ABSTRACT

Emotion and Attention in the Psychopath: An Investigation of Affective Response and Facilitated Attention Using Event-Related Potentials

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A prominent concern in psychopathy research is a deficit in processing emotionally relevant information, which may occur in the very early neural processing stages of stimulus evaluation. While contemporary functional imaging techniques like fMRI have unparalleled spatial resolution, their poor temporal resolution makes them inadequate for measuring the time-course of very early stages of information processing. Conversely, electrocortical measures, particularly event related potentials (ERPs), are capable of determining the time-course of such processing on the order of milliseconds. The goal of this investigation was to establish the existence of differences between psychopaths and controls in their integration of emotional information in the very early stages of information processing as indexed by ERP waveform differences, and determine whether manipulations of attentional focus are capable of modulating these differences. In a series of presentations of emotionally evocative pictures and words, psychopaths and controls indeed displayed robust differences in their ERP waveforms. Psychopaths lacked a persistent emotion-related positivity present in controls beginning around 200 ms into the processing stream and continuing throughout the 900 ms epoch of interest. Under conditions where the emotional information was relevant to an ongoing task, psychopaths showed moderate changes in ERPs for emotional stimuli, yet these waveforms remained dissimilar from those of controls. These data provide evidence that psychopaths present with deficits in early-stage discrimination of emotionally salient information, which may be partially sensitive to manipulations of effortful attention. These outcomes have implications for later-stages of processing such as the integration of this information into memory systems and the utilization of this information for the modification of ongoing behavior.

Emotion and Attention in the Psychopath: An Investigation of Affective Response and Facilitated Attention Using Event-Related Potentials

by

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LIST OF ABBREVIATIONS

ASPD: Antisocial Personality Disorder

ANEW: Affective Norms for English Words

BIS: Behavioral Inhibition System

BAS: Behavioral Activation System

DSM: Diagnostic and Statistical Manual of Mental Disorders

EEG: Electroencephalogram

EMG: Electromyogram

EPN: Early Posterior Negativity

ERP: Event Related Potential

FD: Fearless Dominance, factor of the PPI-R

fMRI: Functional Magnetic Resonance Imaging

IAPS: International Affective Picture System

LPP: Late Positive Potential

PCL-R: Hare's Psychopathy Checklist Revised

PPI-R: Psychopathic Personality Inventory Revised

RMH: Response Modulation Hypothesis

SCI: Self Centered Impulsivity, factor of the PPI-R

VIQ: Verbal IQ, of the WASI

WASI: Wechsler Abbreviated Scale of Intelligence

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DEDICATION

To my father, the smartest man I know, for reminding me to pace myself,

and to my mother, for her continued prayers

CHAPTER ONE

Emotional Processing and Psychopathy: A Review

Emotion and Cognition

There exists an unfortunate and stubborn popular consensus that emotion and rationality are opposing forces governing our everyday behavior; however, recent developments in psychology and neuroscience are helping to inform us that emotion plays an important role in rational, cognitive processes (Cacioppo & Gardener, 1999; Damasio, 1994). Much of the foundational information which allows us to study the neuroscience of emotion in humans is derived from functional descriptions of the amygdala, a phylogenetically old brain structure critical for the formation of basic emotional reactions such as fear (Davis, 1997; LeDoux, 1992). The amygdala receives input from all sensory modalities and higher-order association areas of the brain, which makes this structure capable of responding to even remote threat-related stimuli. It has been demonstrated that damage to the amygdala, impairs advantageous decision-making in humans (Bechara, Damasio, Damasio, & Lee, 1999). Likewise, damage to the ventromedial prefrontal cortex, a brain structure capable of forming associations with experienced emotional states, disrupts these rational choices (Bechara et al., 1999; Bechara, Damasio, & Damasio, 2000).

Findings like these, while revolutionary in some respects, are not unprecedented. It has been clear for some time that the brain processes emotionally charged information differently than emotionally neutral information. Stimuli with emotional significance command attention automatically (Rigoulot et al., 2008). Affective content invokes the activation of primary defensive or appetitive networks eliciting physiologically measurable outcomes in a diverse set of systems throughout the body including peripheral autonomic arousal (Lang, Greenwald, Bradley, & Hamm, 1993), the modulation of startle reflexes (Lang, Bradley, & Cuthbert, 1990), and event-related brain potentials (ERPs; Cacioppo, Crites, Gardner, & Berntson, 1994). Our primary appetitive and defensive reactions are likely precursors that aided the evolutionary development of complex human decision-making. Our phylogenetically modern decision-making processes are indeed an intricate combination of motivating forces, all colored by emotional states (Blanchette & Richards, 2010); however, these processes may have developed from simpler tactics, which operated directly through emotional reactions like recognizing potential threats while navigating the environment (Cabanac, Cabanac, & Parent, 2009). Consistent with this notion, investigations into the very early stages of stimulus processing in humans have revealed that our attention is automatically captured by features of our environment that are salient to our survival and reproduction, and this *orienting response* occurs involuntarily, prior to our conscious awareness (Ohman, Hamm, & Hugdahl, 2000; Bradley, Codispoti, Cuthbert, & Lang, 2001). It should be apparent, then, that emotional responses are not a vestigial remnant but rather an advantageous component of high-level cognition that facilitates rationality, constructive decision-making, and even moral thought. This point is made clear by examining individuals with particular emotional deficits which impair the incorporation of affective information into their cognitive processes and decisive behavior.

Psychopathy: Consequences of Emotional Deficits

Psychopaths are characterized in part by callous, unemotional traits and a propensity for disinhibited, self-serving behavior fostered by an apparent insensitivity to punishment and a disregard for the impact of such behavior on others (Cleckley, 1941). Contemporary investigations into the neurobiological underpinnings of psychopathy have emphasized major deficits in emotional processing ultimately stemming from dysfunctions in the amygdala and its connections with the prefrontal cortex (Blair, 2006; 2004). Inadequate emotional processing and the subsequent integration of emotional cues into behavioral inhibition has striking effects on one's personality and behavioral style. For instance, psychopaths show an increased propensity for violent attacks and aggressive behavior (Salekin, Rogers, & Sewell, 1996). Rates of criminal and violent recidivism are much higher for psychopaths than non-psychopathic criminals (Porter, Birt, & Boer, 2001). Therapeutic intervention and rehabilitation strategies in adults have often proven to be simply ineffective and in some cases counterproductive (Rice, Harris, & Cormier, 1992). Psychopathy is also associated with higher rates of substance abuse (Taylor & Lang, 2006) and earlier onset of substance abuse (Gustavson et al., 1997). This disorder has captured the attention of a diverse set of researchers, since understanding the nature of psychopathy has the potential to inform our knowledge of criminal behavior, moral decision-making, and the routine integration of emotion into rational thought and behavior.

While vague notions of the disorder had existed earlier, the first clinically-derived composite sketch of psychopathy came in the form of a set of case studies published as *The Mask of Sanity* (Cleckley, 1941), which described several individuals with similar personality traits and overlapping deficits. Cleckley ultimately delineated 16 traits common to the disorder which included a poverty of emotions, narcissism, dishonesty, guiltlessness, shamelessness, and antisocial tendencies. He also described these individuals as having normal to high levels of intelligence accompanied by superficial charm, which underscored psychopathy's distinction from common criminality. This distinction is one of the most enduring components of more modern descriptions of psychopathy, fuelling sustained interest in describing how these individuals differ from those with the more prominently diagnosed *antisocial personality*.

The value of such a distinction is particularly relevant considering the ongoing debate over the exclusion of psychopathy from the DSM-IV-TR (APA; 2000) in favor of an intended all-encompassing Antisocial Personality Disorder (ASPD), which many experts believe is insufficient and imprecise (Cunningham & Reidy, 1998; Hare, Hart, & Harpur, 1991). A prominent etiological theory of psychopathy emphasizes evidence which suggests antisocial behavior is only a potential secondary consequence of the primary deficits in emotional processing (Blair, 2006). A clinical diagnosis of ASPD is predominantly defined by ongoing criminal behavior, which may or may not be recognizable in psychopaths. Consequently, there has been longstanding interest in studying non-criminal psychopaths (e.g. Widom, 1977), also referred to as *adaptive* psychopaths or *successful* psychopaths, presenting with the core affective deficits and subsequent personality traits but possessing resources which have either allowed them to refrain from conventional criminal activity or which have at least gifted them with an ability to evade legal ramifications for their actions. Some experts even consider the inclusion of ASPD in the construct a hindrance to progress which could be made with a more stringent reliance on psychopathy's primary features (Blackburn, 2007).

Many tools have been developed to operationalize psychopathy in clinical and experimental settings independent of DSM criteria for ASPD, and these measures have been instrumental in advancing empirical research on the disorder. The two most prominent of these are Hare's psychopathy checklist, now in a revised form (PCL-R, Hare, 1991) and the psychopathic personality inventory, also in a revised form (PPI-R, Lilienfeld and Widows, 2005). The PCL-R is prominently used in forensic settings, and the PPI-R is more common as a self-report test administered to non-incarcerated samples (Lilienfeld & Andrews, 1996). With respect to the distinction between antisocial behavior and the core affective deficits giving rise to psychopathy, both of these measures have demonstrated similar two-factor structures (Hare et al., 1990; Benning, Patrick, Hicks, Blonigen, & Krueger, 2003), with separate factors accounting for each of these features. The structure of these measures has been a convenient feature, allowing researchers to determine unique correlates of each factor, helping to distinguish these composite elements further based on their divergent relationships with specific psychophysiological traits, discussed in more detail below. There have been some recent suggestions for more complex factor solutions for both the PCL-R and the PPI-R (e.g. Cooke & Michie, 2001; Hare, 2003; Neumann, Malterer, & Newman, 2008); nonetheless, each of these alternative solutions have factors which distinguish antisocial behavior from emotional deficits, and this distinction is by far the most widely supported in terms of their neuropsychological antecedents. Furthermore, it should be recognized that these solutions are based on statistical analyses of specific measurement tools, rather than a model of personality traits.

A recent conceptualization of psychopathy, adopting a *triarchic* description of personality traits, is given by Patrick, Fowles, and Krueger (2009). This model incorporates three facets of personality: *Disinhibition*, accounting for aspects of poor impulse control; *Meanness*, accounting for aggressive and inconsiderate goal-seeking; and *Boldness*, accounting for shallow affect and attitude of invulnerability. It should be recognized that the facets of this triarchic model are familiar constructs, similar to established factors on several personality measures. For instance, *Disinhibition* and *Meanness* are comprised of traits accounted for in the antisocial dimension of the PCL-R and PPI-R. The *Boldness* construct is very similar to the *Fearless Dominance* factor in the PPI-R measure of psychopathy.

Since the primary focus of this project will be in clarifying aspects of emotional processing in psychopaths, a broad two-factor perspective of these personality traits will be adhered to with a particular emphasis on affective deficits over antisocial traits or social deviance. Even with this limited focus, there remains a debate whether the deficits underlying psychopathy are based on the raw processing of emotional information or if the deficits are more specifically related to improper integration of emotion into behavioral regulation (e.g. Newman & Lorenz, 2003). Investigating this question will provide valuable information about the utility of affective information in various stages of the cognitive process; but before examining it in more detail, it will be helpful to review some of the fundamental research which has helped build our current conception of psychopathy.

With the goal in mind of proceeding with a more informed notion of the possible manifestations of psychopathy, it is necessary first to examine the origin of the concept and proceed to examine several major distinctions that have been identified within the overall construct of psychopathy. For example, it will be important to recognize the distinction between primary psychopathy and secondary psychopathy (Karpman, 1948), along with the distinction between the sociopath and the psychopath (Lykken, 1957; 1995), as well as the non-criminal psychopath (Widom, 1977). Understanding these concepts is important to the broader recognition of psychopathy as a clinical disorder with a continuum of severity that is impacted both by one's environment and phenotypic deficits in emotional processing, yielding a spectrum of individuals between the healthy, well-socialized majority and the quite literally criminally insane.

The Low Fear Hypothesis: Evidence for a Deficit in the Raw Processing of Emotion

Accumulated evidence over the past several decades appears to suggest that psychopaths suffer some deficits in the raw processing of emotions, especially threat-related emotions. This notion developed into the *Low Fear Hypothesis*, which still plays a prominent role in etiological theories of psychopathy (Lykken, 1995). Briefly stated, psychopaths suffer from impoverished neural responses to aversive stimuli and are consequently poor at forming associations between their behavior and the aversive emotional states ordinarily garnered through punishment in normal social environments. As a result, psychopaths have a neuropsychological make up detrimental to proper socialization, and are thereby more likely to develop antisocial tendencies. Furthermore, it is suspected that this basic deficit in response to aversive stimuli is a consequence of impaired functioning of the amygdala (Blair, 2006), a neural structure which has an instrumental role in threat detection (Davis, 1997).

Some of the earliest psychophysiological investigations demonstrated that psychopaths have weak autonomic responses when experiencing aversive stimuli (Hare, 1968; Hare & Quinn, 1971; Lykken, 1957) and during the anticipation of aversive stimuli, such as watching a countdown timer prior to an electric shock (Hare, 1965a; Hare, 1982; Hare & Craigen, 1974; Hare, Frazelle, & Cox, 1978). There were also several early reports of poor fear conditioning and poor passive avoidance learning in psychopaths (Hare, 1965b, Newman & Kosson, 1986; Schmauk, 1970). Studies like these helped cultivate the *Low Fear Hypothesis*; however, peripheral, autonomic measures, such as electrodermal response and heart rate, lack a degree of specificity in that they fluctuate similarly under both positive and negative affective states (Lang, Greenwald, Bradley, & Hamm, 1993). A more tractable line of research in these endeavors is startle reflex modulation because it is capable of differentiating between these positive and negative states.

The startle reflex is a hardwired, species-specific set of stereotypical behaviors associated with the reaction to a sudden and unexpected aversive stimulus such as a 100 decibel burst of noise, called a startle probe. It is a brainstem reflex, originating in the caudal pontine reticular nucleus, which receives direct projections from the amygdala (Davis, 1989; LeDoux, Iwata, Cicchetti, & Reis, 1988). In humans, the reflex is usually quantified by the amplitude of electromyogram recordings from the *orbicularis oculi* muscle responsible for blinking the eye. It has been demonstrated that viewing emotionally evocative pictures reliably modulates the magnitude of this reflex such that blinks produced during aversive pictures (e.g. grotesque images of human injury) are larger than those during neutral pictures (e.g. mundane household objects), and blinks during positive pictures (e.g. erotic images) are smaller than those during neutral pictures (Bradley, Cuthbert, & Lang, 1990). Furthermore, because of the well-understood dependence of this modulation on affective states and amygdala activity, this technique is considered a highly valuable measure of emotional reactivity (Bradley, Cuthbert, & Lang, 1999). Startle modulation has been an indispensible measure in psychopathy research since it was first demonstrated by Patrick, Bradley, and Lang (1993) that psychopaths lacked the typical pattern of blink modulation. Specifically, they lacked potentiation of the startle reflex during aversive pictures, and this lack of potentiated startle was associated solely with the core emotional facets of psychopathy measured by Factor 1 scores on the PCL-R (Patrick et al., 1993; Patrick, 1994). This finding has been replicated using incarcerated samples (Levenston, Patrick, Bradley, & Lang, 2000) and non-incarcerated, *community* samples (Benning, Patrick, Blonigen, Hicks, & Iacono, 2005; Justus & Finn, 2007; Vanman et al., 2003). It remains one of the most reliable and highly replicated psychophysiological correlates of psychopathy, as well as a valuable example of the divergent correlates of antisocial behavior and the more fundamental emotional deficits.

Contemporary techniques in neuroscience have continued to support the notion of a primary impairment in emotional processing. For instance, functional neuroimaging studies have consistently demonstrated psychopaths' reduced activity in regions of the brain devoted to emotional processing. For instance, Birbaumer and colleagues (2005) reported that during an aversive conditioning paradigm, healthy controls show high levels of activation in the limbic-prefrontal circuit (including the amygdala, orbitofrontal cortex, insula, and anterior cingulate), while criminal psychopaths showed no significant activity in these regions and failed to acquire the appropriate skin conductance responses concomitant with acquisition of the learned association. When Kiehl and colleagues (2001) compared criminal psychopaths with non-psychopathic criminals, psychopaths had reduced activity in limbic regions including the amygdala, ventral striatum, and cingulate cortex while performing an affective memory task. These patterns also exist in non-criminal samples; however, it is less likely to find differences in the prefrontal cortex using these samples. For instance, in an fMRI investigation using a *prisoner's dilemma task*, which assesses social cooperation, subjects from a community sample with high scores on psychopathy measures demonstrated less cooperation and lower amygdala activation when cooperation was not reciprocated. Gordon, Baird, and End (2004) reported that subjects with high psychopathy scores had lower activity in the amygdala during a task involving recognition of facial affect, even though accuracy was the same between groups. It has also been reported that non-criminal psychopaths exhibit less amygdala activity while performing moral decision-making (Glenn, Raine, & Schug, 2009). In a review of relevant brain imaging findings, Raine & Yang (2006) conclude that apparent dysfunction in both the amygdala and areas of the prefrontal cortex have been consistently associated with psychopathy and antisocial behavior; however, a recent meta-analysis (Yang & Raine, 2009) emphasized the specificity of prefrontal deficits in those displaying antisocial traits, rather than psychopaths who may or may not present with antisocial behavior. The authors also emphasized that an over-reliance on criminal samples and improper experimental controls has contributed to some apparent ambiguity regarding the roles of the amygdala and prefrontal cortex.

