Emotion Processing and Regulation: An Electrophysiological Investigation Among High Borderline Trait Individuals

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Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy

in the
Department of Psychology
Faculty of Arts and Social Sciences

SIMON FRASER UNIVERSITY

Summer 2014

Approval

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Degree: **Doctor of Philosophy (Psychology)**

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Abstract

Emotion processing and regulation are fundamental for stable mental functioning and healthy interpersonal relationships. Borderline personality disorder (BPD) is a severe mental disorder where emotional dysregulation is a core feature, yet the neural processes underlying this dysfunction remain poorly understood. We examined bottom-up and top-down mechanisms involved in emotion processing among females selected for high and low levels of BPD traits (HBT and LBT groups). Study 1 (30 participants) employed a modified eStroop paradigm to investigate group differences in event-related potential (ERP) components associated with the implicit (*Overt*) versus explicit (*Covert*) processing of prototypical expressions of facial affect (Angry, Fearful, Sad, Happy, and Neutral). Study 2 (32 participants) employed a cognitive modulation paradigm to examine ERPs associated with *Reducing* one's emotional response to unpleasant high arousal (HA) and low arousal (LA) images versus *Allowing* one's emotional responses to occur. Results from both studies supported the prediction that ERP components would be differently modulated as a function of group status and task. In Study 1, the HBT group showed enhanced Early Anterior Positivity (EAP) modulations to Angry facial expressions relative to Fearful ones when these were not the focus of attention, whereas the LBT group showed enhanced EAP modulations when facial expressions were the focus of attention. This finding suggests hypervigilance to social threat among HBT individuals, with early modulations over the frontal scalp observed as early as 150 ms post-stimulus. In Study 2, the HBT group showed heightened sensitivity to HA images, with dampened responses to LA images observed for the occipital P1 and the frontal EAP. Additionally, they demonstrated difficulties in down-regulating the impact of LA images as measured by enhanced LPP amplitudes over the posterior scalp. Both experiments provide support for a model of abnormal functioning of a neural network sensitive to personally threatening information in BPD and offer evidence for altered processing within early, possibly pre-attentive stages of information processing over the anterior scalp. These findings provide important clues for the understanding of neural mechanisms underlying emotion dysregulation difficulties in BPD.

Keywords: nonverbal communication; borderline personality disorder traits; emotion processing; attention bias, event-related potentials, emotion regulation

To all those who have believed in me and my success

Acknowledgements

First, I would like to express my sincere thanks to Dr. Liotti who provided insights, assistance, and knowledge over the course of many years acting as my research supervisor. His kindness and expertise were invaluable to this project. I would also like to thank Dr. Chapman and Dr. Ribary for serving on my committee and for their helpful comments and feedback on my dissertation, as well as my lab mates, in particular Adam Burnett and Deyar Asmaro, who helped me achieve my goals.

Many thanks goes to my grad school friends, teachers, supervisors, and colleagues. I am truly blessed to have known so many talented individuals who provided the guidance, inspiration, mentorship and support that has helped me along this path. You have all contributed to my personal and professional development throughout the years and for this I will be forever grateful. I would also like to thank all of my clients, patients, and research participants who contributed to my learning and development throughout the years.

Much appreciation and thanks goes to my family and friends for supporting and encouraging me, but also for helping me achieve a balanced life. In particular, I would like to thank my parents, Yarmila and Rudolf Sramko, my number one fans, and Jennifer Kinsley and Laurent Debacker, the best of friends one could have. Last, but not least, I would like to thank my husband, Terrence Kuiper, who has been encouraging, supportive and incredibly patient throughout this process. Your unfaltering belief in me and my success has helped me tremendously.

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List of Acronyms

ACC	Anterior Cingulate Cortex
ADHD	Attention Deficit Hyperactive Disorder
BDI-II	Beck Depression Inventory - 2
BPD	Borderline Personality Disorder
BSI	Brief Symptom Inventory
CLARA	Classical LORETA Recursively Applied
dACC	Dorsal Anterior Cingulate Cortex
DLPFC	Dorsolateral Prefrontal Cortex
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, 4th edition
DSS	Dissociation Tension Scale
EAP	Early Anterior Positivity
EEG	Electroencephalography
EPN	Early Posterior Negativity
ERP	Event-related potential
FFA	Fusiform Face Area
fMRI	Functional Magnetic Resonance Imaging
HA	High Arousal
HBT	High BPD Trait
LA	Low Arousal
LBT	Low BPD Trait
LPP	Late Positive Potential
MEG	Magnetoencephalography
OFC	Orbitofrontal Cortex
PAI-BOR	Personality Assessment Inventory – Borderline Scale
PFC	Prefrontal Cortex
SCID-II	Structured Clinical Interview for DSM-IV
vPFC	Ventral Prefrontal Cortex

Chapter 1.

