0.32$, $t(72) = 1.21$, $p = 0.23$; Stroop: $\beta = -0.19$, $t(72) = -1.33$, $p = 0.19$; DVT time: $\beta = 2.04$, $t(72) = 1.92$, $p = 0.06$; WMI: $\beta = 0.27$, $t(72) = 1.56$, $p = 0.12$; WMII: $\beta = 0.18$, $t(72) = 1.09$, $p = 0.28$; CVLT trials 1-5: $\beta = 7.00$, $t(72) = 0.06$, $p = 0.96$; CVLT Short Delay: $\beta = 3.77$, $t(72) = 0.72$, $p = 0.47$; CVLT Long Delay: $\beta = -3.75$, $t(72) = -0.09$, $p = 0.93$). We further investigated impulsivity trait associations with reactivity by using separate hierarchical regression analyses with each impulsivity trait separately with regard to reactivity data and results remained null (Barratt Impulsivity Scale: all p's > .10; Zuckerman Sensation Seeking Scale: all p's > .09).

While we did not have measures of psychopathy per se, we created a proxy measure for this construct by combining impulsivity scores with a self-report measure of aggression. We used a measure of impulsive aggression (Buss Perry Aggression Questionnaire; BPAQ) from a parent study from which subjects had initially been recruited. We created z-scores from the BPAQ and the Barratt Impulsivity Scale Total Score (disinhibition) and added them together to create a combined variable that would estimate impulsive aggression. Regression analyses using gender and baseline cardiovascular measures in step one and the impulsive aggression variable in step two revealed significant findings for impulsive aggression and diastolic blood pressure such that higher impulsive aggression was associated with lower diastolic blood pressure in response to the serial subtraction task. No other significant findings were revealed with these analyses. See Tables 12 and 13.

Table 12

Impulsive Aggression Predictor of Cardiovascular Reactivity to Serial Subtraction Task

Δ Systolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.05
Gender (1=male; 2=female)	-2.85	-.20	-1.34	.19	
Baseline Systolic Blood Pressure	.04	0.05	.33	.74	
Step 2					.07
Impulsive Aggression	-.60	-.13	-.95	.35	

Δ Diastolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.14
Gender (1=male; 2=female)	-1.42	-.11	-.91	.37	
Baseline Systolic Blood Pressure	-.35	-.35	-2.81	.01*	
Step 2					.21
Impulsive Aggression	-1.10	-.27	-2.17	.04*	

Δ Heart Rate

	B	β	*t*	p	r^2
Step 1					.10
Gender (1=male; 2=female)	.85	.05	.42	.68	
Baseline Heart Rate	-.25	-.31	-2.35	.02*	
Step 2					.10
Impulsive Aggression	-.10	-.02	-.15	.88	

Note: **p < .001; *p < .05

Table 13.

Impulsive Aggression Predictor of Cardiovascular Reactivity to Speech Task

Δ Systolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.00
Gender (1=male; 2=female)	-.93	-.05	-.30	.76	
Baseline Systolic Blood Pressure	-.07	-.06	-.39	.70	
Step 2					.02
Impulsive Aggression	-.95	-.14	-1.04	.30	

Δ Diastolic Blood Pressure

	B	β	*t*	p	r^2
Step 1					.07
Gender (1=male; 2=female)	.10	.01	.05	.96	
Baseline Diastolic Blood Pressure	-.37	-.27	-2.09	.04*	
Step 2					.08
Impulsive Aggression	-.20	-.04	-.26	.80	

Δ Heart Rate

	B	β	*t*	p	r^2
Step 1					.05
Gender (1=male; 2=female)	1.16	.07	.50	.62	
Baseline Heart Rate	-.19	-.21	-1.56	.13	
Step 2					.07
Impulsive Aggression	-.68	-.12	-.89	.38	