Reports of deficits in individuals following acute, specific brain injuries are a useful supplement to findings from neuroimaging, allowing us to dissociate the impairments specific to the brain areas most often implicated in psychopathy. There have been many incidental reports of damage to areas of the prefrontal cortex, especially orbitofrontal/ventromedial and ventrolateral regions, leading to behavioral dysregulation and antisocial tendencies (e.g. Cato, Delis, Abildskov, & Bigler, 2004; Damasio, Grabowski, Frank, Galaburda, & Damasio, 2005; Meyers, Berman, Scheibel, & Hayman, 1992). In a useful review of neuropsychiatric literature Brower and Price (2001) support a relationship between frontal lobe dysfunction and behavioral dysregulation, including violence and antisocial behavior, but the authors also emphasize that the relationship between frontal lobe dysfunction and violent behavior applies more appropriately to the impulsive subtype of aggression, as opposed to the premeditated subtype more prevalent among psychopaths (Patrick & Zempolich, 1998; Skeem, Johansson, Andershed, Kerr, & Louden, 2007). The distinction being a relative incapacity to suppress transient aggressive urges resulting in emotional displays of violence, contrasted with a more stoic predilection for deliberate aggressive behavior, instrumental for achieving a desired purpose.

Reports on the effects of focal amygdala damage have suggested resultant deficits of a different nature than the disinhibitory behavior seen after frontal lobe damage. A commonly reported consequence of amygdala damage is impaired recognition of emotion, especially in human facial expression (Graham, Devinsky, & LaBar, 2007;

Rotshtein et al., 2010). There are also reports of weakened phenomenological experience of emotion (Tranel, Gullickson, Koch, & Adolphs, 2006), deficient aversive learning (De Martino, Camerer, & Adolphs, 2010), poor memory for episodic emotional content (Adolphs, Cahill, Schul, & Babinsky, 1997), and a lack of startle potentiation by aversive stimuli (Buchanan, Tranel, & Adolphs, 2004), a classic primary symptom of psychopathy. A particularly interesting report attributed early-life amygdala damage to impairments in *theory of mind*, the ability to recognize another person's perspective or state of mind (Shaw et al., 2004). These deficits more closely represent the personality traits ascribed to the primary emotional facets of psychopathy: poverty of emotions, callousness, narcissism, a disregard for the rights and feelings of others. They also exemplify the subtle differences which necessitate a distinction between antisociality and psychopathy. For instance, in the report by Shaw and colleagues, amygdala damage acquired later in life did not produce the same impairments to *theory of mind*.

This draws attention to an important concept related to the developmental nature of certain psychopathic traits, and the difference between behavioral dysregulation and emotional dysfunction. While damage to the prefrontal cortex commonly causes dramatic and rapid changes in self-regulatory behavior, conspicuously absent are reports of focal amygdala damage resulting in acute behavioral dysregulation. Damage to the amygdala does not generally produce such dramatic changes in personality. Because of the amygdala's role in *bottom-up* behavioral regulation, the acquired deficits are more subtle. Aversive learning is critical even at very early life stages for proper socialization, and many of the identifying characteristics of psychopaths are a consequence of a lifetime of inadequate neural responsiveness to punishment, and insensitivity to threatening cues.

Such observations were an early indication that psychopathy was an inherited trait. Subsequent behavioral genetics studies have concluded that the primary emotional facets of psychopathy are highly heritable (Taylor, Loney, Bobadillo, Iacono, & McGue, 2003; Glenn, Raine, Venables, & Mednick, 2007), with requisite traits identifiable as early as seven years of age and heritability rates estimated as high as 75 percent (Vidding et al., 2005; Viding, Jones, Frick, Moffitt, & Plomin, 2008). Favorable results in these behavioral genetics studies have spurred on very recent investigations of psychopathy using molecular genetics approaches which have widely favored differentiation between behavioral dysregulation and emotional dysfunction (Gunter, Vaughn, & Philobert, 2010). At least one report has linked psychopathic "unemotional" traits to variants in genes coding for monoamine oxidase A and the serotonin transporter, 5HTTLPR (Fowler et al., 2009).

The evidence reviewed above supports a prominent view, as expressed in Lykken's *Low Fear Hypothesis* that psychopaths suffer from a deficit in emotional processing which makes them relatively unresponsive to punishment. Furthermore, it seems likely that this deficit is partially, if not completely dependent upon the functional properties of the amygdala in processing aversive emotional cues. Occasionally, however, there have been reports of findings which either do not fit, or which are at least not specifically predicted by the *Low Fear Hypothesis*. For instance, an early report by Jutai and Hare (1983) provided evidence that psychopaths may also present with abnormal modulation of attention. This report examined attention to a distracting noise by measuring a component of the electroencephalographic event-related potential called the N100, which is an early indication of sensory processing. Psychopaths had smaller cortical responses to the distracting noises indicating a more persistent focus on the primary task. To account for such evidence, an alternative theory has been suggested that presupposes a slightly more specific set of deficits in psychopaths. It relies heavily on an understanding that ordinary, healthy individuals use more than just aversive cues in the utilization of emotion in rational decision-making. Our behavior is influenced by how our attention is allocated to stimuli with different levels of inherent significance, and the proficiency with which we devote attention to a broad range of stimuli. Incorporating these elements, Newman and colleagues have proposed the *Response Modulation Hypothesis*, which states that the specific deficit psychopaths have is using motivationally relevant cues to shift attention and thereby regulate behavior, but are otherwise able to process emotional stimuli at normal levels (Newman & Lorenz, 2003).

The Response Modulation Hypothesis: Emotion and Attention

The *Response Modulation Hypothesis* has received modest, but influential empirical support. It was first outlined in a broader form, proposing a general theory of disinhibited behavioral styles including extraversion, impulsivity, antisociality, and psychopathy (Patterson & Newman, 1993). The theory was based, in part, on similarities between the behavior of psychopaths and animals with septal lesions—specifically, poor passive avoidance learning, and a tendency to perseverate an ongoing, dominant response even amidst aversive cues which should promote inhibition of that response (Gorenstein & Newman, 1980). These animals didn't have damage to the amygdala which would disrupt processing of aversive stimuli, but instead had damage to a part of the brain that helps to modulate reward contingencies. Therefore, it was proposed that if punishment fails to deter behavior it could theoretically be from either insensitivity to punishment or hyper-responsiveness to reward. Fowles (1980) had similarly tried to account for psychopath's varying reward contingencies in terms of Gray's (1981) model of personality, proposing that psychopaths have a weak *Behavioral Inhibition System*, but a healthy *Behavioral Activation System*, which was essentially left to operate unchecked, making them much more responsive to reward contingencies than to punishment.

Early evidence in support of the *Response Modulation Hypothesis* came from a set of investigations into psychopaths' passive avoidance learning under various kinds of punishment and reward scenarios. Newman and colleagues reported that psychopaths indeed had impaired passive avoidance learning, but this deficit was only apparent under mixed-incentive conditions, when punishment interferes with ongoing rewards. Errors were driven by perseverating responses to reward contingencies; however, in situations where the punishment is the only incentive, psychopaths showed no impairment (Newman & Kosson, 1986; Newman, Patterson, & Kosson, 1987; Newman, Patterson, Rowland, & Nichols, 1990). While these reports suggested that reward contingencies also play a moderating role in psychopaths' apparent passive avoidance deficits, they did not contribute any direct evidence to support the hypothesis that psychopath's have a specific deficit switching their focus of attention. This assertion specifically suggests that psychopaths not only have difficulty processing peripheral aversive cues, but must also suffer deficits processing emotionally neutral stimuli when they are peripheral to immediate focus. This notion has received some support from data which suggest that in a motivated attention task, psychopaths suffer less interference by motivationally neutral information than control subjects (Newman, Schmitt, & Voss, 1997). Until very recently, evidence for the *Response Modulation Hypothesis* has been primarily based on behavioral performance during complex learning tasks. According to Newman and colleagues, the first physiological support for deficits in attention shifting was offered in a demonstration that psychopaths are capable of normal fear-potentiated startle under conditions where attention is specifically directed toward fear-related cues (Newman, Curtin, Bersch, & Baskin-Sommers, 2010). This investigation examined fear-potentiated startle under two conditions, one where task parameters required attention to be devoted to non-emotional cues and a second condition requiring a behavioral response to an explicit cue indicating the potential for receiving a painful electric shock. Under the first condition, psychopaths demonstrated the typical deficits in startle potentiation; however, they demonstrated normal potentiation effects when their task performance depended on attention to the emotionally modulating stimulus.

The evidence presented for the *Response Modulation Hypothesis* is persuasive, but it must be evaluated cautiously, especially where it appears to contradict existing reports. Particularly interesting is the recent report (Newman et al., 2010) that challenges one of the most universally accepted findings in psychopathy research, i.e. deficient startle potentiation. In evaluating this outcome and determining how to apply it to extant data, it is important to recognize some key differences between Newman's recent study and more traditional startle modulation paradigms. First, Newman and colleagues used threat of electric shock to induce a state of anxiety, thereby eliciting conditional startle potentiation; past reports of psychopaths' deficits in startle modulation have almost invariably been carried out using pictures from the *International Affective Picture System* (IAPS; Lang, Ohman, & Vaitl, 1988), a large set of photographs with standardized ratings of valence and arousal, which have been widely used in the experimental modulation of emotional arousal (Lang et al., 1993). Nevertheless, a few previous reports have demonstrated that psychopaths still exhibit reduced startle potentiation under conditions anticipating a noxious stimulus (e.g. Patrick, 1994). Likewise, there have been extensive demonstrations of smaller skin conductance responses while anticipating noxious stimuli (e.g. Hare, 1965b; Hare, 1982; Hare & Craigen, 1974), and these data should not be ignored.

Another methodological difference in this investigation is that Newman and colleagues (2010) provided task instructions that required an active response to threat cues, and this may be the most valuable difference implemented therein. Most startle modification tasks involve passive reception of all cues, the task instructions being something like, "*Simply watch the picture presentation and ignore the sounds you hear*." When a goal-directed behavior is introduced, the cognitive process of evaluating stimuli becomes more complex, but arguably adds ecological validity, since it is the automated modification of ongoing behavior that ultimately leads to pathological and/or maladaptive behavior. When task performance is introduced, one is no longer simply addressing the degree to which emotional information primes reflexes, but rather how something like anxiety is automatically incorporated into behavior, even when it is from an unattended source. Previous research has shown that altered directions of focus during startle tasks affect the outcomes of startle modification in normal subjects as well (e.g. Anthony & Graham, 1985; Cuthbert et al., 1998; Steele-Laing & Hicks, 2003), but this may be the first time this has been specifically addressed in a psychopathic population.

Newman incorporated this altered focus into his interpretation, but I don't believe his conclusions follow naturally, without presumption of certain untested details. The given conclusion is that psychopaths are fully able to process emotional information as well as non-psychopaths when it is the only goal-oriented, task-relevant information available, and that peripheral cues, whether positive or negative, go unattended—unable to gain access to resources ordinarily accessed for behavioral modification. While the outcome of the experiment (Newman et al., 2010) does not contradict that hypothesis, it is at least partially unsupported by the data. The given conclusion implies that the automated capture of attention by peripheral emotional stimuli is deficient; however, this experiment more specifically tests psychopaths' ability to actively focus attention on emotionally relevant details when it is their intention to do so—possibly resulting in potentiation due to directed attention to the startle probe rather than integration of emotional cues. The *Response Modulation Hypothesis* is an intriguing idea that brings a welcomed, more detailed assessment of what differences exist in psychopaths' cognitive processing stream, but in saying that psychopaths actually process emotional information at normal levels, the model seems to ignore a great deal of evidence from functional imaging studies and lesion studies, discussed above, which have suggested that psychopaths have diminished basic responses to emotional information at the level of processing carried out by the amygdala. Ultimately, more evidence will be needed before any robust conclusions can be made. What is most important is that Newman has affirmed an important notion that the deficits associated with psychopathy may involve an interaction between emotion and attention, rather than a simple deficit in emotional processing.

Psychopathy, Emotion, and Attention

Certain aspects of previous experimental outcomes are often overlooked or minimized when referencing psychopaths' basic deficits in emotional processing, because they may not seem immediately relevant; however, these details become important when employing the notion that attention is a critical factor of psychopaths' deficits. For instance, it is commonly referenced that startle modulation investigations indicate deficient blink potentiation during the viewing of aversive pictures for psychopaths, but it is often ignored that simultaneous measures of peripheral autonomic arousal across picture valences often have not indicated any deviation from that of healthy controls (e.g. Patrick et al., 1993; Patrick, 1994). Part of the reason for this is that peripheral measures are reliably increased for both positive and negative valenced stimuli based on general sympathetic arousal, independent of valence (Lang et al., 1993). Seeing an erotic picture increases one's heart rate and skin conductance just the same as seeing a disturbing picture of a burn victim; that is, these responses are not specific to defensive reactions or threat detection where psychopaths' theoretical impairments lie.

This helps to explain a phenomenon often ignored in general reference to the literature on startle physiology and psychopaths. While, again, it is well-corroborated that psychopaths have deficient startle potentiation during aversive cues, it is regularly neglected that psychopaths have often demonstrated *attenuated* blink reflexes for both positive and negative stimuli (e.g. Levenston et al., 2000; Patrick et al., 1993; Sutton, Vitale, & Newman, 2002). Levenston and colleagues (2000) attributed this effect to foreground attention taking precedence over motivational priming; that is, a picture that fails to motivate specific defensive or appetitive reactions may still be more elaborate and interesting than their neutral counterparts, thereby achieving stronger activation of attention particularly under passive viewing conditions (Bradley, Cuthbert, & Lang, 1990).

Recognition of attention's moderating influence on startle physiology has allowed the development of a specific hypothesis incorporating this effect. The startle probe is, itself, an aversive stimulus eliciting a defensive behavioral response, but this is a hard-wired response which exists parallel to influences of emotional state. When positive, appetitive, approach networks are primed, or when attention is otherwise engaged, this will have an inhibitory effect on the hard-wired defensive posture elicited by the startle probe. Conversely, when aversive stimuli prime a defensive state, startle magnitude is facilitated (Lang et al., 1990). With two motivating forces imparting influence on an aversive, reflexive response, a dynamic interplay of inhibition and facilitation is achieved, but for someone with an impaired threshold for distinguishing threat, intervening stimuli may only serve to inhibit defensive responses to the startle probe (Patrick, 1994). When Cuthbert, Bradley, and Lang (1996) carried out a startle modification design using only pictures with low to moderate arousal ratings, healthy non-psychopathic subjects demonstrated significant attenuation for both positive and negative valences—similar to the results often obtained when showing psychopaths photos with high arousal ratings. So it seems that moderately arousing, novel stimuli attenuate the startle reflex by diverting attentional resources from the aversive startle probe, while intensely arousing stimuli of a negative valence are capable of arousing defensive networks which results in potentiated startle reflexes, unless the facilitative defensive arousal fails, as in the case of psychopaths.

Existing reports are not sufficient to determine with great specificity the true nature of the emotional deficits associated with psychopathy. Functional neuroimaging and startle modulation studies have both suggested impairments in amygdala function, but it is not clear what role attention serves when utilizing defensive cues to modulate behavior. If it is true that psychopaths have raw deficit in processing emotional information, it is unclear why they have often demonstrated appropriate peripheral autonomic responses to aversive and pleasurable stimuli. If it is true that psychopaths are capable of processing emotional cues when it is the only contingency of task performance, it is unclear why they fail to achieve appropriate emotional facilitation under completely passive conditions. Furthermore, it is unclear what stage of information processing benefits from attention to emotional valence in experiments demonstrating psychopaths' apparent ability to achieve affective integration during goal-oriented task performance. If the goal is to determine with greater specificity what causes the breakdown in priming defensive networks in psychopaths, it will be necessary to supplement existing data using methods that effectively account for both attentive and pre-attentive stages of information processing.

While functional neuroimaging studies have consistently demonstrated reduced amygdala activation for psychopaths during tasks that require processing emotional information, this technique has not fully explained how, exactly, psychopaths process emotional information differently or where along the information processing stream things go awry. The current capabilities and limitations of functional neuroimaging make this technique inadequate for the investigation of cognitive processes which happen very quickly. Methods such as fMRI rely on ratios of blood oxygenation which changes as a secondary consequence of neural activity. Subsequently, the temporal resolution of functional imaging is notoriously poor (on the order of several seconds); therefore, the time course of neural events during emotional perception is greatly obscured with this method. Furthermore, the sudden rise in popularity of functional imaging studies has perhaps allowed the emerging data to outrun the development of meaningful interpretive theories. While such critiques are beyond the scope of this project, useful evaluations of these and other issues surrounding fMRI methodology have been offered by Logothetis (2008) and Van Horn & Poldrack (2009), among others.

An alternative psychophysiological technique with a longer history of experimental use involves recording electroencephalographic (EEG) activity, sorting and averaging these waves in a time-locked manner with special attention to changes in brain activity induced by carefully controlled delivery of stimuli. These event-related potentials (ERPs) have several advantages over fMRI not the least of which is a direct measurement of neural activity, resulting from massed synchronized post-synaptic activity near the surface of the cerebral cortex. Modern EEG recordings sample this neural activity at high rates, from several hundred to thousands of samples per second; therefore , ERPs are also capable of deciphering changes in neural activation on the order of milliseconds, making them well-suited for investigating quickly processed information. Despite diminished spatial resolution reducing the specificity of localizing neural activity with electrocortical recordings, modern techniques using high density electrode arrays are capable of making meaningful estimates of source activity (Michel et al., 2004; Scherg & Picton, 1991). Moreover, cortical potentials have been widely investigated for over five decades, endowing this methodology with the longevity necessary to support some robust and detailed theories regarding the relationship between ERP components and specific cognitive functions. ERP methodologies, therefore, continue to complement findings from functional imaging studies, providing more specific details about the temporal progression of cognitive events and basic information processing. It is my intention to utilize these advantages in the investigation of the temporal progression of affective processing in psychopathic individuals.