General Introduction

Emotions are an integral part of everyday living. They allow us to communicate with others and to better understand our environment. While as humans we have developed the ability to communicate our intentions and moods through words (e.g., “This traffic is frustrating” or “I’m so excited that I passed my test!”), it is the richness of non-verbal cues such as speech intonation, facial expressions and body postures, that add depth to our social interactions and allow for complex and nuanced emotional communication. Despite this complexity, emotion processing occurs very rapidly and often outside of conscious awareness. The ability to quickly and accurately decipher information through nonverbal cues, in particular facial expressions, develops in early childhood (e.g., Herba & Phillips, 2004), and is not only apparent cross-culturally (e.g., Ekman et al., 1969), but also among other species (e.g., primates; Parr et al., 2005) suggesting that this ability is hard-wired and of evolutionary importance.

Although emotion processing represents a fundamental ability, individuals differ in how they process affective information. For instance, in autism and schizophrenia there is a reduced ability in the recognition of emotions in others (Dawson et al., 2005, Dalton et al., 2005; Fullam & Dolan, 2006). In contrast, patients with anxiety or depression display concern-specific attention and memory biases such as attending preferentially to sad or threatening stimuli relative to healthy individuals (see Jukka, 2006 for depression review; see Bar-Haim et al., 2007 for anxiety review). In fact, a whole stream of research has been dedicated to detailing and understanding individual differences in the processing of emotions (e.g., Calder et al., 2011).

Emotion cues are associated with observable behavioural and physiological responses, and in the experience of subjective feelings; however, humans also have the unique ability to control and modulate such reactions through cognitive processes (Oschner & Gross, 2005). The ability to regulate one's emotions is essential for mental health and psychological well-being. Individuals, however, are not equally adept at regulating their emotions, an ability which develops throughout life (John & Gross, 2004). Emotional dysregulation has been emphasized as a core difficulty among those with Borderline Personality Disorder (BPD), a complex and severe form of mental illness characterized by a pervasive pattern of instability of interpersonal relationships, self-image, affects, and marked impulsivity (American Psychiatric Association, 1994). Emotion dysregulation in BPD has been characterized by an unstable expression and more intense subjective experience of negative emotions (Trull et al., 2008). However, the precise mechanisms underlying this dysfunction are only beginning to be understood. Technological advances have provided tools to explore the brain mechanisms underlying the automatic physiological responses that occur in response to affective cues, as well as the more elaborate cognitive processes involved in the modulation of emotional responses.

In some situations, explicit interpretation of the meaning of social cues may be required to guide social responses, while in other situations, social signals may be processed covertly and behavior responsively adapted without full cognitive awareness. Similarly, the modulation of emotional responses generally occurs explicitly via intentional strategies, though implicit emotion regulation mechanisms are presumed to occur without conscious awareness. In the studies that follow the primary aim was to contribute to our current understanding of the behavioural and electrophysiological correlates involved in the processing and modulation of affective cues among individuals with high levels of BPD traits relative to healthy controls. Specifically, the following studies were intended to examine bottom-up and top-down electrophysiological event-related potential (ERP) responses associated with the implicit and explicit processing and modulation of affective cues in order to shed light on the emotion dysregulation difficulties that are central to BPD.

Chapter 2.

Neuropsychology of Emotion Processing & Regulation

2.1. Emotion Processing

Research accumulated over the last decade has shown that emotional stimuli are prioritized for processing. Behavioural studies have demonstrated that individuals have strong attentional biases towards emotional words and images (Anderson & Phelps, 2001; Keil & Ihssen, 2004; Mogg & Bradley, 1999; Carlson & Reinke, 2008). Emotional stimuli draw attention rapidly and involuntarily and appear to be processed and encoded automatically (Holmes et al., 2009; Ohman, 2005; Phelps, 2006). This is particularly the case for threatening and aversive stimuli, since these types of stimuli are generally of motivational importance. For instance, angry faces presented among happy faces are detected faster than vice versa (Hansen & Hansen, 1988). Simply viewing angry or fearful faces has been found to trigger visceral responses such as increased heart rate and sweating (Ohman & Soares, 1998). A number of neural markers associated with the processing of emotion cues have even been observed under conditions where the emotional stimuli are task-irrelevant (Eimer et al., 2003; Holmes et al., 2003), unattended (Vuilleumier et al., 2001), or presented below conscious awareness (Whalen et al., 1998), suggesting a certain level of automaticity in the detection of emotional cues. However, a number of established neural markers also appear to be affected by attentional resources (e.g., fMRI activation in the fusiform face area (FFA): Vuilleumier et al., 2001; early frontal positivity ERP responses to emotional faces: Eimer et al., 2003). The automatic processing of affective cues is not surprising given that the capacity to quickly process emotional information is likely adaptive in light of the potential significance of emotion cues to one’s safety and well-being.