Note: **$p < .001$; *$p < .05$

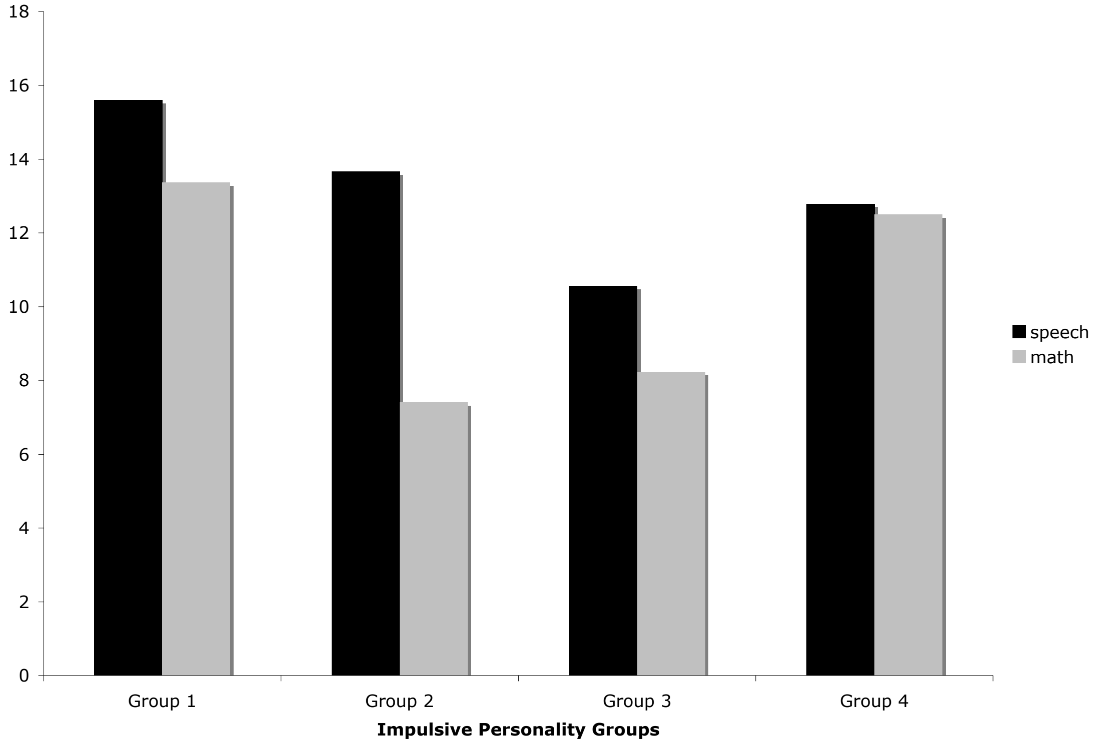
Psychopathy literature dichotomizes psychopaths as successful psychopaths, those who use covert and nonviolent methods to achieve goals and have normal to superior cognitive functioning, compared to unsuccessful psychopaths who get caught and are typically characterized to have a lower verbal IQ (Gao & Raine 2010). Therefore, we assessed whether stress reactivity in our sample would be differentiated by "successful" impulsivity. Here again, we created a proxy measure for this construct by combining a centered IQ (that is, mean IQ of the sample minus participants' IQ score) with centered disinhibition (Barratt Impulsivity Scale Total Score) (or sensation seeking [Zuckerman Sensation Seeking Scale]; that is mean Barratt Impulsivity Scale Total Score minus participants' Barratt Impulsivity Scale Total score). We called this new variable BIQ (or ZIQ). Next, we employed hierarchical regression analyses using gender and baseline cardiovascular variable (i.e., systolic) in step one, disinhibition (Barratt Impulsivity Scale; or sensation seeking – Zuckerman Sensation Seeking Scale) in step two, and BIQ (or ZIQ) in step three. However, no significant findings were revealed (Barratt Impulsivity Scale: all p's > .07; Zuckerman Sensation Seeking Scale: all p's > .22). We then repeated these same analyses and substituted Trails scores for IQ due to related literature that identified Trails scores as a means to determine cognitive function (Lezak, 2004). No significant findings were revealed (Barratt Impulsivity Scale: all p's > .06; Zuckerman Sensation Seeking Scale: all p's > .09).