Event Related Potentials and Psychopathy

For the purposes of this project, it should be recognized that ERPs have a rather unique capacity for investigating the very early stages of affective processing; however, before it is possible to outline a thorough hypothesis regarding how ERPs might elucidate the specific problems psychopaths have with emotional processing, it will be necessary to describe what is currently known and suspected about these ERPs in healthy individuals. The following will be a brief review of this information.

General Comments: What is an ERP Component?

There are several naming conventions applied when referring to specific electrocortical potentials, and given the long history of this methodology, there are many "standard" ERP components which have been named and categorized as to their correspondence to specific stages of information processing. Most of these standard ERPs are named by identifying the direction of its deflection—positive or negative—and the approximate time at which the component occurs in milliseconds after the evoking stimulus. Thus the N200 (or N2) is a negative-going deflection occurring approximately 200 ms after an evoking stimulus. Other times, ERPs are named more generally by their cortical distribution and general order of processing such as the *Early Posterior Negativity*, and the *Late Positive Potential*. An alternative technique for defining ERPs is to eschew the standard set of components and simply label them based on their polarity and precise latency, e.g. P375, N275 (Kiehl, Smith, Hare, & Liddle, 2000); however, it should be recognized that components labeled in this manner probably represent the same cognitive processes defined by their more general, categorical definitions which vary slightly in latency depending on the exact task parameters.

Another commonly used but simplistic categorization principle is to divide ERPs into early, middle, and late components, but there is no universal consensus for defining cut-offs for these categories. Early components are, generally speaking, related to automated processes of evaluating stimulus properties. They are sensitive to the physical qualities of a stimulus, like loudness and brightness, and may occur regardless of conscious awareness or active assessment. Later components gradually incorporate a more complex concert of active interpretation, and may only arise if specific task parameters are adhered to. In order for these later components to become apparent in the ERP complex, certain things are required such as conscious awareness, attention, and working memory processes together. These parameters will be discussed in more detail below.

Many empirically defined ERPs coincide with each other or are synonymous, their nuances existing only in the experimental conditions under which they are evoked rather than in an obvious sensitivity to distinct information processing characteristics. One obvious example of this is the distinction between the N1, which has historically, most often been studied using auditory stimuli, and the "visual N1," which almost certainly reflects similar processing characteristics only for visual rather than auditory stimuli. Regardless of sensory modality, the N1 marks the initial arrival of sensory information to the appropriate cortical area for further processing. Other examples of this will be discussed in more detail below. As one examines the literature on any given application of ERPs, one inevitably encounters some reports focusing on the traditional components, which have relatively well-defined interpretations, as well as other reports of more nebulous components with novel interpretations. The goal here will be to focus on the traditional components and ultimately their relevance to attention and affective processing; and where necessary, relate more nuanced components to recognizable features of information processing.

Early ERP Components

The earliest ERP components are reflections of the most basic stimulus-driven processes in the brain, including stimulus discrimination and relaying of information from sensory organs such as the eyes and ears to the appropriate cortical areas for further evaluation. One of the earliest recognizable sensory potentials, the P50, occurs approximately 50 ms post stimulus and is traditionally evoked with simple auditory stimuli and is often used as a marker for inhibitory sensory gating, especially in studies of neuropsychiatric disorders such as schizophrenia (Clementz, Geyer, & Braff, 1998). The P50 may be the only component with qualities that are completely stimulus driven, where attention plays no role in its appearance or modulation (Jerger, Biggins, & Fein, 1992).

Other experimentally defined early potentials include the P1, N1, P2, and N2 (Makeig et al., 1999); although of these, the N1 is most prominent, both in physical form and in volume of published research. Many early investigations studied P1, N1, and P2 together as a complex form, often referred to as the "vertex potential" because of its mid-central scalp distribution. More recently these components have been treated as independent indices of information processing with subtle, distinctive traits, but it is widely recognized that they share many of the same qualities with regard to their relationship to stimulus processing, their physical characteristics, and their modulation especially by selective attention (Hillyard, Vogel, & Luck, 1998). This set of components share the quality of being pre-attentive, meaning that attention is not *required* to elicit them; however, selective attention does *modulate* them. The N1, for instance, can be evoked by any unpredicted stimulus in a variety of sensory modalities, and has a scalp distribution related to anatomical divisions for cortical processing of respective modalities. Visual stimuli, such as flashes of light, produce negative peaks in the occipital cortex which are larger (more negative) and have a shorter latency in the hemisphere contralateral to the visual field in which a stimulus is presented (Wascher, Hoffman, Sanger, & Grosjean, 2009). Although unattended stimuli will elicit an N1, attention has long been recognized as having a modulating effect on this potential. Haider, Spong, & Lindsley (1964) demonstrated that attended stimuli produce larger potentials than their unattended counterparts, and as attention diminishes so does the amplitude of these early potentials. The large, negative N1 component is flanked on either side by its positive neighbors, the P1 and P2. Both of these components, like N1, are sensitive to manipulations of attention (Crowley & Colrain, 2004; Van Voorhis & Hillyard, 1977). The relative gain (amplification) of these neural signals which accompanies attended stimuli has therefore been suggested as the actual mechanism by which selective attention operates (Hillyard et al., 1998).

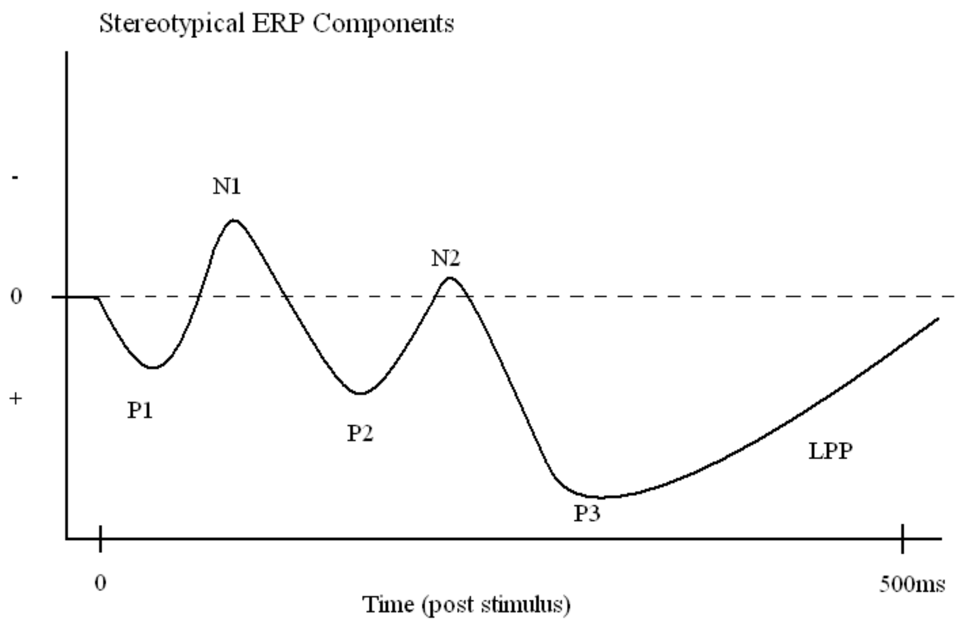

Figure 1: A typical ERP waveform, with negative polarity up and positive polarity down, includes 5 robust peaks of alternating polarity and a long-latency sustained positivity before returning to baseline.

Middle and Late ERP Components

The neural components of sensory processing get more complex around 200 ms post-stimulus. While nearly any visual or auditory stimulus will produce the P1-N1-P2 complex, the N2 is selectively generated when there are variations in repeated stimuli, or uncertainty regarding the task-related significance of a stimulus (Sutton, Braren, Zubin, & John, 1965). Luck and Hillyard (1994a, b) have interpreted the N2 as an automatic filtering stage for selective attention toward novelty, while earlier components represent more basic processes of stimulus feature analysis, which have the potential to be enhanced by ongoing selective attention. The N2 has often been interpreted as a mismatch detector in tasks where sequential stimulus monitoring is necessary, but it is also sensitive to effortful cognitive control under conditions of response monitoring and strategic regulation (Folstein & Van Petten, 2008). This stage of information processing seems to be a critical step involving task-related attention-switching since unattended variations in stimulus sequences will elicit an N2, but variations (or subtypes) in the form of N2 may be elicited by parameters requiring active attention and task relevance (Picton, Alain, Otten, Ritter, & Achim, 2000). It is also the first ERP component that has task-relevant subtypes, which include the N2a, N2b, and N2c.

These subtypes are discrete and physically differentiable, being elicited under different experimental task conditions (Folstein & Van Petten, 2008). The N2a is synonymous with an electrocortical potential called *mismatch negativity* (MMN), a component elicited automatically when there are physical variations in repetitive stimuli, regardless of whether or not a person is attending to the stimulus (Picton, Alain et al., 2000). N2b and N2c are closely integrated with two subtypes of the later P3—the P3a and P3b respectively, described below— each subtype functionally linked to its counterpart (Patel & Azzam, 2005). Since the P3 marks the detection of a target stimulus in task-related streams of information, the N2 associated with it still signals a kind of mismatch detection; however, for the N2b and N2c, attention and recognition are required, distinguishing them from the N2a. So, as it seems, attention plays a purely modulating role in early components, and at about 200 ms it determines the subtype of ERP that is generated. At about 300 ms, attention is fully required for elicitation of these and later potentials.

The P3 is one of the most robust and experimentally investigated components of the ERP. Originally the P3 was mainly studied in pair with the N2, since it was apparent that both potentials vary as a function of uncertainty in a changing stimulus set (Sutton et al. 1965). They are different, however, in that a change in stimulus quality will evoke an

N2 regardless of whether or not those stimulus features are attended to (e.g. N2a/MMN), while the P3 results from recognizing a stimulus change that is task-relevant, promoting modification of ongoing behavior. That is to say, attention is required for elicitation of the P3. Furthermore, its amplitude is largely dependent on stimulus probability (Johnson & Donchin, 1982) and task difficulty (Isreal, Chesney, Wickens, & Donchin, 1980). While earlier components indicate allotment of attention by variations in amplitude, P3 on the other hand is an index of recognition, where stimulus properties are evaluated for inclusion in a schematic set (Kok, 1997). Donchin and Coles (1988) described P3 as an index of information processing related to the engagement of working memory in the evaluation of incoming information for the purposes of updating or modifying the mental representation of the stimulus environment—or more succinctly, a marker for *context updating*. The P3 is typically evoked using parameters in which a relatively rare target stimulus, or *oddball stimulus*, is incorporated in a series of frequently occurring, non-target stimuli. So while stimulus rarity influences the amplitude of the P3—the same as N2—a distinguishing quality of the P3 is that one must attend to the rare stimulus, and mentally categorize its relevance to the task being performed.

The P3 has two variable forms distinguished by topographical arrangement and functional sensitivity. The classic P3 has a relatively posterior scalp distribution and occurs approximately 300 – 600 ms after the recognition of a task-relevant target stimulus; this potential is more precisely described as P3b. The P3a, by contrast, has a more anterior distribution and usually occurs slightly before or very near 300 ms after the introduction of a novel, distracting, non-target stimulus. For example, in a standard oddball paradigm consisting of frequent low tones and infrequent high tones designated as response targets, an infrequent, novel, task-irrelevant sound such as a white-noise burst will elicit a relatively early, frontocentral P3a. For this reason it is often called the *novelty* P3. It has been interpreted by some as an index of inhibition of inappropriate responses to non-target, novel events (Goldstein, Spencer, & Donchin, 2002). These task-dependent differences along with reports verifying their independence using a statistical procedure called Principal Components Analysis (Spencer, Dien, & Donchin, 1999) have helped distinguish the P3b and P3a as unique ERP components. Moreover, attempts to localize neuroanatomical generators of P3 have determined that there are multiple sources responsible for differences in the size and latency of these components, depending on task parameters (e.g. Halgren, Marinkovic, & Chauvel, 1998), which adds credence to the independence of these two varieties of the P3. For reviews of these and other distinguishing features, see Friedman, Cycowicz, & Gaeta (2001) and Polich (2007). Given their place as markers for the evaluation of the task-related significance of a stimulus and the modification of ongoing behavior, the P3a and P3b may be important in the analysis of psychopaths' attention and response to emotional information.

Emotion Specific ERPs: LPP and EPN

In addition to these standard ERP components, there exist two additional components which appear to have properties specific to the processing of emotional information. First, a longer latency potential, appropriately named the Late Positive Potential (LPP) or sometimes the Positive Slow Wave, appears to be specifically sensitive to emotionally evocative stimuli, independent of stimulus rarity or task relevance (Naumann, Bartussek, Diedrich, & Laufer, 1992; Diedrich, Naumann, Maier, & Becker, 1997). The LPP has been interpreted as an index of automatic attention capture by emotionally significant information, which persists beyond physical stimulus evaluation, suggesting maintenance of this information in working memory (Hajcak & Olvet, 2008). The LPP arises anywhere between 300 and 600 ms, and is maximal around centro-parietal scalp regions. Since these are also familiar characteristics of the P3, the LPP can visually appear as a sustained continuation of the P3, and some have suggested that the LPP is simply synonymous with or another variety of the P3 (e.g. Kok, 1997); however, other evidence suggests this sustained positive deflection is a separate component with unique properties, including the recent use Principle Components Analysis to empirically define the independence of these elements (Foti, Hajcak, & Dien, 2009). Unlike the P3, the LPP appears to be sustained indefinitely under conditions of prolonged attention to affective stimuli; Cuthbert, Schupp, Bradley, Birbaumer, and Lang (2000) reported this potential reached maximum amplitude around one second after stimulus onset and sustained this augmented amplitude for the full 6 second duration of the stimulus—much different from the characteristic form of the P3. It has been further clarified that the LPP is enhanced for affective content outside of an oddball-like stimulus presentation usually used for generating P3s (Schupp et al., 2000). Further differentiating the LPP from the P3, many studies have demonstrated that the amplitude of the LPP can be attenuated by instructing subjects to actively reappraise their emotional reactions to the stimuli, effectively reducing their emotional reactions to them (Hajcak & Nieuwenhuis, 2006; Krompinger, Moser, & Simons, 2008). Manipulating the contextual information to make the stimuli more arousing or less arousing also effectively attenuates the LPP (Foti & Hajcak, 2008), which has led some to interpret the LPP more specifically as a marker of emotional regulation. Since LPPs are enhanced for emotionally arousing stimuli, independent of stimulus rarity, and may remain augmented after stimulus offset by engaging in effortful evaluation processes, many researchers consider it as a unique component, separate from P3.

Recently, another component has achieved the attention of many researchers of emotion as a marker for selective processing of emotional stimuli. In a study examining ERPs to a rapid succession of pictures with varied emotional content, Junghofer, Bradley, Elbert, and Lang (2001) reported early differences in the ERP between emotionally evocative pictures and neutral pictures starting at about 150 ms after stimulus onset and reaching significant differences in negative polarity in the range of the N2, at approximately 260 ms. This finding was also recognized and replicated by Schupp, Junghoffer, Weike, & Hamm (2003a,b), who noted that the apparent selective processing of emotional information produced differences in the ERP primarily over the visual cortex during early stage processing, a finding similar to with other forms of selective visual processing, enhanced by attention to specific visual features (e.g. Noesselt et al., 2002). However, unlike other attention-modulated differences, these enhancements for emotional stimuli, occur independent of attention to emotional content.

Described by Schupp and colleagues (2003b) as the earliest ERP for selective processing of emotional information, this *early posterior negativity*, or EPN as they now commonly refer to it, is found in a time window corresponding to the N2, specifically around 232-292 ms post stimulus onset. It is described as an enhanced negative flux for both positive and negative emotional pictures, which begins to differentiate at the end of the P100—the down slope near 150ms—but is maximally different in the range of 200-300 ms, prior to the P3. It is apparent from examining the averaged waveforms (Schupp et al, 2003a; 2003b) that the EPN is not necessarily negative in any absolute sense, but may more appropriately be called less-positive, depending on its cortical topography and the relative amplitude of the waves surrounding it. Given the available evidence, and in light of other reports discussed below which demonstrate virtually universal modulation of even very early ERP components by emotional information, it seems likely that the EPN may be described more simply as an augmented N2 for emotional information. But since the available research devoted to this component is relatively sparse, further examinations will be necessary. Any attempt to use ERPs as an indication of emotional integration into psychopaths' information processing stream should require an evaluation of these purportedly emotion-specific components.

Affective Modulation of ERPs

While the LPP and EPN may be highly specialized to index appraisal of affective information, they are not the only ERP components that are sensitive to emotional arousal. Many investigations have been carried out to identify which components are modulated by emotional information, and determine exactly how early in the information processing stream the brain is capable of responding to emotional valence. Davidson (1998) coined the term *affective chronometry* to describe the study of potential individual differences in the time course of emotional processing, which may influence personality and pathology alike. The central idea behind this class of investigation is that it may be enlightening to learn which stages of information processing, as indexed by ERP components, benefit from incorporation of emotional content of a stimulus, based on what we know about the type and extent of cognitive processing associated with specific portions of the ERP.

As noted above, some early studies had recognized differences in late potentials during evaluation of emotional stimuli, which led to broader theories about enhanced potentials for emotional stimuli. Soon, investigations began recognizing differences in earlier potentials as well. Palomba, Angrilli, and Mini (1997) reported enhanced amplitudes for ERP components during an emotional memory task, apparent for N2s (at 282 ms), P3s (351 ms), and LPPs (600+ ms). Note that this report was prior to Schupp and colleagues' (2003a; 2003b) initial reports of the EPN, but demonstrates the same enhancement of ERPs as early as the N2. In a more recent study designed to assess covariation between ERPs and autonomic arousal, Cuthbert and colleagues (2000) reported augmented potentials for positive valence stimuli relative to neutral stimuli as early as 200 ms. Even more recently, there have been reports of augmented ERPs for emotional stimuli as early as about 100 ms post stimulus. For instance, Smith, Cacioppo, Larsen and Chartrand (2003) found P1 amplitudes (< 120 ms) were augmented for negative stimuli compared to positive and neutral. Similarly, Carretie, Hinojosa, Martin-Loeches, Mercado, & Tapia (2004) found enlarged P1 peaks (105 ms), and again, this was exclusively for negative stimuli, not positive stimuli. Keil and colleagues (2001) found augmentations in brain activity as early as 80 ms post stimulus, which was also exclusively related to negative stimuli.