Orientation towards biologically important stimuli generally involves automatic attentional mechanisms which are stimulus-driven (Ohman et al., 2011). Such a bottom-up process allows for efficient responding to environmental cues; however, this process can also result in measurable interference in ongoing cognitive processes and ongoing goals. Emotional Stroop (eStroop) paradigms offer a measure of the interference effects of emotional cues on cognitive processes. Modelled after the colour Stroop task where behavioural interference is observed when the meaning of the word mismatches the word colour, the eStroop task measures interference effects of emotions by measuring the slowing of reaction time in naming the ink of coloured affective words (e.g., “war”, “cancer” and “kill”) relative to neutral words (e.g., “clock”, “lift”, “windy”; Gotlib & McCann, 1984). This interference effect is typically explained by the fact that *task-irrelevant*, yet personally salient emotional words involuntarily capture limited attentional resources. Consequently, this attentional capture results in decrements in performance in the *task-relevant* colour discrimination task. In affective disorders**,** symptom-specific concerns such as depression words for depressed individuals (e.g., “misery”) or anxiety words for anxious individuals (e.g., “panic”), are associated with greater interference effects (Williams et al., 1996). As such, emotional content may act as a potent distracter from one’s goals. Interestingly, attentional biases may reflect individual and disorder-specific concerns providing insights into the underlying processes involved in different disorders.

While several streams of evidence point to the powerful nature of affective cues in automatically capturing processing resources, emotion processing is not solely a bottom-up process. Attention towards emotional content can occur voluntarily and affective cues may be processed consciously in a top-down fashion. The explicit processing of affective cues plays a significant role in social communication and understanding. As previously mentioned, assessing individual differences in the overt processing of emotion cues (e.g., emotion discrimination, affect labelling) has yielded useful data with regard to understanding deficits in the processing and recognition of non-verbal cues in a number of disorders (e.g., autism, schizophrenia, depression, anxiety). Top-down control mechanisms can also impact how environmental signals are interpreted and may help determine whether further processing is needed. For example, contextual cues such as positive or negative labels presented prior to seeing potentially ambiguous facial expressions (e.g., surprised faces) has been found to bias amygdala activations in the direction of the cues (Kim et al., 2004). Similarly, subjective belief that a masked emotional face was present in a white noise context resulted in amplification of various emotion-specific components (amygdala activations: Pessoa et al., 2006; For ERPs: N170 components: Wild & Busey, 2004; EPN and LPP components: Lee et al., 2010). These examples illustrate how top-down cognitive mechanisms can impact how individuals detect and discriminate incoming emotional cues.

Emotions are generally thought to arise from a combination of bottom-up and top-down influences. To better understand these processes, researchers are beginning to determine the relative contributions from bottom-up affective analyses of stimuli versus the top-down cognitive appraisals involved (e.g., Ochsner et al., 2009). Interestingly, investigations into the emotion processing deficits in schizophrenia have revealed aberrant processing of emotional prosody when processed overtly, whereas covert processing in a modified eStroop task revealed intact functioning (Roux et al., 2010), suggesting dissociation between the explicit and implicit processing of affective cues. While research on affective cue processing is fundamental in understanding how individuals experience emotions, an equally important and complimentary domain relates to the modulation of these cues.

2.2. Emotion Regulation

Cognitive processing of emotions not only allows for more in-depth understanding of affective cues in one's environment, but it also allows for the modulation of affective responses. Emotion regulation refers to the ability to suppress, maintain or enhance one's subjective responses to emotional stimuli (Gross, 1999). It encompasses a diverse set of processes that influence the occurrence, intensity, duration, and expression of emotions which are integral to our physical and mental well-being (Gross & Thompson, 2007). Emotion regulation, which can take many forms, allows for flexibility in emotional responding consistent with one's immediate and long-term goals. Akin to the implicit versus explicit processing of affective cues, Gyurak and colleagues (2011) recently proposed a dual-process model of emotion regulation which differentiates explicit and implicit means for modulating one's affective responses based on the extent to which cognitive modulation strategies are consciously applied.