Finally, due to Gray's (1987) posited plausible interaction between the BIS and BAS such that the BIS may inhibit BAS activity and the BAS may moderate BIS activity, we set out to observe potential interactions of the different personality traits of impulsivity. We created four mixed variables that represented the ends of the trait continuums. We used the means of the Barratt Impulsivity Scale Total Score (disinhibition) and the Zuckerman Sensation Seeking Scale Total Score (Sensation

Seeking) as a cutoff to attain four groups to assess the impact of impulsivity on stress reactivity change scores: Group 1: low disinhibition and low sensation seeking, Group 2: low disinhibition and high sensation seeking, Group 3: high disinhibition and low sensation seeking, and Group 4: high disinhibition and high sensation seeking. No significant differences were revealed, see Figure 4.

Figure 4

Integrated Impulsive Personality Groups Mean Change Heart Rate by Task



Note: Group 1 = low disinhibition and low sensation seeking; Group 2 = low disinhibition and high sensation seeking; Group 3 = high disinhibition and low sensation seeking; Group 4 = high disinhibition and high sensation seeking. No significant differences among groups.

DISCUSSION

This study examined the relationships between two dimensions of impulsivity, sensation seeking and disinhibition, with cognitive performance and cardiovascular reactivity among young adults in college.

Neurocognitive Performance

Our first hypothesis, based on the association between attention and processing affective information, was not supported; we did not find a relationship between the behavioral inhibition system and attention. More specifically, we did not find a relationship between the Barratt Impulsivity Scale and the Digit Vigilance Task of attention. While we did find a relationship between the Zuckerman Sensation Seeking Scale and the Digit Vigilance Task, this was most probably a chance finding. These null findings contrast with previous research (Newman, Curtin, Bertsch, & Baskin-Sommers, 2009), which may be due to some limitations in our study discussed below. Previous literature has discussed an association between the behavioral inhibition system and conflict monitoring, yet evidence has relied on neural correlates of motor inhibition tasks (i.e., No-Go; Amodio, Master, Yee, & Taylor, 2008). In our study, we conducted cognitive tasks that did not include motor aspects, which perhaps may be one reason for our contrasting findings. Another study that required a motor aspect to cognitive control utilized the n-back task to assess via fMRI the neural correlates associated with working memory and personality traits BIS and BAS. They found that high BAS participants had a better performance with regard to accuracy and that the high BAS participants recruited less activity in the caudal anterior cingulate cortex (Gray & Braver 2002).

Results related to our second hypothesis, based on studies that found associations between cognitive flexibility and a goal-oriented focus, were also not as expected. We predicted a negative association between cognitive flexibility and the behavioral activation system, that is, personality traits with a goal-oriented focus. In our study, correlations between tasks of cognitive flexibility did not reveal a significant relationship with the Zuckerman Sensation Seeking Scale. A possible explanation for this finding is that in our study, our test of cognitive flexibility was not emotionally salient. Previous studies that found goal-driven individuals to have a deficit in cognitive flexibility used aversive or appetitive peripheral stimuli (Patterson & Newman, 1993).

Cardiovascular Activity

In line with low arousal theories, our final hypothesis stated that those with increased disinhibition would have attenuated reactivity to stress, specifically with cognitive tasks. Our hypothesis was supported with regard to diastolic blood pressure and will be discussed in greater detail below.

Sensation seeking, had no significant relationship to heart rate or blood pressure at baseline or during reactivity to stress in our study. This lack of associations, between sensation seeking and heart rate and blood pressure, contradict Raine (2002), who described multiple mechanisms (i.e., low arousal) by which individuals with low heart rate may be prone to aggressive or antisocial behaviors. One of the mechanisms is a stimulation seeking theory that substantiates Eynsenck's earlier arousal theory (1997) which describes that physiological underarousal is experienced as an unpleasant state that leads individuals to increase their arousal to an optimal level by engaging in potentially risky acts that they perceive as stimulating. The theory is corroborated with evidence from a study which found that sensation seeking mediated the relationship between resting heart rate and aggression (specifically rule breaking), yet this was only during adolescence and not during preadolescence (Sijtsema, Veenstra, Lindenberg 2010). In another study however, (Heponiemi, Letikangas-jarvinen, Kettunen, Puttonen, & Ravaja, 2003), while BAS sensitivity was unrelated to resting heart rate, it was associated with higher heart rate *reactivity*.