Findings like these support the general theory that emotional stimuli, particularly those with significance for survival and reproduction engage basic motivational circuits in the brain and gain preferential access to attention, enhancing cognitive processing in various ways (Bradley et al., 2001; Lang, Bradley, & Cuthbert, 1997). They have also contributed to the growing number of reports suggesting that this effect, in the earliest stages of information processing, may be limited to or particularly exaggerated for negatively valenced stimuli; however, the accelerating number of reports examining affective chronometry has progressed with little standardization, leaving this field vulnerable to inconsistency and sometimes contradiction. In an integrative review, Oloffson, Nordin, Sequeira, and Polich, (2008) assessed reports concerning affective chronometry published over several decades. They concluded that the most reliable findings, when visual stimuli are used, are enhanced ERPs for unpleasant pictures at processing stages earlier than 300 ms, and enhanced ERPs for both positive and negative emotional pictures for later components, including the P3 and LPP. These findings are interpreted by the authors as a facilitated orienting response for potentially threatening stimuli—an obviously advantageous information processing strategy. Conversely, the enhanced processing of both positive and negative stimuli, relative to neutral, beginning at approximately 300 ms indicates enhanced memory encoding for pictures with intrinsic motivational relevance, regardless of valence.

This interpretation complements a prominent theory that there is an early processing stage *negativity bias* evident in early affective processing (e.g. Cacioppo & Gardner, 1999), which may adequately explain the relative consistency of reports that the earliest potentials (around 100 ms) are preferentially augmented by negative but not positive emotional stimuli (e.g. Smith et al., 2003; Carretie et al., 2004). This may lead to some crucial behavioral consequences which are relevant to our present focus on psychopaths' apparent deficits using emotional information for modification of ongoing behavior. In an examination of the interaction between attention, emotion, and behavioral responses, it has been reported that early attention activation for aversive stimuli apparently favors automatic motor responses designed for defensive action or escape—for instance, modification of startle reflexes—while later attention augmentation by affective stimuli serves more complex systems such as enhanced memory, and may actually favor positive (appetitive) stimuli (Carretie, Martin-Loeches, Hinjosa, & Mercado (2001).

If the goal is to implement emotion modulation of ERPs in the investigation of psychopaths' deficits in emotional processing, special attention must be paid to existing methodological strategies. Two general methodologies have been implemented in investigations of affective chronometry. The more traditional method defines ERP components *a priori*, by means of time-windows corresponding to the particular latency range where a given component should be found. For instance, one might look for amplitude differences in the N2 by examining negative potentials between 180 and 300 ms, post stimulus. This method has often been used in the examination of specific individual components (e.g. Schupp et al., 2003 a, b), but has also been implemented in larger scale multi-component studies (e.g. Keil et al., 2002). The second methodology employs statistical techniques such as principal components analysis (PCA) and independent components analysis (ICA) as a means to empirically define unique components without relying on *a priori* estimates of latency windows. This technique has been increasingly recommended due to the vulnerabilities traditional visual inspection of spatial averages is prone to, especially due to slight variations in component latency (Chapman & McCrary, 1995). PCA/ICA is particularly effective when multiple ERPs are being investigated through nonspecific evoking strategies such as passive picture-viewing paradigms (e.g. Foti et al., 2009). However, there has been debate regarding the legitimacy of ERP component analysis if a task was not specifically designed to evoke those ERPs, therefore it has also been strongly recommended that tasks be employed which are specifically designed to elicit components of interest (Picton, Bentin et al., 2000).

The most recent existing reports utilizing either of these methodologies have produced similar outcomes with only slight variations; that is, these reports confirm that most components have enlarged amplitudes for emotionally evocative stimuli compared to neutral stimuli and that this augmentation may begin as early as about 100 ms post stimulus onset. For example, a recent large sample (N = 82) investigation employed temporal PCA to determine which, in the full range of ERP components, have amplitudes that depend on the relative affective content of pictures in a passive viewing task. The findings suggested that components with polarity and epochs consistent with N1, EPN, P3a, P3b, and LPP demonstrated enhanced amplitudes for emotional pictures versus neutral pictures (Foti, Hajcak, & Dien, 2009). A similar study examining pre-defined epochs (rather than PCA derived components) reported that P3a (300-340 ms), P3b (380-440 ms), and LPP (550-900 ms) were all enhanced for both positive and negative stimuli relative to neutral and that N1 (120-150 ms) was enhanced for positive stimuli (Keil et al. 2002). An earlier study by the same group, however, had indicated that N1 amplitude was augmented for both positive and negative pictures relative to neutral (Keil et al., 2001). So, it appears that both large scale, multiple-component studies and smaller scale investigations of specific ERPs have validated claims that emotional information attains a perceptual priority even prior to conscious awareness, facilitating ongoing processing, which is manifest through augmented potentials as early as N1. ERPs, therefore, may be a valuable resource for examining in closer detail the stages at which emotional information is incorporated into the processing stream of psychopaths.

ERPs in Psychopathy Research

The use of ERPs in studying psychopathy has proven to be a fruitful realm of investigation as several studies have shown differences in the amplitudes of specific ERP components among psychopaths; although, to date, these studies have been limited to the investigation of raw amplitude differences for only a few ERP components, and the interpretation of these differences is still under debate. Raine and Venables (1987; 1988) reported that psychopaths showed enlarged P3s in a target detection task, and interpreted this as psychopaths showing enhanced resources for certain focused cognitive tasks. However, Kiehl, Hare, Liddle, and McDonald (1999) reported reduced P3 amplitude in criminal psychopaths, which is more consistent with literature on ERPs in individuals presenting with antisocial behavior, impulsivity, and other forms of externalizing behavior (Patrick et al., 2006). Again, Keihl, Bates, Laurens, Hare, and Liddle (2006) recently demonstrated enlarged N2, reduced P3, and enlarged late frontocentral negativities (N550), relative to the average amplitudes of these components in nonpsychopths. The authors interpreted these as general deficits in paralimbic processing, which despite being a routine finding in the psychopathy literature seems to be a liberal interpretation of the data which did not include any manipulations of affective information. Carlson, Thai, and McLarnon (2009) reported that smaller P3 amplitudes were associated with the antisocial facet of the psychopathy, while the factor measuring emotional deficits actually predicted enlarged P3 amplitudes.

A recent metanalysis by Gao and Raine (2009) expressed a conclusion that reduced P3 amplitude is an indication of inefficiencies in processing task-relevant information, and is a more consistent outcome among those with disorders of behavioral regulation such as antisociality and impulsivity, whereas this outcome varies with specific task parameters among those who demonstrate primary psychopathic traits. As mentioned above, it may be true that psychopaths have a specific attentive proficiency during goal-oriented tasks (Jutai & Hare, 1983; Raine, 1989) and this may be fostered by a reduction in automated attention capture by non task-related stimuli (Newman, Schmitt, & Voss, 1997). Furthermore, it is reasonable to suspect that this elusive psychophysiological feature of psychopathy may be obscured by an over-reliance on incarcerated samples, in which antisocial and externalizing disorders are an inescapable corollary.

While studies like these have largely focused on raw differences in the amplitude of the P3 ERP component, this elemental property is limited in its interpretive utility since there is no thoroughly established explanation about what such differences in P3 amplitude actually suggest about mental function. Some interpretations have been discussed above, converging on the notion that P3 marks the engagement of task-related attention, where working memory is employed for the purpose of stimulus discrimination (Donchin & Coles, 1988), but it has not been established what individual differences in mean amplitude might suggest about cognition. For instance, even if it were clear that psychopaths produce larger P3 amplitudes than healthy controls during a simple target detection task, this may be a sign of increased processing resources, as has been suggested by Raine (1989); alternatively, it may be a sign of a narrow allotment of attention possibly signifying overactive inhibitory processes in early stages of information processing (see Soltani & Knight, 2000). Even still, it could suggest that psychopaths have deficiencies in the allotment of attention for peripheral cues, as has been suggested by Newman and colleagues (1997). The relative strengths of these and other theories would require a more comprehensive understanding of the fundamental neural events which give rise to these ERPs, and these processes are not yet fully understood.

Rather than simply measuring raw differences in average ERP amplitudes between groups, it may be more productive to investigate how these potentials are modified by emotional stimulus content, much in the same way that startle reflex modification has been studied in psychopaths. As described above, several studies have demonstrated that a variety of ERPs are sensitive to levels of emotional content in stimuli; that is, stimuli with greater emotional valence receive preferential perceptual processing and generally increase the amplitude of ERP components (e.g. Foti, Hajcak, & Dien, 2009; Keil et al., 2002; Schupp, Junghofer, Weike, & Hamm, 2003b). Given that a key feature of psychopathy is abnormal processing of emotional information, it will be important to determine how affective stimulus content modulates ERPs in psychopaths, if it does at all. Currently, there are no existing reports investigating the modulation of psychopaths' ERPs with emotionally evocative stimuli. If any divergences exist between psychopaths and healthy controls in these cortical potentials, this would suggest previously unrecognized differences in the basic stages of information processing and may elucidate the true nature of the affective deficits which accompany psychopathy. Furthermore, it may be possible to determine if such differences are more closely related to deficits in the raw processing of emotion, deficits in automated attention capture by emotional information, or in effortful processing stages, such as the integration of emotion in working memory. Interpretation of such results would require careful reference to what is currently known about the affective modulation of ERPs in healthy individuals.

The Current Study

Since there are no existing published reports on this topic, the present investigation will be largely exploratory, but it is possible to make some preliminary hypotheses regarding possible outcomes. For instance, if psychopaths indeed have a raw deficit in emotional processing, I suspect that even the earliest ERPs will fail to show augmentation for emotional content, and there will be no emotion-related variation in ERP amplitude for any subsequent components. Alternatively, it may be true that emotional information is incorporated into early processing stages for psychopaths, but this does not trigger any kind of salience-related amplification for task-relevant processes. If this is the case, psychopaths may demonstrate amplification of early sensory ERPs, but fail to show augmentation of P3 amplitudes. With respect to the P3a and P3b, it will be interesting if differences in augmentation exist for either or both of these components, which may add credence to claims that psychopaths are capable of processing emotion-related information when it is a task-relevant property, but not when it is a feature of peripheral or distracting information. Furthermore, manipulations of attention toward specific affective features of stimuli may be capable of moderating any differences that exist in the waveforms of psychopaths and non-psychopaths.

It is the goal of this investigation to reveal more specifically the deficits in emotional processing evident in psychopaths by examining differences in the modulation of ERP components with affective stimulus content. The current study will employ a novel task specifically designed to elicit the components which have been shown to be reliably modulated by emotional information in healthy individuals—specifically P3a, P3b, and LPP, and will also examine early sensitivity to affective information in components such as N1 and N2/EPN. If differences on these measures are apparent between psychopaths and healthy controls, the stages of processing affected will shed some much needed light on an area of interpretation which has been obscured by a sustained reliance on less specific psychophysiological measures.

CHAPTER TWO

Experimental Methodology

Power Analysis

In order to achieve an a priori estimate of the number of subjects needed to achieve appropriate statistical power, results from several published studies were considered to gain an estimate of effect sizes for augmentation of ERPs using affective pictures (Cuthbert et al., 2000; Foti et al., 2009; Keil et al., 2002; Palomba et al., 1997). Effect sizes varied widely between studies and the specific contrasts examined, but they were generally medium to large effects, with an overall average Cohen's *f* value of about 0.3 (medium effect). A power analysis was carried out using *G*Power 3* software (Faul, Erdfelder, Lang, & Buchner, 2007) in order to determine sample sizes necessary to achieve statistical significance for various effects and interactions of interest. The required number of subjects depends heavily on the format of analysis, especially the number of repeated measures implemented. With ERP values recorded at 64 electrodes, it is theoretically possible to analyze 64 repeated measures, which drives the estimated required number of subjects down to about 6; however, though very detailed, this would not be the most efficient way to represent topographical differences in amplitude across the scalp. It is more economical and comprehensive to use regional summaries to represent variations in amplitude across the full array of electrodes. For instance, it is traditional to create summaries of up to nine or more regions as a better representation of these topographical variations. With α set at .05 and estimating a medium effect size (f = .30), a (2 x 2 x 3 x 3) mixed-model ANOVA with a 2-level between groups factor

(Psychopath vs. Non-Psychopath) and three repeated-measures factors representing emotional content (emotional vs. non-emotional), 3 lateral regions (Left, Middle, Right) and 3 anteroposterior regions (frontal, central, parietal) would require 14 total subjects (7 per group) in order to achieve a minimum power of .80 for detecting a main effect on either repeated measures factor; however, detecting a significant psychopathy group x repeated measures interaction would require 16 total subjects (8 per group). Anticipating potential outliers, recording failure, or other unforeseen issues with data analysis, a conservative goal of achieving at least 12 subjects per group was set.

Subject Recruitment

In order to avoid the potential confounding influences of severe antisocial personality disorder, it was preferred to seek out non-incarcerated subjects from the local community with the residual requirement of attaining disparate scores for psychopathic traits between groups. Selectively recruiting and analyzing “extreme groups” has been a common method of protracting differences that likely exist on a continuum in a normal range sample. One method used to selectively recruit volunteers with elevated psychopathy scores from community samples has been to use non-pejorative descriptions of psychopathic personality traits in advertisements for the study, framing these as desirable qualities for participants in the experiment (Widom, 1977), although some have reported only modest success with this technique. For instance, in a recent study DeMatteo, Heilbrun, and Marczyk, 2005 implemented this recruitment method and used the following advertisement distributed in local newspapers and flyers.

Are you charming, intelligent, adventurous, aggressive, and impulsive? Do you get bored easily and like to live life on the edge? If you would like to make some easy *money ($25) by participating in a confidential 2-hour interview at XXX University, please call xxx-xxx-xxxx to set up an appointment. You must be 18 years of age to participate.*

This advertisement produced 207 responses over 8 weeks. Phone interviews confirmed the eligibility of 104 individuals who met specific criteria including the ability to provide a collateral contact for scoring of the PCL-R which requires information from a collateral source. The PCL-R is administered using a semi-structured interview and additional scoring of collateral information (in this case obtained from the contact provided by the volunteer), thereby requiring a significant investment of resources before the scores are even obtained and before any further assessment might be done. Of the original 207 respondents, 54 completed the study with a PCL-R range of 4 to 27—a fairly normal range of scores, which ultimately was analyzed using a median split—a common methodology for assessment of normal-range continuous data. This would not be an ideal analytic strategy for an exploratory assessment of psychophysiological differences which may produce subtle effects. It was decidedly preferable to use a more economical assessment of psychopathic traits and limit psychophysiological investigations to more disparate groups of volunteers, therefore a few simple adaptations to this methodology were implemented.

An advertisement using a description very similar to the one above was placed in local newspapers, and fliers were distributed around campus and the local area. A second advertisement was also distributed which advertised contrasting qualities such as being humble and cautious. Fliers and newspaper space advertised compensation of *"up to $75"* for participation, and directed volunteers to visit an online survey posted on a widely-used survey website, www.surveymonkey.com, which allows participants to log on at their own convenience and complete the survey from any computer with internet access. Results can be scored and downloaded by experiment facilitators, thereby screening participants for scores on psychopathic traits using the PPI-R, which is an economical alternative to lengthy interviews needed for the PCL-R. This also allowed for more precise control over participants who eventually provided psychophysiological data.

The initial web page, when visited by interested candidates, included a great deal of preliminary information regarding their participation. It informed them that we were looking for volunteers to come to a Baylor University science laboratory where we would record physiological data including *"brain waves and muscle activity."* Participants completing this portion of the study would be guaranteed a compensation of at least $25 (in the form of a Wal-Mart gift card). In order to qualify for this portion of the study, volunteers were required to fill out the online survey, which would also automatically enter them into a drawing to receive a $50 Wal-Mart gift card. Following this, a selected portion of those completing the survey would be contacted and invited to participate in the physiological data collection at Baylor University.

Exclusions and Qualifications

Requirements for participation in physiological data collection were that volunteers be at least 18 years of age, able to access the internet to complete the online survey, able to provide a home address and phone number where they can be reached, and able provide their own transportation to and from the Baylor sciences facility. A short preliminary inventory included in the online survey screened for any major exclusionary criteria. These consisted of a history of any prior major head injury, treatment for Axis I thought or mood disorders (examples of schizophrenia and major depression were given), post-traumatic stress disorder, recent treatment for drug or alcohol dependence (not within the past 12 months), epilepsy, any hearing deficits or required use of a hearing aid, and any uncorrected visual deficits. Participants reporting any exclusionary criteria were precluded from selection for psychophysiological assessment. Additionally, demographic information was gathered including age, sex, race, and level of education.

Qualification for participation was based on participants' scores on the PPI-R. Since psychopathic personality traits exist on a continuum of individual differences, the PPI-R does not provide any cutoff scores for categorical assessment of psychopathy; therefore, percentile ranks based on published norms (Lilienfeld & Widows, 2005) were used as a means to distinguish disparate groups to be assessed for psychophysiological differences. Participants with PPI-R scores in the upper and lower quartiles of published norms were contacted regarding their eligibility to participate in psychophysiological data collection at Baylor University. This method of recruitment was used to ensure assessment of individuals with more extreme variations in personality traits, thereby minimizing unnecessary effort evaluating individuals with moderate range scores and increasing the odds of recognizing physiological differences related to the psychopathy construct. Willing participants were scheduled for laboratory sessions during which all additional data were collected, including an assessment of intelligence using the verbal subscale (VIQ score) of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999).