In *explicit* emotion regulation, top-down cognitive influences are deliberate and consciously applied. Empirical investigation has largely focused on the explicit regulation of emotions using intentional strategies such as cognitive reappraisal, effortful distraction, and suppression of emotional responses. Such strategies are applied to attend, ignore, enhance or suppress emotional information with the intention of altering one's emotional responses. By definition, these strategies are available to conscious manipulation. As such, research on intentional emotion regulation strategies is particularly relevant for emotional disorders and can potentially yield findings that translate to clinical intervention and treatment (Campbell-Sills & Barlow, 2007; Mennin et al., 2005).

Emotion regulation is also believed to occur unconsciously. Researchers have recently started describing less effortful and more automatic forms of emotion regulation. *Implicit* emotion regulation refers to a process that is aimed at modifying the quality, intensity, or duration of an emotional response, yet operates without the need for conscious supervision or explicit intentions (Gyurak et al., 2011). Consequently, implicit down-regulation need not be deliberate or intentional and is said to occur without an individual's awareness. An implicit emotion regulation system is likely to be highly adaptive. Since individuals are continually inundated with emotionally charged stimuli throughout the day, emotional responses need to be regulated repeatedly in order to keep them from interfering with people's ongoing activities, situational demands, and long-term goals (see Koole & Rothermund, 2011 for review).

Thus, according to the dual-process model of emotional regulation, individuals have recourse to a number of means for modulating their emotional responses, including conscious or deliberate means, as well as more automatic or unconscious means. Recognizing both implicit and explicit emotion regulation systems may be useful in understanding how individuals regulate their emotions in everyday life.

2.3. Neural Bases of Emotions

Over the last few decades, there has been tremendous interest in how the brain processes emotions. As one might expect, the neural network underlying emotion processing is complex and involves multiple brain regions which interact in complex ways. For facial affect processing, processing begins with initial perceptual analysis in the inferior occipital regions, followed by structural processing in the fusiform gyrus and dynamic processing in the superior temporal region (Adolphs, 2003; Jehna et al., 2011). Emotional processing and conscious representations occur within a network of paralimbic and higher cortical regions. Accumulated evidence suggests that the neural network for processing emotions in healthy individuals includes the medial/ventral prefrontal cortex (PFC), subcallosal/anterior cingulate cortex (ACC), insular cortex, the basal ganglia, and the amygdala-hippocampal region, although other regions have also been implicated (Phan et al., 2002; Vytal & Hamman, 2010; Monk, 2008; Koenigsberg et al., 2009b).

According to LeDoux (1996), emotion recognition occurs along two distinct neural pathways. Along one pathway, information that is biologically relevant is transmitted through the thalamus directly to the amygdala to provide a rapid, but unrefined assessment of potential emotional and motivational stimuli. Such processing is thought to occur below the level of conscious awareness and as such may be particularly relevant for the automatic processing of affective cues. Simultaneously, a longer pathway involving higher-order cortical processes which is accessible through conscious attention provides more extensive analysis of the stimuli and allows for the generation of potential response alternatives (LeDoux, 1996). This longer pathway would appear particularly relevant for the explicit processing of affective cues. While such pathways appear to offer an oversimplified view of the network underlying emotion processing, there is evidence for separable neural substrates involved in the implicit versus explicit processing of affective cues. For example, in a functional magnetic resonance imaging (fMRI) study (Scheuerecker et al., 2007), the implicit processing of emotional facial expressions was associated with increased activations within the thalamus, hippocampus, frontal inferior gyri and the right middle temporal region whereas the explicit processing of these cues was associated with increased activity within the caudate nucleus, cingulum, and the right prefrontal cortex.

2.4. Fronto-Limbic Cognitive Modulation Network

Converging evidence from animal lesion studies and human neuropsychological, psychophysiological, and functional neuroimaging studies, points to a neural circuit consisting of subcortical limbic regions and several prefrontal regions which are essential for emotion regulation and together form a fronto-limbic neural network (Davidson & Irwin, 1999). The prefrontal cortices subserve a number of executive processes including attention, conflict monitoring, inhibitory control, decision-making and the integration of emotional and cognitive information (Barbas, 2000). The prefrontal cortex (PFC), notably the orbitofrontal cortex (OFC), shares robust interconnections with subcortical structures and is believed to exert inhibitory influences on these structures, particularly on the amygdala (Hariri et al., 2003). The anterior cingulate cortex (ACC) is involved in parallel distributed attentional networks and the integration of emotional and cognitive information (Bush et al., 2000). The amygdala is a subcortical structure which is involved in emotion recognition and generation and has a specialized ability in detecting stimuli which may impact the well-being of the organism. It mediates numerous physiological and behavioural responses associated with different emotions, and tends to elicit strong neural responses to threatening and aversive stimuli, most notably fear (Phan et al., 2004; Adolphs et al., 1999). The neural network formed by these frontal and subcortical regions is thought to mediate the cognitive modulation of emotions.