In contrast, our findings that revealed a lack of a relationship between sensation seeking and heart rate are more consistent with Hansen, Johnsen, Thornton, Waage, & Thayer (2007), who conducted a study aimed to investigate whether the facets of Hare’s Psychopathy Checklist-Revised (PCL-R; Hare, 1991) were related to physiological mechanisms. Indeed, the facet related to sensation seeking did not show any association with heart rate (resting or reactivity to stress) and thus corroborates our findings. In a more recent meta-analysis (Wilson & Scarpa, 2011) that examined the relationship between sensation seeking and aggression across studies, and the role of several putative relevant moderator variables including heart rate, the authors were unable to conclude that heart rate plays such a specific role toward aggression. Therefore, while clear evidence was revealed that sensation seeking does in fact play a role in aggression (Wilson & Scarpa, 2011), more research is necessary in understanding the link between sensation seeking and heart rate and/or blood pressure.

As stated earlier, our study did find that the personality trait disinhibition is related to resting diastolic blood pressure and change in diastolic blood pressure in response to stress. More specifically, the higher one’s tendency is to be disinhibited, the higher their diastolic blood pressure at rest, and the lower their diastolic blood pressure response to stress, with the latter finding consistent in the direction of our hypothesis. To reiterate from previously discussed basic physiology, diastolic blood pressure is reflective of one's vascular resistance, that is, the pressure in one's blood vessels between heartbeats, while the heart is resting. These findings are somewhat different from previous studies that examined cardiovascular activity and externalizing behaviors in individuals labeled as disinhibited. Antisocial and aggressive behaviors have repeatedly been shown to be associated with low resting heart rate (Raine, 1993; Lorber, 2004). However, we must be careful in our interpretation as these maladaptive *behaviors* have only been associated with traits such as fearlessness and disinhibition thought to lower inhibitions to violence and aggressive behaviors. Several studies have failed in their attempts to find a direct relationship between the behavioral inhibitory scale and any cardiac autonomic activity (Heponiemi, Letikangas-jarvinen, Kettunen, Puttonen, & Ravaja, 2003; Sijtsema, Veenstra, Lindenberg 2010; Scholten, van Honk, Aleman, & Kahn, 2006). However, there are a few studies that have found meaningful relationships between disinhibition and heart rate reactivity. One study showed a positive correlation between heart rate reactivity to stress and disinhibition yet the study was somewhat different in that their task was not stressful (or aversive) per se, but rather an engaging task (administration of a Rorschach test; Keltikangas-jarvinen et al 1999). In another study, Mathias and Stanford (2003) found higher disinhibition to be associated with under-arousal at rest and greater reactivity to stress, measured by heart rate. However, the results that revealed higher reactivity was only upon initial task stimulation; arousal diminished in response to sustaining exposure to the stimulation. The stress task for

Mathias and Stanford (2003) was considerably longer than our stress task as their task included a six-minute practice period (not included in initial arousal measure, albeit differing from our study). In our study, we took the mean of all time periods measured during the stress task. Therefore our findings for reactivity may be commensurate with the findings of Mathias and Standford (2003) in terms of directional change, yet our significant findings were via a measure of diastolic blood pressure, not heart rate. Similarly, Allen, Hogan, and Laird (2009) showed a significant negative correlation between disinhibition and cardiovascular reactivity to stress which suggests less sympathetic activation for these disinhibited individuals. The same study also revealed a similar pattern to our findings with regard to a positive relationship between disinhibition and resting cardiovascular score. While further research is necessary to gain a reliable understanding as to whether there is a true relationship between the behavioral inhibition system and autonomic function, it is interesting to consider the implications of our findings. Why would individuals with higher disinhibition, associated with a lack of fear, have a higher baseline and lower reactivity?