Self-Report Assessment

Psychopathic traits were assessed using the Revised Psychopathic Personality Inventory (PPI-R; Lilienfeld & Widows, 2005), administered in an online format. The PPI-R is a self-report test designed for use in identifying psychopathic personality traits in a non-institutionalized population; however, it has been validated for use in both institutionalized and community samples (Patrick, Edens, Poythress, Lilienfeld, & Benning, 2006) and is widely used in the assessment of psychopathy in normal-range community samples (e.g. Benning et al., 2005; Carlson et al., 2009; Justus & Finn, 2007). An earlier version exists (PPI; Lilienfeld & Andrews, 1996), which had been similarly validated (Poythress, Edens, & Lilienfeld, 1998); however, this most recent revision has removed a few poorly worded questions from the original. Sandler (2007) has validated the congruency of the PPI-R in an online, computer-based format, versus the standard paper form.

The test consists of 154 items requiring responses on a 4 point, Likert-type scale, with responses ranging from false to true. It yields a total score representing global psychopathy, and grades on 8 separate factor scores. *Machiavellian Egocentricity* represents a willingness to exploit others for personal benefit, *Social Potency* measures interpersonal fortitude, *Fearlessness* is a measure of willingness to take physical risks with low anticipatory anxiety, *Coldheartedness* represents an absence of empathy, *Impulsive Nonconformity* measures one's disregard for tradition, *Blame Externalization* scores a tendency to divert responsibility, *Carefree Nonplanfulness* measures an apparent disregard for the future, and *Stress Immunity* represents low anxiety response in ordinarily anxiety-provoking situations. Seven of these elements have been found to feed into two primary factors (Benning et al., 2003): an interpersonal/affective component labeled *Fearless Dominance* and a component of social deviance dubbed *Self Centered Impulsivity*. The subfactor *Coldheartedness* stands on its own. Because it was developed and originally implemented in a university sample, antisociality items do not necessarily suggest criminal behavior as unequivocally as the PCL-R items, but rather suggest personality traits consistent with rule-breaking and a subversive attitude toward authority. A non-incarcerated sample, then, can still be expected to show a normal distribution of scores on this impulsive/antisocial component, as it is not synonymous with DSM-IV-TR criteria for ASPD.

Psychophysiological Assessment

Participants who were selected to undergo psychophysiological assessment based on PPI-R scores were scheduled to complete this portion of the study in our lab at the Baylor Sciences Facility. After administration of the WAIS for assessment of verbal IQ, participants underwent two components of psychophysiological assessment. Since examination of the affective modulation of ERPs and its relationship to the psychopathy construct will be predominantly exploratory in nature, it was decidedly beneficial to include a more elementary assessment of emotional processing on a predictable psychophysiological measure, which can provide a manner of validation that selected groups indeed demonstrate certain differences expected to accompany psychopathic traits. Participants therefore underwent a standard affective picture-viewing eye-blink startle paradigm in addition to a novel task developed to assess the modulation of various ERP components with emotionally evocative stimuli.

Startle Paradigm

Physiological recordings took place in a sound and light attenuated, radio frequency anechoic chamber (Raymond EMC Enclosures Ltd. Ottawa, Ontario, Canada) designed to minimize interference from superfluous electromagnetic waves. Participants were seated in a padded chair at a desk directly in front of a computer monitor, and fitted with a pair of noise-canceling headphones, through which the startle probes were delivered. Subjects were instructed simply to watch the picture presentation and that they would occasionally hear noises which sound like bursts of static, and that these noises could simply be ignored.

The affective picture-viewing startle modulation task utilized pictures from the International Affective Picture System (IAPS; Lang et al., 1988), a set of images with standardized ratings of affective valence and arousal level (Lang & Greenwald, 1988). Valence ratings indicate scores on a scale from pleasant to unpleasant. Arousal ratings indicate a valence-independent measure of how stimulating the image is. Forty-five total pictures[1] were chosen from the set, with 15 pictures falling into each of three valence categories: pleasant, neutral, and unpleasant. These pictures were chosen such that neutral pictures do not favor positive or negative valences, and have very low arousal ratings. These images mainly consist of household items, mundane landscapes, and non-emotional pictures of people. Emotional images were chosen such that valence and arousal levels were matched for both male and female raters. That is, valences for pleasant and unpleasant pictures are equidistant from neutral ratings with arousal levels

[1] Pictures used are as follows, asterisks mark pictures matched with startle probes. Positive: 4658, 4659, 4660*, 4670, 4680*, 4687*, 4690*, 5626, 5629*, 8030*, 8190*, 8200*, 8370*, 8470*, 8490. Neutral: 6150*, 7009*, 7010*, 7035*, 7050*, 7140, 7150, 7185, 7186*, 7205*, 7211*, 7224, 7235, 7500*, 7595*. Negative: 2730, 3010, 3150*, 3250*, 3400*, 3500*, 6020, 6210, 6212*, 6230*, 6360*, 6370, 6510*, 6530*, 9250*.

matched. Pleasant images consist of thrilling events, awe-inspiring nature scenes, and romantic heterosexual couples. Unpleasant images consist of scenes of attack, victim abuse, and human injury.

During the presentation, all pictures remained on the screen for 6 seconds, separated by 10 second inter-trial intervals, during which a small cross hairs was centered on the screen to indicate a center of focus. Ten of the fifteen pictures from each valence were paired with a startle probe, a 50 millisecond, 100 decibel white-noise burst with near instant rise. Probes occurred randomly between 3 and 5 seconds after picture onset. Pictures were ordered pseudorandomly, such that no two pictures of the same valence, paired with a startle probe, occurred sequentially. The presentation began with three startle probes, three seconds apart, during an initial screen with cross-hairs (same as ITI screen). This was intended to accommodate the subject to the startle probe, and to avoid the initial large blinks associated with initial probes. These blinks were not included in the analysis (*cf*. Patrick and Berthot, 1995). The startle paradigm was designed and delivered using Superlab 4.0 software (Cedrus Corporation, San Pedro, CA).

Magnitude of the startle response was measured by electromyogram recordings from the *orbicularis oculi* muscle of each subject's right eye. A pair of Ag-AgCl electrodes (Biopac Systems Inc., Goleta, CA) was placed 1 cm below the lower lid of the right eye, one directly below the pupil and a second 1 cm to the right of that electrode. A third electrode was placed in the center of the forehead as a ground. Skin was prepared with isopropyl alcohol and a mildly abrasive gel (NuPrep) to improve surface conduction; *Signa gel* brand saline gel was used as a conducting medium.

EMG signals were collected using BioPac MP150 data acquisition hardware using a sampling rate of 2000 Hz and a 10-500 Hz bandpass filter, rectified and integrated with a time constant of 10 ms. Data was recorded and processed using AcqKnowledge 3.9 software (Biopac Systems Inc.). Blink magnitudes were defined as a smoothed EMG signal, recorded as baseline to peak differences for each startle probe. The baseline is defined as the mean *orbicularis oculi* EMG reading during the 25 ms prior to onset of the noise; peaks are defined as the maximum EMG amplitude between 40 and 150 ms after the onset of the noise.

Event Related Potentials Paradigm

The ERP modulation task is a novel paradigm developed with the intention of eliciting several different ERP components within a single task-session. ERP recordings took place in the same radio-frequency shielded room described above. Participants were seated in a padded chair at a desk directly in front of a computer monitor and had a response device on the desk to indicate identification of target stimuli. Participants were instructed that they would see a picture presentation consisting of two types of images: a repeated abstract design and occasional actual photographs, which are response targets. Their task was to respond as quickly as possible (under the guise of a "reaction time" test) by pressing a response button whenever they saw an actual photograph. Participants were also informed that certain pictures would be superimposed with a word, and that they should withhold their response during these trials, read these words (silently).

The target stimuli, photographic images which required a physical response from the participant, occurred with an overall probability of 0.12, and were meant to elicit a

P3b. These images were selected from the IAPS[2], and were either neutral or unpleasant. This decision to exclude positive pictures was made to eliminate the necessity for multiple pairwise comparisons to account for valence effects, and to eliminate superfluous evaluation of the *negativity bias* in early stage processing. Images with a superimposed word were all previously unseen neutral pictures from the IAPS, superimposed with words from the Affective Norms for English Words list (ANEW; Bradley & Lang, 1999). This stimulus category also occurred with an overall probability of 0.12, but because they are non-target, distracter stimuli, they were intended to elicit a P3a (no-go P3). ANEW words were either neutral or negative and were matched for word length, commonality of usage, and arousal levels per gender (i.e. word are equally arousing for both males and females).

Both of these categories of rare stimuli came in two forms: (negative) emotional and non-emotional, allowing for the evaluation of emotional arousal on both P3a and P3b. Furthermore, each of these categorical stimuli elicit early sensory potentials (e.g. P1, N1, P2, N2), which were all analyzed for effects of emotional arousal. Elicitation of these components by means of a single task is an economical approach for evaluating the integration of emotional information into distinct stages of information processing, and easily allow comparisons of amplitude changes between groups selected for extreme scores on psychopathy measures.

To assess the potential moderating effects of attention to emotional information, a second version of the ERP task was implemented for each participant. The participants were informed that they would see the same picture presentation they had just watched,

[2] Neutral: 2190, 2440, 2570, 2840, 2880, 2890, 5130, 5390, 5510, 5740, 7000, 7020, 7031, 7040, 7175, 7217, 7490, 7491, 7950, 2480. Emotional (Negative): 1201, 3000, 3053, 3071, 3080, 3110, 3120, 3130, 3170, 6313, 6350, 6550, 6560, 6570, 9040, 9252, 9253, 9410, 9592, 9921.

however, their instructions were to categorize each photographic target as either emotional or neutral, using two response buttons. For pictures superimposed with words, their instructions remained the same: to withhold their response, but to read the word silently. For photographic targets, this second condition was intended as a means to make attention to emotional information task-relevant, which would allow comparisons against the first condition in which processing of emotional information was implicit, and only an incidental feature of stimuli which were response targets.

To obtain electrocortical measurements, EEG data was recorded from scalp sites using a fitted, elastic cap (Electro-Cap International, Inc. Eaton, OH) consisting of 64 tin electrodes arranged in the international 10-20 system, with standard and intermediate positions. To improve scalp conduction, electrode sites were cleansed with isopropyl alcohol and prepared with a mildly abrasive gel (Nuprep). Impedences of electrodes were kept below 5 kΩ. During recording, scalp electrodes were referenced to a single electrode, Cz, and re-referenced offline to electrodes affixed to the mastoids. Additionally, four electrodes placed around the subjects eyes were used to record blinks and eye movements for offline removal of ocular artifacts via spatial filter. EEG data were recorded continuously at a sampling rate of 1,000 samples per second and amplified by SYNAMPS^2 amplifiers (Compumedics Neuroscan, Charlotte, NC). Offline analysis consisted of a bandpass filter set at 0.1 Hz to 35 Hz, removal of artifacts, rereferencing to the mastoids, implementing a correction to the baseline, and averaging trials within subjects to obtain relevant ERPs, time-locked to each of the four categories of evoking stimuli described above. Data collection and offline analysis was obtained using Scan 4.3 software by Neuroscan. Relevant ERP amplitudes are defined as maximum peaks relative to baseline, 100 milliseconds prior to stimulus onset. Each peak was defined under pre-determined epochs as follows N1: maximum negative (50-200 ms), P2: maximum positive (100-250 ms), N2: maximum negative (200-350 ms), P3: maximum positive (300-500 ms), LPP: maximum positive (500-900 ms). All peaks were manually, visually checked for accuracy, before amplitudes and latencies were compiled into spreadsheet format for statistical analysis.

Data Analysis

Analyses were carried out with the goal of exhibiting differences in both startle modulation and ERP modulation between high and low scorers on the PPI-R. Analyses were carried out separately for startle physiology and ERP modulation, but the design implemented for each will be practically very similar, with the exception that ERP analyses will be more complex due to the involvement of several repeated measures factors representing topographical features of cortical potentials and multiple ERP components. While startle data have well-established expectations to reveal smaller or absent startle potentiation effects in the high psychopathic trait group, the ERP analysis was more exploratory. It was expected that augmented amplitudes for several ERP components would accompany emotionally evocative pictures for non-psychopaths, those with high psychopathic traits would fail to demonstrate augmentation of at least one ERP component, but possibly several. Furthermore, it was expected that conditional direction of attention toward emotional information as a task-relevant property of the photographic targets would augment ERP differentiation between stimulus categories for psychopaths. For all analyses, group divisions were determined by PPI-R total score.

For analysis of startle data, standardized blink amplitudes were analyzed with a (2 x 3) mixed-model ANOVA comparing two groups (high psychopathy x low psychopathy) and three picture valences (Pleasant, Neutral, and Unpleasant). A significant psychopathy group by picture valence interaction would be the main effect of interest and would indicate different patterns of blink modulation between groups, which would be further analyzed by comparing scores at individual picture valences.

For analysis of ERP data, each component peak was analyzed separately, as its own independent variable, and submitted to a (2 x 2 x 3 x 3) mixed model ANOVA comparing the two groups (high psychopathy x low psychopathy) on three within-subjects variables representing emotional content (emotional and non-emotional), lateral scalp region (Left, Middle, Right), and anteroposterior scalp region (frontal, central, parietal). A significant psychopathy group by emotional content interaction would be the main effect of interest and would indicate differences in emotional modulation of ERP amplitude, without any necessary follow up tests. This same set of analyses was carried out for the second ERP task, which directed attention to emotional information. Differences in patterns of modulation were analyzed by follow up ANOVAs which used this task condition as its own repeated measure, allowing for comparisons of this effect within-groups.

The nature of these *effect-modulation* analyses is a bit peculiar, since they are designed to demonstrate deficiencies in an effect that is ordinarily present in healthy individuals. It is common to see in the startle modulation literature that psychopaths "lack potentiated startle," but it is actually impossible to prove this statistically. It is only possible to show that psychopaths' modulation patterns are significantly different from controls and that the effects of potentiation are diminished or not apparent in a given sample size. This is a more appropriate interpretation since amygdala functionality likely varies on a grand continuum, and its effects on physiological measures such as startle reflex and ERP modulation probably occurs in a dimensional fashion. Because of the nature of this analysis comparisons of effect sizes between groups are an important and appropriate means of quantifying the differences in modulation between groups.

CHAPTER THREE

Results

Participant Data and PPI-R Scores

43 participants attended lab sessions for physiological data collection. Three participants' data were eliminated from analysis, one participant fell asleep during data collection and there were recording failures/errors on two participants, leaving 40 total participants (20 per group) with useful data. Of these 40, 21 were female, 32 were Caucasian/white with 7 Hispanic and 1 Asian/Pacific Islander. The mean age was 25 years, with a range of 18 to 57. Examining possible differences between groups on variables of gender, age, ethnicity, and verbal IQ (VIQ) revealed no significant effects. Level of education was divided into five categories and also revealed no significant differences between groups. Participants for each group had been selected for disparate scores on the PPI-R total scores. PPI total score and factor scores (SCI and FD) and their respective ranks were, of course, significantly different between groups. Because individual percentile ranks differ based on gender and age, average ranks (which take these variables into account) are a better representation of group characteristics. These results are summarized in Table 1.

Startle Modulation Data

Examining raw blink amplitudes, groups did not differ overall, t (38) = .189, p > .80. Examining blinks standardized within subjects, the (2 x 3) mixed model ANOVA revealed a main effect of valence [F (2, 76) = 22.43, p < .001, η^2 = .371] indicating that

Table 1

Demographics and Sample Characteristics

Variable	Psychopaths (n = 20) Mean (SD)	Non-Psychopaths (n = 20) Mean (SD)	Test Statistic
PPI Total score	349.05 (26.73)	233.60 (19.03)	t (38) = 15.73*
PPI Total rank	92.95 (6.40)	8.9 (7.33)	t (38) = 38.63*
SCI score	164.65 (20.54)	111.15 (13.89)	t (38) = 9.65*
SCI rank	79.95 (20.63)	15.2 (11.32)	t (38) = 12.30*
FD score	147.25 (17.31)	95.30 (14.23)	t (38) = 10.37*
FD rank	90.50 (14.34)	19.80 (16.98)	t (38) = 14.23*
Age	26.1 (11.3)	23.1 (6.8)	t (38) = 0.731
Gender (Males, Females)	12, 8	7, 13	X^2 (1) = 2.51
Level of education			X^2 (4) = 5.55
Some High School	0	1	
High school grad	0	2	
Some college	16	11	
Bachelor's Degree	2	1	
Graduate School	2	5	
Ethnicity			X^2 (2) = 1.27
Caucasian/White	17	15	
Hispanic	3	4	
Asian/Pacific	0	1	
WASI Verbal	108.2 (8.55)	105.6 (11.9)	t (38) = .811

Note: There were no significant differences between groups on any demographic data, the only differences were those defined by group division on PPI-R total and factor scores.
*p-values <.001

the amplitude of blinks varied significantly across the three affective valences of pictures. This effect was superseded by a psychopathy group by valence interaction [F (2, 76) = 4.66, $p < .02$, $\eta^2 = .109$] indicating that the modulation effects due to picture valence vary significantly between the two groups. There was no difference, however, in standardized amplitude between groups, collapsed across valence category.

Follow-up repeated measures ANOVAs for each group revealed the nature of the significant modulation differences. Non-psychopaths demonstrated a strong effect [F (2, 38) = 17.28, $p < .001$, $\eta^2 = .476$] of the typical modulation patterns for standardized blink magnitudes such that blinks during negative pictures were larger (mean $z = .311$) and blinks during positive pictures were smaller (mean z = -.254) relative to those during neutral pictures (mean z = -.058). Paired t-tests confirmed that non-psychopaths demonstrated significant blink potentiation during negative pictures [t (19) = 3.10, $p <$ .01], and significant blink attenuation during positive pictures [t (19) = 2.10, $p < .05$]. Psychopaths, however, exhibited a different modulation pattern, while still showing a large valence-dependent modulation effect [F (2, 38) = 10.09, $p < .001$, $\eta^2 = .347$]. Psychopaths exhibited smaller blink amplitudes during both positive (mean z = -.261) and negative (mean z = .100) pictures relative to neutral (mean z = .161). Paired t-tests revealed that the attenuation effect during positive pictures was driving this effect [t (19) = 3.981, p < .001], while the small difference in amplitude between negative and neutral pictures was not significant [t (19) = .646, p > .50]. A comparison of blink modulation patterns for each group is represented in Figure 2.

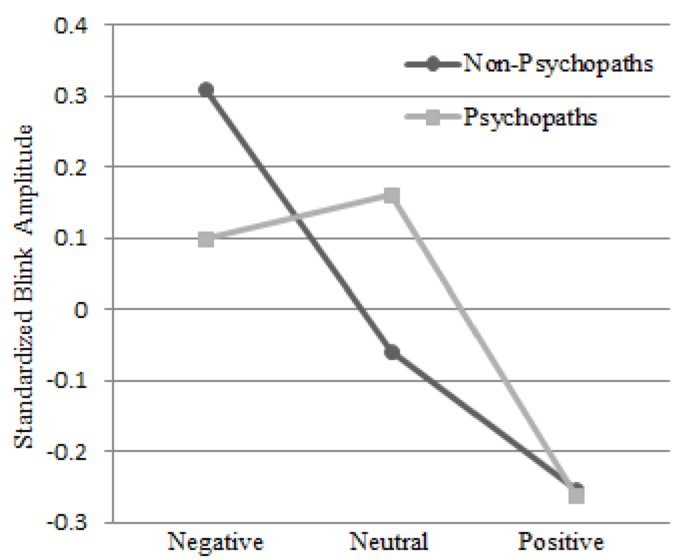

Figure 2: Psychopaths and non-psychopaths show different startle blink modulation patterns; most notably, the absent potentiation effect between negative and neutral valences for psychopaths.

Event Related Potential Data

The first task for all participants was designed to elicit a linear progression of ERP components with response targets in two distinct categories, emotional and neutral, where these differences in valence were incidental. That is, participants were simply asked to respond to photographic slides, and were not aware that they varied in emotional content. The content of the pictures was, therefore, irrelevant to the task, and any differences in ERP components between the two categories would represent differences related to the automatic/involuntary processing of the emotional content represented in each photograph. The second task each participant performed was designed to require attention to emotional cues. Unlike the first task in which the emotional content of the pictures was irrelevant to the task, participants were required to classify each target photo from the same presentation as either emotionally evocative or neutral. Differences in ERP components for these target categories would suggest processing differences for emotional stimuli when it is specifically being attended to, and relevant to performance in the task at hand. Performance data was analyzed using mixed model ANOVAs with psychopathy categorization as a between groups factor and task variables as repeated measures.

ERP Behavioral Performance Data

Behavioral performance was expectedly different across the two tasks [F (1, 38) = 120.19, p <.001, η^2 = .760], in that response latencies were much longer on task 2: 95% CI [737.69 ms, 866.59 ms] compared to task 1: 95% CI [510.50 ms, 611.87 ms], indicating participants' cognitive appraisal of the emotional content of the pictures in task 2. These overall differences in response latency between the tasks did not vary significantly across groups. There was a significant main effect of target category (emotional vs. neutral) on reaction times [F (1, 38) = 34.80, p <.001, η^2 = .478] such that, collapsed across psychopathy groups, reaction times were faster for emotional targets than for neutral targets. For Task 1 emotional targets: 95% CI [517.82 ms, 592.63 ms], for Task 1 neutral targets: 95% CI [537.97 ms, 616.83 ms]. This difference was simply exaggerated for Task 2. Task 2 emotional targets: 95% CI [681.75 ms, 763.75 ms], Task 2 neutral targets: 95% CI [754.95 ms, 865.87 ms]. These exaggerated differences for Task 2 lead to a significant task by category interaction effect [F (1, 38) = 13.43, p <.001, η^2 = .261], but the main effect for emotional category remained significant for both tasks analyzed independently; that is, responses for emotional content compared to neutral content were faster for both Task 1 [F (1, 38) = 6.17, p <.02, η^2 = .140] and Task 2 [F (1, 38) = 30.35, p <.001, η^2 = .444]. Responses were simply much faster for emotional content in Task 2 compared to Task 1. Again, there were no significant differences in reaction time between groups, nor were there significant interactions involving groups.

The number of task errors for each subject was also examined, including errors of commission and omission on both tasks, and examining emotional content categorization on Task 2. Groups did not differ on the number of errors in either case; in fact, error rates were very small over all. Each group averaged between one and two errors of commission and less than one error of omission. For Task 2, each group averaged less than 1 categorization (emotional vs. neutral) discrepancy per individual.

ERP Component Amplitude Modulation

Separate mixed model ANOVA's were performed for each of 5 ERP components (N1, P2, N2, P3, and LPP), using electrode sites as repeated measures, to compare amplitudes across emotional valence categories (within groups), and to examine overall amplitude differences between groups, as well as interactions between these effects which would indicate differences between groups in the patterns of emotional ERP modulation. Because of the extensive nature of these data and numerous effects of interest, pertinent effects will be described below, while a detailed account of F-values and probabilities will be given in accompanying tables. Graphical representation of these comparisons and average amplitudes are presented in Figures 3, 4, and 5.

For Task 1, in which the emotional content of photographs was task-irrelevant, a significant main effect for target picture category indicated that amplitudes were significantly augmented for emotional targets compared to neutral targets at the P2, N2, P3, and LPP components, but not the N1 component. This main effect was superseded by a significant target category by psychopathy group interaction at components P2, N2, P3, and LPP, but again not at the N1 component. Between groups effects were not significant; therefore neither group demonstrated larger amplitudes for any of the components when collapsed across target category. These results are given in more detail in Table 2. The trends evident in this set of analyses suggest that the group by target content interaction, then, represents different emotional modulation patterns between groups.

To confirm this, follow up ANOVAs were conducted for each psychopathy group separately. These analyses revealed that non-psychopaths indeed exhibited significant

Table 2

ERP ANOVA Results for Photographic Target Stimuli

Task 1 Component	Effect	*F* value (1, 38)	*p* value	Effect Size (η^2)
N1	Stimulus Category	0.164	.688	.004
	Stimulus x Group	0.116	.736	.003
	Between Groups	2.168	.149	.054
P2	Stimulus Category	12.191	.001	.243
	Stimulus x Group	4.222	.047	.100
	Between Groups	0.332	.568	.009
N2	Stimulus Category	23.006	< .001	.377
	Stimulus x Group	4.458	.041	.105
	Between Groups	0.600	.443	.016
P3	Stimulus Category	21.902	< .001	.366
	Stimulus x Group	13.006	.001	.255
	Between Groups	0.061	.806	.002
LPP	Stimulus Category	37.309	< .001	.495
	Stimulus x Group	8.725	.005	.187
	Between Groups	1.338	.255	.034
Task 2				
N1	Stimulus Category	6.072	.018	.138
	Stimulus x Group	4.270	.046	.101
	Between Groups	0.172	.681	.004
P2	Stimulus Category	23.571	.000	.383
	Stimulus x Group	3.495	.069	.084
	Between Groups	1.522	.225	.039
N2	Stimulus Category	17.411	< .001	.314
	Stimulus x Group	1.762	.192	.044
	Between Groups	0.172	.681	.005
P3	Stimulus Category	50.728	<.001	.572
	Stimulus x Group	5.789	.021	.132
	Between Groups	1.233	.274	.039
LPP	Stimulus Category	47.715	<.001	.557
	Stimulus x Group	6.653	.014	.149
	Between Groups	0.083	.775	.002

Note: For photographic targets, trends show emotional modulation differences in ERP amplitudes between psychopaths and controls as early as about 200 ms when affective content is processed passively. When affective content is processed actively, differences appear earlier, but less consistently and perhaps smaller effect sizes.

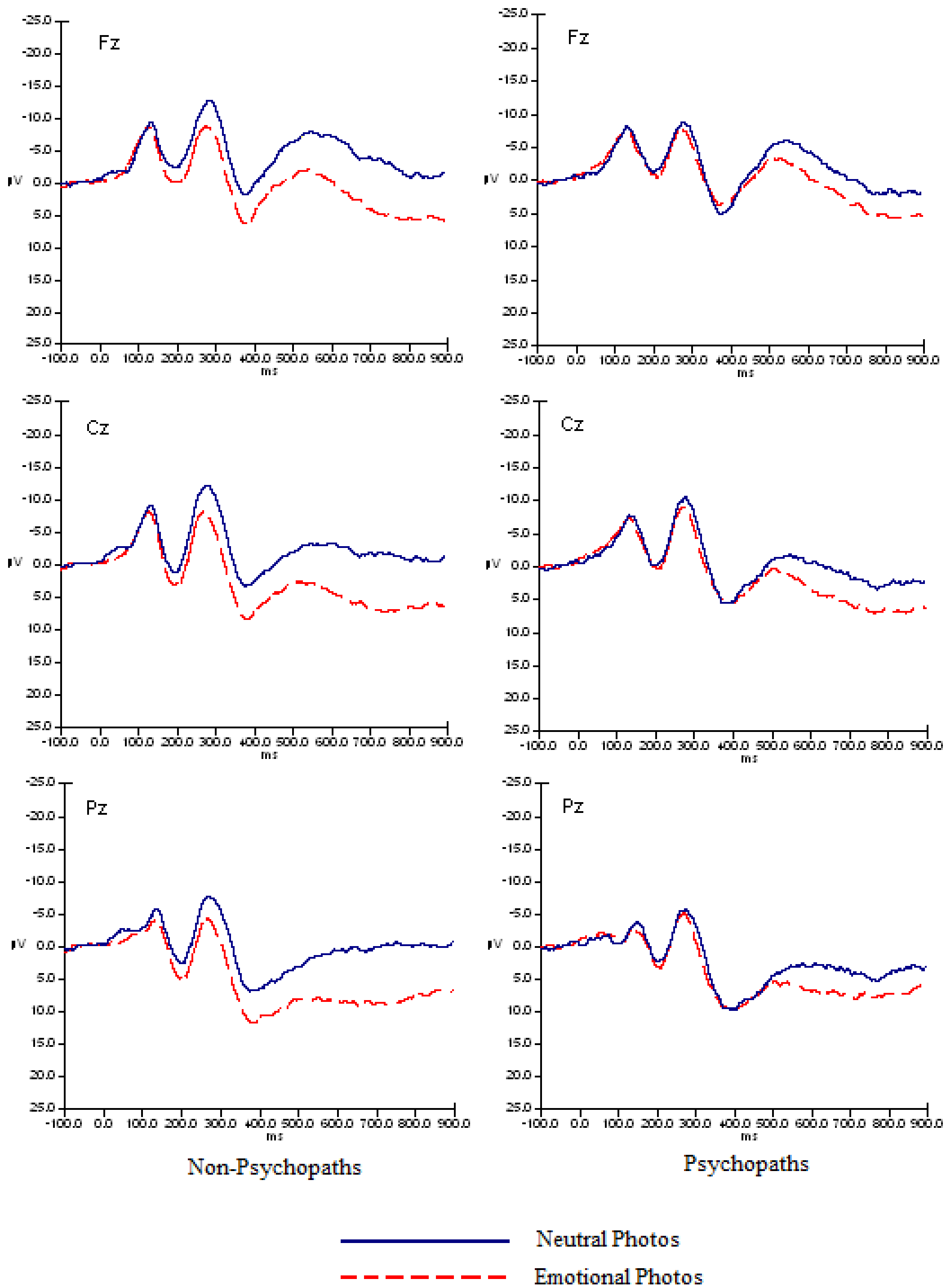

Figure 3: Significant augmentation of ERP components elicited by photographic target stimuli for non-psychopaths is apparent beginning at approximately 200 ms (P2) and continues through LPP. Psychopaths only demonstrate marginal augmentation of the LPP, and no apparent augmentation at earlier processing stages.

ERP augmentation for all components excluding the N1 during photographic targets with emotional content. *F* statistics ranged from 14.62 to 48.27, all p-values < .001 [N1: F (1, 38) = 0.002, p = .996, η^2 = .000; P2: F = 14.62, p = .001, η^2 = .435; N2: F = 27.94, p < .001, η^2 = .595; P3: F = 22.86, p < .001, η^2 = .546; LPP: F = 48.27, p <.001, η^2 = .718]. For psychopaths, however, there were no significant differences between amplitudes for emotional and non-emotional targets for components prior to the LPP, and the valence effect at LPP was marginally significant [F (1, 38) = 4.33, p = .051, η^2 = .186].

None of these effects were superseded by three way interactions involving electrode site, which would have indicated regional scalp differences in augmentation patterns. The ANOVA on each component revealed an (expected) main effect for electrode site, indicating larger amplitudes near specific topographical sites. For example, the P3 is largest around the centro-parietal midline and the N2 is largest around fronto-central regions. These component-specific topographical distributions were typical, and did not vary by group.

ERPs were also examined for the stimuli which included words (emotional or neutral) superimposed over neutral pictures. The participants' instructions were to withhold their response for any picture superimposed with a word, and this was designed to elicit a No-Go or inhibitory set of components including what might be categorized as a P3a. The same analyses were done for these components, and these results are given in Table 3. Significant main effects for word category (emotional vs. neutral) revealed that ERP components were augmented for emotional words compared to neutral words at the N1, N2, P3, and LPP components, but not the P2 component. For these No-Go evoked responses, there were no significant between-groups effects, nor were there any

Table 3

ERP ANOVA Results for Lexical, No-Go Stimuli

Task 1 Component	Effect	*F* value (1, 38)	*p* value	Effect Size (η^2)
N1	Stimulus Category	8.400	.006	.181
	Stimulus x Group	0.529	.472	.014
	Between Groups	0.238	.629	.006
P2	Stimulus Category	2.290	.138	.057
	Stimulus x Group	0.066	.799	.002
	Between Groups	2.833	.101	.069
N2	Stimulus Category	4.673	.037	.109
	Stimulus x Group	0.464	.500	.012
	Between Groups	0.132	.718	.000
P3	Stimulus Category	9.610	.004	.202
	Stimulus x Group	0.448	.507	.012
	Between Groups	0.070	.793	.002
LPP	Stimulus Category	13.983	.001	.269
	Stimulus x Group	3.143	.084	.076
	Between Groups	0.037	.849	.001
Task 2				
N1	Stimulus Category	0.085	.773	.002
	Stimulus x Group	3.198	.082	.078
	Between Groups	0.077	.783	.002
P2	Stimulus Category	1.657	.206	.042
	Stimulus x Group	2.741	.106	.067
	Between Groups	0.017	.898	.000
N2	Stimulus Category	0.812	.373	.021
	Stimulus x Group	0.446	.508	.012
	Between Groups	0.165	.687	.004
P3	Stimulus Category	0.789	.380	.020
	Stimulus x Group	3.671	.063	.088
	Between Groups	0.363	.550	.009
LPP	Stimulus Category	1.416	.241	.036
	Stimulus x Group	0.288	.594	.008
	Between Groups	0.949	.336	.024

Note: For lexical stimuli compared to photographic stimuli, there appear to be smaller overall effects for passive emotional modulation, making differences in modulation between groups inconsequential. In Task 2 the emotional modulation effects are no longer apparent in either group.

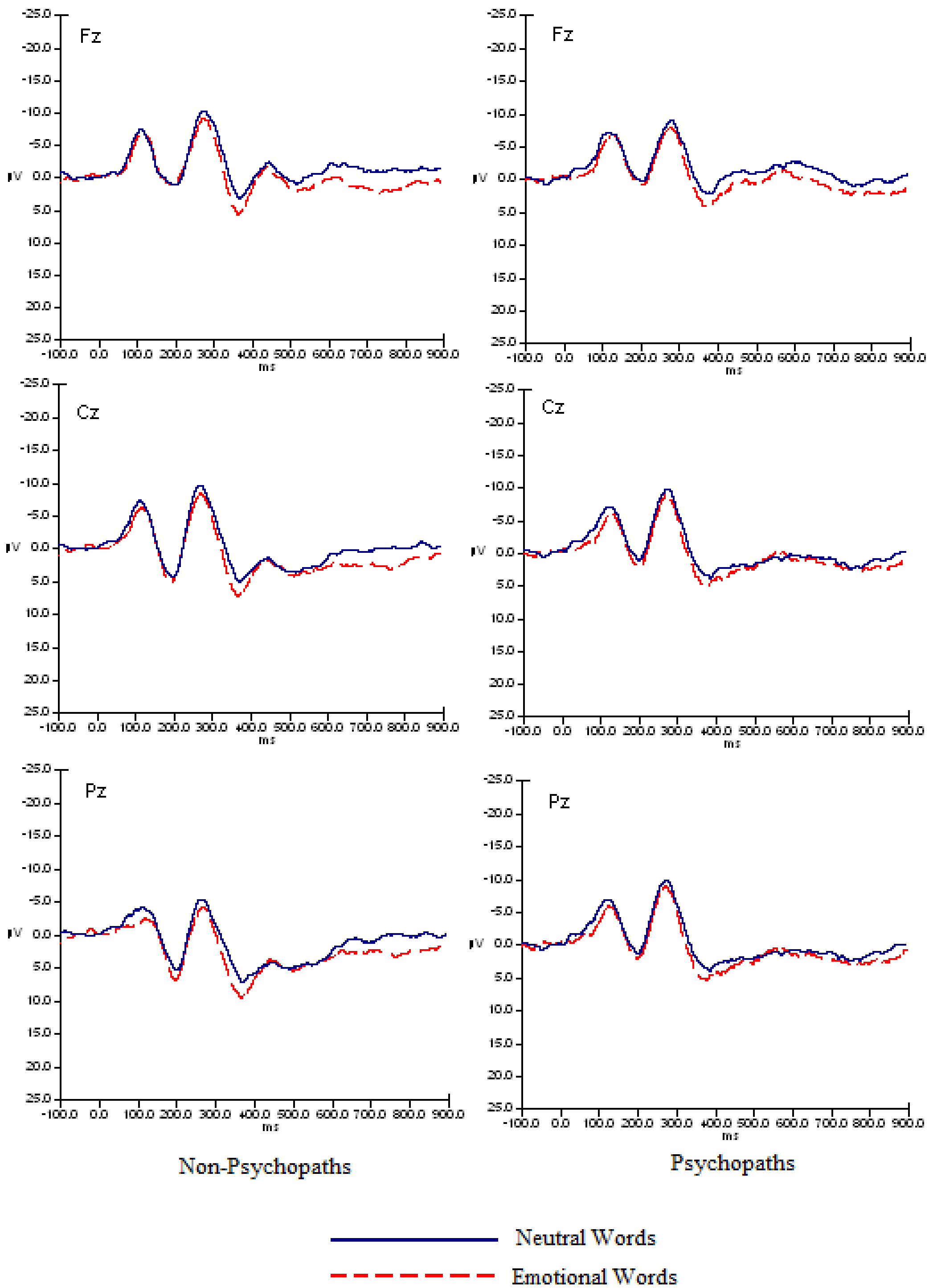

Figure 4: Emotional lexical no-go stimuli only modestly augmented ERP components for non-psychopaths. Psychopaths demonstrated no significant emotion-modulation by these stimuli at any stage of component analysis.

significant interactions involving the grouping variable, which suggests similar modulation patterns between psychopaths and non-psychopaths. The only other significant effects for these stimuli were the main effects for electrode site indicating the topographical distribution of the particular component. Again, these topographical distributions were typical and did not vary by group.