The consideration of psychopathy may help answer this question. Earlier, we discussed the difference between a ‘successful’ versus ‘unsuccessful’ psychopath. Briefly, Widom (1978) conducted research by recruiting participants with similar personality attributes as a psychopath, but instead of recruiting from institutions, they were recruited from the community via newspaper advertisements. The advertisement stated, “Psychologist studying adventurous carefree people who’ve led exciting impulsive lives”. Widom (1978) reasoned that psychopaths would self-select themselves due to their tendency for being exhibitionists without concern for consequence. Upon completion of a battery of tests and an interview, subjects who fulfilled criteria associated with sociopathy (e.g., frequent arrests), were considered ‘successful’. Ishikawa, Raine, Lencz, Bihrle, & Lacasse (2001) conducted a study that revealed autonomic differences between these two types of psychopaths such that unsuccessful psychopaths showed reduced cardiovascular reactivity to stress and successful psychopaths exhibited heightened reactivity to stress. While the face validity of our sample, recruited from a hopeful and aspiring college population and not from those in prison, would coincide with what one might consider a successful impulsive type of person, our post-hoc analysis of successful and unsuccessful impulsivity did not reveal any significant findings, and is thus inconsistent with the previous study. Therefore, according to our study, the theory that either sensation seeking or disinhibition mediates a role between arousal and aggression or externalizing behaviors is null.

Despite these results, the possibility remains that one or both of these impulsivity traits may be relevant in playing a role toward aggression in combination with other traits. For example, psychopathy and aggressive or violent behavior have been classified into two different forms (Scarpa & Raine, 1997). Theorists have postulated a reactive or hostile aggression that involves aggressive behavior in the context of associated angry and/or frustration with high emotionality versus an instrumental or proactive aggression that involves a non-emotional display of aggressive behavior (Dodge & Coie, 1987). Similarly, Gray (1975) suggested two biological pathways to arrive at these types of aggression, the BIS and the BAS. Therefore, because we were able to estimate impulsive aggression in our sample, we examined its relationship with cardiovascular response in a post-hoc analysis. Results revealed a significant association between impulsive aggression and cardiovascular reactivity such that those with higher impulsive aggression tended to have lower cardiovascular reactivity. Gray (1975) understood the relationship between aggression and an underactive BIS to be a result of an inability to learn from cues of punishment. Our findings of an attenuated diastolic blood pressure response to stress may be explained by the violence inhibition mechanism (Blair, Jones, Clark, & Smith, 1997). The mechanism is thought to be a system that typically (in normals) results in increased sympathetic activity when activated by distress cues such as sad and fearful expressions of others. As previously discussed, we know that the processing of emotional stimuli in psychopaths is atypical in brain activation patterns in response to facial expressions in comparison to controls (Hoff, Beneventi, Galta, & Wik, 2009). Such deficits may be born through the poor aversive conditioning and underactive BIS as described above.

Another consideration to understand the association between disinhibition and high resting diastolic blood pressure is to look at other research that has shown other various diagnoses of individuals with a higher resting autonomic activity. These include depression (Dawson et al., 1985; Iacono et al., 1983), manic-depression (Iacono et al.,1983), schizophrenia (Zahn , 1986), and alcoholism (Hill et al., 1992). All of these diagnoses encompass some type of disinhibited clinical feature. However, there may be some other common factor to explain these associations and thus requires further research. Therefore, it would appear that these constructs are not causal to disease, but rather, correlated. Whether these trait characteristics may be considered risk markers would require repeated prospectively designed longitudinal studies as the current literature is marked by conflicting data.

With regard to general cardiovascular activity, men tended to have higher resting heart rate and blood pressure than women, which is consistent with the literature (Wiinberg et al. 1995). During the stress tasks, as expected, heart rate and blood pressure and perceived stress levels significantly increased from baseline. The pattern of men tending to have higher heart rate and blood pressure than women persisted through both stress tasks. However, heart rate and blood pressure changes from baseline to each stress task revealed no gender differences. Cardiovascular reactivity to stress correlated significantly with resting measures such that the higher the resting measure, the lower the change in reactivity from stress, and the lower the resting measure, the higher the change in reactivity. While these findings may have been driven by the resting cardiovascular levels and the Law of Initial Values effects (Wilder, 1962), baseline levels were entered as a covariate so the Law of Initial Values does not appear to be an explanation for the negative correlations observed between baseline and reactivity scores. However, the relationship between measures of heart rate and blood pressure at baseline with measures of heart rate and blood pressure during reactivity to stress remains important. Autonomic organization and control is too complex to be viewed along a single spectrum of sympathetic and parasympathetic reciprocity and thus “autonomic space” should be considered as two-dimensional (Bernston, Cacioppo, & Quigley, 1991). Although their model has yet to be extended to humans, Bernston, Cacioppo, and Quigley, (1991) continue that the sympathetic and the parasympathetic divisions may vary reciprocally, coactively, or independently. Reciprocal changes in the two divisions of the ANS yield mutually synergistic effects on the target organ, whereas nonreciprocal modes minimize functional response of the target organ. Thus, the authors suggest that baseline and reactivity are constrained by the dimensions of the ‘autonomic space’. Autonomic flexibility (adjustments or recovery rate to expected arousal) may further explain our findings and has been studied in clinical anxiety populations. Children with social phobia were observed to have a pattern of elevated baseline heart rates that was correlated with lower reactivity, which was explained by restricted autonomic flexibility (Schmitz, Kramer, Tuschen-Caffier, Heinrichs, & Blechert, 2011). As discussed below, our findings are not commensurate with the latter study (we observed a *positive* correlation between baseline blood pressure and disinhibition), yet the concept of autonomic flexibility is important and may relate to tonic cardiovascular activity.