Follow-up ANOVAs were carried out to examine groups separately on these lexical stimuli as well. Psychopaths exhibited no significant main effects for emotional category of the words at any of the ERP components. For non-psychopaths, the emotional valence main effects were relatively small with the exception of the LPP, and were non-significant in some cases [N1: $F(1,38) = 5.25$, $p = .03$, $\eta^2 = .217$; P2: $F = 1.17$, $p = .29$, $\eta^2 = .058$; N2: $F = 2.95$, $p = .10$, $\eta^2 = .134$; P3: $F = 5.80$, $p = .03$, $\eta^2 = .217$; LPP: $F = 26.07$, $p <.001$, $\eta^2 = .578$]. The absence of a group by emotional category main effect in the preceding analysis appears, then, to be a result of smaller emotional modulation overall among non-psychopaths for these lexical-stimuli, while emotional modulation was absent for psychopaths as it was for photographic targets.

For Task 2, in which participants were required to attend to the emotional content of the photographs, the same progression of analyses was carried out and these results are given in lower half of Table 2. ANOVAs revealed that the emotional category of the picture (emotional vs. neutral) again had a significant effect on component amplitude, this time at all components (N1, P2, N2, P3, LPP), demonstrating that emotional modulation was preserved across the two tasks. As in task 1, these effects were superseded by significant group by target category interactions at N1, P2, P3, and LPP, but not N2. There were no significant between-groups differences in amplitude

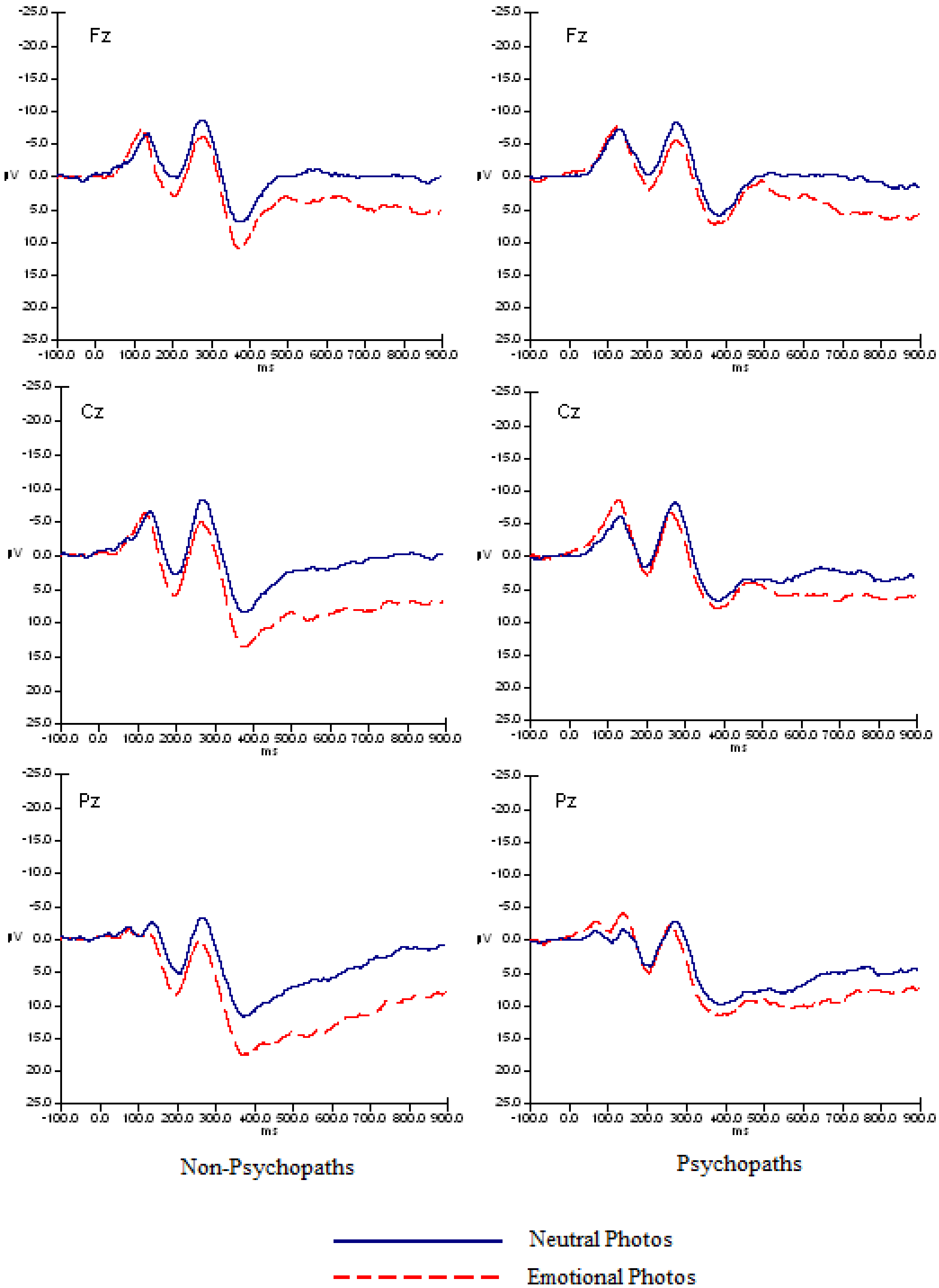

Figure 5: Task 2, photographic target stimuli when actively categorized as emotional or non-emotional produced similar augmentation patterns as Task 1 for non-psychopaths, but elicited significantly more pronounced augmentation in psychopaths.

collapsed across valence category; that is, neither group exhibited larger overall component amplitudes for Task 2.

Follow up ANOVAs run on each group separately revealed the nature of these interaction effects. For non-psychopaths, just as in task 1, robust emotional modulation was apparent beginning about 200 ms onward [N1: F (1, 19) = 0.08, p = .78, η^2 = .004; P2: F = 22.15, p <.001, η^2 = .538; N2: F = 13.77, p < .001, η^2 = .420; P3: F = 32.69, p <.001, η^2 = .632; LPP: F = 38.50, p <.001, η^2 = .670]. Psychopaths, in contrast to Task 1, demonstrated significant modulation effects between target categories at most components; however, the effects remained relatively smaller than those for non-psychopaths, thereby driving the interaction effects apparent in the mixed-model analysis [N1: F (1,19) = 9.56, p < .01, η^2 = .335; P2: F = 3.59, p = .07, η^2 = .159; N2: F = 8.08, p < .010, η^2 = .298; P3: F = 19.19, p <.001, η^2 = .502; LPP: F = 11.49, p <.01, η^2 = .377].

Another means of analyzing the given effect of task requirements is to examine groups individually using task condition as a within-subjects repeated measure. A significant task by target category interaction would indicate a change in emotion-dependent ERP amplitude from Task 1 to Task 2. Non-psychopaths exhibited no significant task by target category interactions at any ERP component (all Fs < 1.00), which suggests task requirements had no further impact on the augmentation patterns already evident between target conditions during Task 1. Psychopaths, however, exhibited two significant task x target category interactions: N1 showed significant negative augmentation [F (1, 19) = 13.34, p < .01, η^2 = .412] and P3 showed significant positive augmentation [F (1, 19) = 7.25, p < .02, η^2 = .276], all other Fs < 1.00. These effects can be seen by comparing Psychopaths' augmentation patterns in Figures 2 & 3.

The negative augmentation for N1 is a curious deviation from the other augmentation patterns reported here, as it is the only negative-going augmentation evident in the entire study. This effect will be discussed in more detail below. Considering this and the positive augmentation at P3 in Task 2, these data suggest potentially interpretable cognitive changes in the processing of emotional information by psychopaths based on task-demands.

As in Task 1, significant main effects for electrode site indicate typical scalp distribution of these ERP components, and there were no significant group by electrode site interactions.

ERPs were also examined for the lexical No-Go stimuli in Task 2, although the instructions for these stimuli remained the same (simply read the words silently), as no button-pressing was involved in these No-Go trials. Interpretation of this set of ERP components is, therefore, theoretically ambiguous. As shown in the lower half of Table 3, these data produced no significant differences at any ERP component for emotional content, between-groups differences, or group x target interactions, therefore their spatial averages have been omitted here. Standard ERP components were still present, and significant main effects for electrode site were still present for each ERP component indicating typical scalp distributions, but these components did not vary significantly based on emotional content or group for Task 2.

CHAPTER FOUR

Discussion

While many have examined the time-course of affective processing using ERPs in healthy individuals, very few have applied these techniques to examine individual differences in personality and pathology despite obvious applications to this realm of investigation (Davidson, 1998). The outcomes of this investigation demonstrate that affective ERP modulation is a useful tool for exhibiting emotional processing abnormalities in psychopaths and provide preliminary evidence that mechanisms of voluntary attention are capable of moderating these differences in psychopaths. The methodology described here may prove to be a versatile and adaptable protocol effective for illuminating specific features of emotional and cognitive processing in psychopaths.

Group Characteristics

It was a goal of this study to compare groups of non-incarcerated community members who still represent disparate ends of a continuum of psychopathic personality traits, and who exhibit veritable physiological differences on a conventional measure of emotional processing, i.e. startle modulation, in addition to a more progressive measure of emotional processing—affective ERP modulation. These goals were successfully achieved with the current sample. Recruitment of non-incarcerated community members with high psychopathic traits was accomplished quite efficiently with the methods used here. A large pool of internet survey responses with scores in the middle to high range on psychopathic traits facilitated recruitment of those with extreme scores. Disparate scores for psychopathic traits are clear based on the average percentile ranks for total PPI-R score. There was more variability within groups on the individual factor scores (SCI and FD), yet the mean ranks for each group on each of these factors also fell within the upper and lower quartiles, and isolation of these factor scores did not affect group assignments. Psychopathy remained the only measured variable that distinguished the two groups, as there were no significant differences apparent between groups on age, gender, ethnicity, level of education, or verbal intelligence; therefore, psychopathic traits are the only measured difference which can account for the divergent physiological trends between groups discussed below. Still, the selected groups endow this investigation with inherent interpretive limitations. While the groups contained a wide range of ages and similar distributions of gender, the sample as a whole lacked much ethnic diversity and predominantly represents well-educated Caucasian adults. Future studies may benefit by extending these methods to larger, more diverse samples.

Startle Physiology

Lack of startle potentiation has been a psychophysiological hallmark of psychopathy since Patrick and colleagues (1993) demonstrated this in an incarcerated sample, and it has since been replicated in diverse groups including non-incarcerated (Benning et al., 2005) and female samples (Anderson, Stanford, Wan, & Young, in press). It was utilized here as a means of verifying group deficits commonly attributed to psychopaths, which adds credence to the construct validity of the presently defined groups based on psychopathic traits. The patterns exhibited in the current study reflect those from the original findings; namely, while individuals classified as non-psychopaths demonstrated potentiated blink reflexes while viewing aversive photos and diminished reflexes while viewing pleasant photos, the psychopathic group showed divergent blink modulation patterns, lacking the potentiation effect ordinarily seen under aversive conditions.

In Patrick and colleagues' (1993) report, psychopaths still exhibited significant attenuation of blinks during pleasant photo-viewing, and negatively-valenced photos apparently produced the same effect as the positive photos. This has been interpreted as a preserved orienting response to novel or interesting environmental stimuli in psychopaths, while the defensive cascade ordinarily initiated by aversive stimuli is selectively impaired (see Patrick, 1994; Bradley et al., 1990). Similar patterns were exhibited in the current sample in that psychopaths demonstrated a preserved attenuation effect during positive photos, and average blinks during negative photos were also relatively smaller; however, the difference between negative and neutral slides was not significant. Overall, this effect demonstrates that the selected groups exhibit both the personality traits (as measured by the PPI-R) and physiological characteristics consistent with psychopaths classified by various methods and in various populations. The essential conclusion of these outcomes suggests that the present groups authentically present with several features germane to the psychopathy construct, and the interpretation of outcomes below may be appropriately applied as additional features of this construct.

Event Related Potential Outcomes

The ERP protocol produced data on response performance and physiological measures which include ERPs associated with both photographic target stimuli and lexical no-go stimuli, which will all be considered separately, as they each have different implications for cognitive interpretation. These considerations begin here with the behavioral performance outcomes.

ERP Behavioral Performance

Results varied predictably between the two tasks performed by each participant. To review the protocol, the first task for all participants was designed to elicit a temporal progression of ERP components with response targets in two distinct categories, emotional and neutral, where these differences in valence were incidental. That is, participants were simply asked to respond to photographic slides, and were not aware that they would vary in emotional content. The content of the pictures was, therefore, irrelevant to the task, and any differences in ERP components between the two categories would represent differences related to the spontaneous processing of the emotional content represented in each photograph. The second task each participant performed was designed to elicit the same progression of ERP components, but required active, ongoing attention to emotional content. While viewing the picture presentation, participants were required to classify each target photo as either emotionally evocative or neutral. Differences in ERP components for these target categories would suggest processing differences for emotional stimuli when it is specifically being attended to, and relevant to performance in the task at hand.

The large differences in response latencies between task conditions were an expected consequence of the deliberation required to categorize the stimuli as emotional or non-emotional. Participants required on average approximately 200 ms longer to respond in Task 2 compared to Task 1, regardless of group membership. There were no group differences in accuracy of categorization; the overwhelming equivalence of participants' individual categorization of the photos in Task 2 attests to both the clarity of emotional content and to sustained attention to the affective content across both groups. The fact that there were no between-groups differences in response latency or accuracy of target categorization suggests that the differences observed between groups in ERP waveforms are not related to the behavioral outcome of basic emotive categorization. That is to say, psychopaths were no worse at identifying emotional content in photographs based on speed or accuracy of categorization. There have been some suggestions that psychopaths have an impaired ability to recognize emotional information, especially judging subtle emotive facial expressions (Kosson, Suchy, Mayer, & Libby, 2002). The present data suggests the emotional content was conspicuous enough for this not to be a determining factor in the observed neural processing differences. The observed differences in affective modulation of ERP waveforms must therefore translate into neural processing abnormalities which do not impair on-line, conscious identification of emotionally relevant visual information in late-stage processing (at or around 700 ms), concordant with behavioral responses. It will be discussed in more detail below how these combined data may be suggestive of group differences in neural processes related to the assimilation of this information into memory systems.

In addition to the differences in response latency between the two tasks, there was also a significant difference in response latency between emotional conditions, which was consistent across both groups. Response latencies were shorter for emotional targets compared to non-emotional targets for both versions of the task. This difference was simply exaggerated under conditions of target categorization—that is, both psychopaths and non-psychopaths took longer to categorize neutral photos than to categorize emotional photos as such. This main effect for emotional content is consistent with a large body of research suggesting that emotionally relevant information is processed preferentially, and is capable of facilitating reflexes and behavioral responses (Ohman, Flykt, & Esteves, 2001; Strauss, 1983). Stimuli which prime circuits dedicated to primary approach and withdrawal systems will facilitate behavioral responses consistent with these outcomes (Bradley et al., 2001).

A great deal of the empirical data reviewed here suggests that these systems are, in some way, atypical in psychopaths, so it may seem dubious that psychopaths demonstrated facilitated responses similarly to non-psychopaths; however, it is also important to recognize the complexity of the underlying physiology and not presume that the entire system is necessarily dysfunctional in psychopaths. There are several distinct systems operating in balance to support modification of physical responses at this level. At a macroscopic, behavioral level there are separate systems supporting both approach and withdrawal behavior—which have been alternately described as Behavior Inhibition System and Behavior Activation System (BIS/BAS; Gray, 1981), and which have been suggested to be abnormal in psychopaths (Fowles, 1980; 1988). Subserving these motivational systems, there are several more fundamental systems supporting attention (Posner, Rueda, & Kanske, 2007), primarily the orienting of attention to novelty (Ohman et al., 2000; Bradley et al., 2001), which subserves the allocation of limited cognitive resources to the immediate detection of potentially harmful or beneficial stimuli. Furthermore, there exists a certain degree of top-down, executive control which must be accounted for when conflicts for attention exist and self-monitoring of behavior is required (Rueda, Posner, & Rothbart, 2005). It has also been suggested that disruptions of these more fundamental components of attention may underlie development of psychopathy (Hare, 1968; Patterson & Newman, 1993).