Impulsive personality traits

Although sensation seeking and disinhibition were related to one another, one aspect of sensation seeking, specifically the thrill and adventure-seeking subscale, proved to be independent of disinhibition. Interestingly, Benning, Patrick, Blonigen, Hicks, and Iacono (2005) found this subscale to be associated with ‘fearless dominance’, more specifically the interpersonal aspects of psychopathy (i.e., glibness, grandiosity, deceitfulness, and manipulativeness) and narcissism, as well as traits of low stress reaction and reduced fears. Benning et al. (2005) also associated thrill and adventure-seeking with Factor 1 of the PCL-R. As described earlier, Factor 1 is associated with primary psychopathy and the behavioral inhibitory system, which conflicts with our finding that thrill and adventure-seeking is orthogonal to the behavioral inhibitory scale. While intuitively it makes sense that thrill and adventure seekers may be fearless in their drive to jump off a high board for example, the fact that the subscale was not related to the behavioral inhibitory scale in our study may reflect that young college students view the items of this subscale as more of an approach for a reward.

Limitations

The fact that our study was age limited (18-25) and encompassed all college students limits our ability to generalize our results to the population at large. Sample size was also a limitation to our study. A larger sample may have allowed for more power in our statistical analyses, especially due to our use of a non-clinical sample. The significant differences observed in the psychopathy literature may be due to the more sensitive comparison of controls with a classified population with marked behavioral differences (psychopaths) versus our dimensional approach with college students. Greater statistical power may have also resulted from a larger alpha level observed on the personality trait questionnaires. Another limitation of the present study is that post-task cardiovascular recovery data were not examined. Cardiovascular recovery, defined as either the time required to return to baseline levels after termination of the stress task, or the degree of elevation above baseline levels within a predetermined post-task interval, has been shown to predict longitudinal blood pressure changes (Stewart & France, 2001). A delayed recovery time may represent excessive energy consumption and drive a constant allostasis overload leading to chronic elevated glucocorticoid secretion and other imbalanced mediators that ultimately result in pathophysiology (McEwan & Wingfield, 2003). Finally, due to the fact that we had minimal significant findings amongst multiple statistical analyses, our significant findings may be due to chance, thereby another limitation due to the lack of alpha control.

While results of this study were not conclusive in relating impulsive personality traits with cognition and/or psychophysiological reactivity to stress, further research is necessary to understand personality trait influence on cognition and autonomic function. Relations between these interdisciplinary systems are sophisticated and represent intricate and complex brain processes (Berntson & Cacioppo, 2007). Further, while various methodological differences are inherent to a field of debatable constructs, innumerable measurements and variables of cardiovascular activity in the current literature is difficult to interpret. Therefore, as research continues to integrate these diverse fields and as we become informed, future progress would benefit from the use of streamlined constructs and terms. Finally, with regard to measurement and assessment of autonomic function, a useful strategy for future studies should assess a composite pattern of autonomic and cardiovascular response, rather than study individuals on the basis of their reactivity to cardiovascular variables in isolation (Allen, 2000). This strategy may provide a more accurate understanding of the neural control of cardiovascular response during both rest and stress.

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