Most of the evidence supporting abnormal attentional processes in psychopaths have demonstrated this under conditions where an ongoing, dominant task is interfered with by the presentation of potentially distracting peripheral stimuli. It has been reported that psychopaths are less vulnerable to emotionally evocative distractors than non-psychopaths (Mitchell, Leonard, Richell, & Blair, 2006; Williamson, Harpur, & Hare, 1991). Furthermore, psychopaths are reportedly less prone to distraction by emotionally neutral stimuli as well (Jutai & Hare, 1983; Newman, Schmitt, & Voss, 1997). These reports do not indicate, however, what effect might be expected regarding emotional facilitation for stimuli of direct interest, which are the primary focus of attention. In fact, certain reports indicate that psychopaths are capable of normal facilitation of reflexes when a task requires direct focus on emotional stimuli (Newman et al., 2010), or when peripheral information is at least spatially contiguous with information required for a primary task (Hiatt, Schmitt, & Newman, 2004). Newman and Kosson (1986) have also demonstrated that psychopaths are capable of appropriate behavioral modification by means of emotional cues, when there is no conflict in punishment/reward contingency—that is, when only aversive cues are present. Kiehl and colleagues (2001) reported that despite presenting with divergent patterns of brain activity during an emotional memory task, psychopaths showed no impairment on performance of the task. So while it seems that psychopaths do show abnormalities in processes of attention, the behavioral outcomes of these attentional differences depend on very specific task parameters; and even where it is clear that psychopaths are devoting alternative brain circuits for processing emotionally relevant information, certain behavioral outcomes may appear unaffected at a macroscopic level.

As mentioned above, startle modulation protocols also seems to indicate that psychopaths demonstrate appropriate orienting responses to emotional stimuli, while demonstrating deficiencies in the system supporting defensive priming in the BIS. Psychopaths do show attenuated blink reflexes under both aversive and pleasant conditions, which has been interpreted as a preservation of appropriate orienting toward novelty/highly arousing stimuli, while lacking the valence-dependent activation of defensive networks (Patrick, 1994). Highly arousing stimuli, whether positive or aversive, divert processing resources from the startle probe. Likewise, both positive and aversive stimuli may promote facilitated behavioral responses to these items if an intact BAS is governing these systems. The data in the current study support this idea since behavioral responses to emotional targets were facilitated for both psychopaths and non-psychopaths, and it is consistent with startle data from this sample, as psychopaths demonstrated appropriate blink attenuation for positive stimuli while lacking potentiation for negative stimuli. An important conclusion here is that differences in ERP modulation across groups cannot be accounted for by any immediate behavioral performance differences, as there were no between-groups differences on these measures.

ERP Modulation: Photographic Targets

Results from Task 1 in the ERP protocol clearly indicate differences between psychopaths and non-psychopaths in processing emotional stimuli. While the waveforms are qualitatively similar across all participants, with clearly defined peaks representing N1, P2, N2, P3, and LPP components, non-psychopaths exhibited a global, persistent, enhanced positivity in waveforms elicited by affective targets as compared to neutral targets. These amplitude differences begin around 200 ms post-stimulus, and continue to increase through the end of each trial. This enhanced positivity was absent in psychopaths until much later—around 500 ms—and then remained modest compared to the emotion-dependent differences observed in non-psychopaths. Further attention must be given to this persistent emotion-related positivity, first regarding the implications of its presence in non-psychopaths before a broader interpretation can be made regarding its absence or diminishment psychopaths. This effect must also be considered in the larger context of results from Task 2, which manipulated attention toward affective content, and produced small, but relevant effects on ERP modulation in psychopaths.

One difficulty inherent to direct interpretation of cortical potentials in terms of underlying cognitive processes is that of non-specificity in the neural sources of these electrical signals. This is often referred to as the "inverse problem" in ERP literature, and refers to the fact that there is no unique dipole solution for the source of a given potential measured at the scalp. In fact there are theoretically an infinite number of dipole solutions (Pizzagalli, 2007). This is particularly relevant in mid-late stage potentials which, unlike the early sensory potentials, are influenced by the combined relative strengths of neural activity at multiple distributed sources. The component potentials elicited by any given stimulus undoubtedly represent diverse and potentially overlapping processes from discrete and often remote brain regions, operating in parallel. For example, the P3 has neural generators which include several structures in frontal, temporal, and limbic regions (Soltani & Knight, 2000). In an fMRI investigation of neural processes associated with target detection in oddball tasks Kiehl and colleagues (2005) reported significant activity in 38 widely distributed cortical and subcortical regions. For this reason, defining a cognitive interpretation of amplitude differences across several stages of processing may be more effectively accomplished through comparisons with similar patterns of modulation which have been reported in conjunction with other experimental protocols.

From previous research we understand that around 200 ms into the processing stream, selective attention becomes an integral correlate of ERP manipulation (Luck & Hillyard, 1994); and around 300 ms, task relevance and the engagement of working memory are important elements contributing to ERP amplitude (Johnson & Donchin, 1982; Donchin & Coles, 1988). As reviewed more extensively above, differences in ERP component amplitude due to affective picture processing in healthy adults have been reported as early as about 100 ms into the processing stream, and are robust by the stage of the P3 and LPP (Olofsson et al., 2008). Results for enhanced potentials early in the processing stream lack some consistency and vary in the direction/polarity reported; but even among these reports, several have indicated generally larger positive potentials for affective stimuli (e.g. Cuthbert et al., 2000; Palomba et al., 1997). After about 200 ms, results have consistently demonstrated larger positive potentials for affective stimuli. This trend for a global, persistent positivity is consistent with another branch of ERP research investigating memory encoding, in which studied words that are subsequently remembered in tests of recall are associated with enhanced ERP positivity (Fabiani, Karis, & Donchin, 1990), and these effects are apparently related to the distinctiveness of the remembered stimulus. In a review of this literature, Rugg (1995) suggests a definitive relationship between middle to late phase ERP positivity and subsequent memory.

While a reconstruction of the neural events resulting in the persistent emotion-related positivity evident in non-psychopaths would be impossible from the data collected here, this effect is apparently consistent with data in which both affective pictures and distinctive lexical stimuli produce enhanced positive ERPs. Furthermore, due to the latency of its onset and the emotional salience of the stimuli that provoke this change, it is reasonable to suspect that this positive deflection in the ERP waveform is influenced by neural systems contributing to enhanced attention and integration of stimulus content into working memory systems. Psychopaths either lacked this effect, or perhaps more conservatively demonstrated a later onset and diminished representation of this effect as measured by cortical potentials. These data suggest that psychopaths fail to engage in early discriminatory processes which demarcate emotionally salient events, but are apparently able to effectively categorize these stimuli as such in a relatively simple behavioral task. The preservation of this behavioral operation may therefore be due to some alternative or compensatory neural mechanisms, which are perhaps represented by the modest, late-onset ERP modulation apparent around 500 ms.

The aim of Task 2 was to provide a comparison condition under which automatic differentiation of emotional content could be contrasted with active processing of emotional content within subjects. It was hypothesized that psychopaths would show increased ERP differentiation between affective and neutral stimuli when task requirements demanded attention to the emotional content of the photos. Results for this task indicated that psychopaths indeed demonstrated increased differentiation between emotional and neutral targets for this task, although their waveforms indicated abnormal emotion-related ERP patterns (compared to non-psychopaths), and they still did not achieve the level of augmentation exhibited by non-psycopaths in the later stages of stimulus processing. Follow-up tests revealed that non-psychopaths showed virtually identical augmentation patterns for the two tasks, while psychopaths showed significant changes in amplitude between tasks at the N1 and P3 components.

Psychopaths' augmentation of the N1 for Task 2 is an unexpected outcome which deserves additional attention here. This exaggerated negative deflection falls outside all the regular patterns recognized in this study as a whole, as it is the only instance in this investigation of an increased negativity for any stimulus with emotional content. It is tempting to discount this as a possible singularity in the data; however, after re-examining individual subject amplitudes on this component, no outliers were found to be driving this effect. It is responsible for driving the significant between-groups interaction apparent at the N1 component when comparing Task 1 and Task 2, as non-psychopaths showed no significant differences between target categories at this stage. The direction of modulation is curious and the latency and distribution of this effect is reminiscent of the EPN described by Schupp et al. (2003a, b). Why this effect would only appear for psychopaths, and further, only under this attentive condition (Task 2) is beyond what the data collected here can explain. A very conservative interpretation is simply to recognize it as a unique marker for differentiation between neutral and emotional targets in psychopaths, when attention is effortfully directed toward categorizing emotional content. And it may suggest alternative cognitive processes being implemented by psychopaths to accomplish this task. The robust augmentation of the P3 for psychopaths in Task 2 is qualitatively similar to what non-psychopaths display for both versions of the task, which suggests that whatever cognitive processes contribute to this pattern occur effortlessly in non-psychopaths, but only through directed, effortful attention in psychopaths.

Taken together, these data are particularly intriguing when considered in the context of hypotheses regarding possible abnormalities in attention in psychopaths. Newman's response modulation hypothesis (Patterson & Newman, 1993; Newman & Lorenz, 2003) is particularly applicable, yet these outcomes may not directly support all the precise predictions of Newman's theory. To reiterate the key features of RMH, it proposes that apparent deficits in emotional processing stem from failure to process peripheral cues not immediately relevant to ongoing, goal-directed behavior. Much of the foregoing support leading to this notion specifically examine the impact of information that is secondary and distracting, appropriating resources from a primary task, and these outcomes have demonstrated that psychopaths are less prone to interference from external distracters (Jutai & Hare, 1983; Newman et al. 1997; Mitchell, Leonard, Richell, & Blair, 2006). In the present task, however, emotional information is not used as a distracting element; it is simply superfluous information in the first task. Still, this emotional information is evidently processed automatically in non-psychopaths, and is undifferentiated in psychopaths. RMH also specifically predicts that psychopaths are capable of processing emotional information at appropriate levels when it is an element of immediate interest, in other words, when it is task relevant (Newman et al., 2010). Interestingly, the present data does support this idea insomuch as psychopaths do show ERP differentiation between emotional and neutral cues when their attention is directed toward these features (Task 2), yet to say that they process this information at normal levels may be incorrect; the present data demonstrates that psychopaths still do not achieve the same level of enhancement recognized in non-psychopaths, despite their improved differentiation of the stimuli. Attention clearly seems to play a moderating role in the information processing abnormalities evident in psychopaths, but care must be taken in the interpretation of the physical characteristics of ERP waveform, which may suggest some alternative neural processes at work. More attention will be given to integrating these interpretations after consideration of the remaining conditions in this ERP protocol.

ERP Modulation: Lexical Stimuli

ERPs elicited by lexical no-go stimuli were also examined. These stimuli were intended to elicit an inhibitory, no-go P3, or what might be categorized as a P3a. While task parameters were theoretically appropriate for eliciting a no-go P3, topographical scalp distributions of the P3 generated were not substantially different from those generated by the affective photographic targets; that is, P3s were largest in the parietal regions for both.

In reviewing features of both P3a and P3b, Polich (2007) discusses how distinctions between these components are further complicated by task parameters which distinguish the "novelty P3a," from the "no-go P3a." The novelty P3a and no-go P3a are likely variants of the same potential, but with slightly different topographical scalp distributions which vary as a function of task parameters, the novelty P3a with a more frontal/central distribution and the no-go P3 with a more central/parietal distribution. They are both distinguishable from the canonical P3b in that prefrontal cortex is clearly integral as a neural generator for both P3a components (Knight, 1984; Knight, Grabowecky, & Scabini, 1995), while neural generators of the P3b are more widely distributed (Soltani & Knight, 2000). Despite these discussions on the variable nature of topographical distributions of the P3a the distribution of potentials in the present data may cast some doubt on whether these stimuli successfully generated a P3a, or whether they simply produce a lexically-induced P3b, and therefore interpretations should be made cautiously.

P3s generated by the lexical no-go stimuli in Task 1 produced essentially the same pattern of effects as the visual target stimuli; however, these effects were much smaller than those elicited by photographs. Emotional words (compared to neutral words) produced larger, more positive potentials across several components in the processing stream for non-psychopaths (excluding P2), but there were no differences between emotional and non-emotional conditions for psychopaths at any component stage during Task 1. These results and their potential interpretations are congruent with those described above. The smaller effect sizes are potentially due to the slightly more challenging cognitive demands of reading a word and having to withhold a response. In general, divided attention and increases in task demands produce reliably smaller overall potentials (Kok, 2001), which would limit the size of differences between differentiable stimulus categories.

Results for lexical stimuli during task 2 are difficult to interpret. There was no evidence across groups for any significant differentiation between emotional and neutral words during Task 2. When comparing these results to those of Task 1, it is important to recognize that the differences between the two task conditions for photographic targets do not generalize to the lexical no-go stimuli, being that the lexical stimuli were cues to inhibit responses to targets. The relevance of emotional content for the words was incidental for both tasks as the instructions remained the same for both tasks—simply read the words silently and refrain from responding during these events. The apparent differences between the two tasks only depended on the individuals' unique strategies to maintain task performance, for which no data is available.

Any interpretation made regarding the difference between Task 1 and 2 for these no-go stimuli are speculative at best. It may be that the increased attention to picture categorization required for task 2 made participants less attentive to the word meanings. Participants had already read these words in Task 1, and were aware that the presentation was the same for Task 2, therefore no new information was being presented to them; therefore, motivation for reading these words may have decreased considerably for Task 2. Furthermore, their only behavioral requirement was to refrain from any response during these stimuli, and it may have been possible for them to better anticipate the progression of no-go stimuli during their second exposure to it. Despite the problematic features of interpreting these particular results, the most pertinent information for these lexical no-go stimuli was gathered in Task 1. The behavioral demands of Task 2 were more purposefully designed to allow for a multifaceted analysis of target identification, and no additional theoretical perspectives were hypothesized regarding features of no-go stimuli in this task. It is a curious diversion in the data, however, which may at least serve as a cue for future investigations of this nature to take better care to ensure motivated processing of these stimuli.

Previous reports have recognized positive ERP augmentations for affective words, but these effects have most often been confined late in the processing stream, around the 300 ms range and beyond. The present data shows very early differentiation between affective and neutral words beginning at the N1 component. Reading and processing the meaning of a word entails a kind of obligatory attention to its emotional content. It may be impossible to read and recognize the meaning of a word and direct any additional attention to its affective content. Nevertheless, psychopaths revealed no evidence of differentiating between affective and neutral words under these conditions, hence the between groups differences are consistent with those recognized using photographic target stimuli.

Summary and Conclusion

Taken together, the outcomes of this investigation exhibit multifaceted demonstrations of how psychopaths process and use emotional information differently. Where conscious recognition of emotional content is required, psychopaths exhibit unencumbered performance on simple behavioral tasks and demonstrate the typical facilitation of physical responses commensurate with an intact orienting response. Consistent with this, startle reactivity is appropriately attenuated under pleasant conditions, similar to orienting responses in healthy, normal individuals. Where psychopaths' divergent physiology appears to have observable behavioral consequences may be limited to the utilization of affective content to prime defensive networks, as evidenced by lack of affective startle potentiation, and other reports of deficient aversive conditioning and poor autonomic response to punishment cues. So, while ample evidence in ERP and fMRI literature suggests divergent patterns of neural processing of affective information, care must be taken in identifying the specific functional circuits that are abnormal and interpreting the appropriate cognitive and behavioral consequences of those deviations.

In the present data, ERP evidence suggests divergent automated differentiation of affective stimuli such that early discriminatory processes which likely represent facilitated attention and memory for emotionally salient stimuli are absent or substantially delayed. However, when effortful attention to emotional information is explicitly required for task performance, ERP waveforms suggest compensatory modification of this level of processing apparent at both the N1 and P3 components. However, the neural representation of these modifications remains quantitatively diminished and qualitatively unusual compared to the consistent patterns exhibited in non-psychopaths across both tasks. These persistent deviations likely represent neural processing differences which may account for specific abnormalities in the means by which psychopaths incorporate and utilize emotional information in the governance of ongoing cognitive and behavioral processes.

The experimental protocol employed in this investigation was intended to explore temporal differences in the affective processes engaged in by psychopaths and the potential moderating effects of goal-directed attention on these processes, and it successfully achieved these goals. Future modifications of this protocol may include variations in stimulus content and modality, rates of presentation, and further manipulations of attention through more complex task requirements. Furthermore, it would be extremely valuable to adapt these methods for an event-related fMRI protocol to more specifically examine functional-anatomical networks engaged as psychopaths attend to affective content, thereby addressing the possibility of an alternative/compensatory mode of processing for this information.

In the search to discover neurophysiological abnormalities that underlie psychopaths' deficiencies in processing emotional information, it is important to recognize that psychopathy is a heterogeneous construct, historically defined by collections of personality traits which tend to occur together in a particular kind of person, i.e. psychopathy is a collection of personality traits that psychopaths have. The circular limitations of such a definition are obvious and underscore the importance of determining the physiological basis for these traits. There may have been a time when it was sufficient to say that psychopaths have a deficiency in emotional processing; but in physiological terms, this descriptive trait may take several forms. This could mean an inability to properly encode information relevant to our safety and survival as such. It could be an incapacity for the estimation of consequences based on environmental threat cues. It could mean an inability to proactively recruit conditioned aversive learning for modification of ongoing behavior. It could take the form of ineffectual engagement of automated attention for facilitated processing of affective information. Each of these is undoubtedly governed by discrete but interrelated neural systems, and a disruption in any one of these could potentially be manifested as psychopathic traits. Therefore, as research in this arena moves forward, it will be essential to denote these traits with greater precision, defining features of psychopathy with reference to very specific, unambiguous physiological indices. This obligation is paramount among those promoting progress in the field and will ultimately allow us to define psychopathy with greater sensitivity and specificity.

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