A growing body of research on intentional emotion regulation supports the fronto-limbic model of emotional regulation in healthy individuals. Many studies on effortful regulation of emotions have focused on cognitive reappraisal, an effective strategy that entails reinterpreting the meaning of a stimulus in such a way that its emotional impact is diminished (Gross, 1998; Gross & John, 2003). Converging neuroimaging evidence suggests that lateral and medial regions of the PFC (e.g., dorsolateral prefrontal cortex [DLPFC], dorsal ACC) down-regulate primary emotion processing areas (e.g., amygdala) during cognitive reappraisal (Ochsner et al., 2002; 2004; Levesque et al., 2003; Kalisch et al., 2005; Phan et al., 2005; Goldin et al., 2008; Koenigsberg et al., 2010). Active suppression of sadness during video viewing was also found to be associated with *activation* within prefrontal regions, specifically the right DLPFC (Levesque et al, 2003), a region reported to exhibit opposite changes (i.e., deactivation) in previous studies of sad mood induction (i.e., Liotti et al., 2000). This contrasts with the *expression* of sadness which is associated with increased activation in limbic and subcortical areas, particularly the subgenual ACC and amygdala (Levesque et al., 2003; Liotti et al., 2000). Similar results have been replicated using positive stimuli. For example, passive viewing of sexually arousing pictures was associated with subcortical activations, whereas active suppression of sexual arousal was associated with activation in the DLPFC and dorsal ACC and elimination of subcortical activations (Beauregard et al., 2001). These studies demonstrate that humans have the capacity to influence emotion-specific neural markers through explicit cognitive modulation strategies in the intended direction. Specifically, expression of affect is associated with increased subcortical activations particularly within the amygdala, while intentional down-regulation of affective cues is associated with increased prefrontal activity with a concomitant decrease in subcortical amygdala activations. As such, these studies support the notion that emotional regulation occurs within a neural network of prefrontal regions and subcortical limbic structures in healthy individuals.

Recent evidence suggests that a similar pattern of neural activations also characterizes implicit emotion regulation mechanisms. One way in which emotional responding can be altered without the explicit intent to do so is by putting feelings into words, otherwise known as *affect labelling.* The overt processing of emotional content is said to engage cortical regions and attenuate emotion neural markers. Using fMRI, Hariri and colleagues (2000, 2003) found that perceptual matching of negative emotional stimuli (i.e., facial expressions and threatening images) elicited *increased* amygdala and thalamic activation. In contrast, they found that cognitive processing of the same stimuli (i.e., labelling the images) attenuated the emotional impact of these negative cues, as measured by *decreased* amygdala activations and a corresponding *increase* in the right PFC and ACC. Similarly, Ochsner and colleagues (2009) found that passive viewing of negatively valenced material was associated with greater amygdala activations, while the overt emotional processing of this material was associated with greater PFC activity. Using a variation of the dot-probe paradigm, Schwabe and colleagues (2011) found that reflexive or automatic emotional processing of emotional faces was associated with amygdala activations, while prolonged processing of emotional faces was associated with activations in the cortical network, including the ACC and the insula. Thus, covert processing of emotional stimuli tends to elicit stronger subcortical activity, which is consistent with stronger bottom-up or stimulus-driven responses. In contrast, overt processing of emotion cues tends to elicit greater activations within frontal cortical regions with a reciprocal decrease in subcortical activations, suggesting stronger top-down or goal-driven responding. This pattern of activations parallels the findings described for intentional emotion regulation.

2.5. Electrophysiological Findings

While functional imaging techniques can point to the neural substrates underlying emotion processing and regulation, electrophysiological studies can provide information relating to the time course of the processes involved. Electroencephalography (EEG) measures bioelectric activity of the brain noninvasively via electrodes placed on the surface of the scalp. It offers exquisite temporal resolution (up to 1 ms) and may be used in tandem with source localization techniques to capture neural activity in the spatial domain (Luck et al., 2005). The high sensitivity of ERPs is particularly well-suited for investigating the time course of affective cues, which are processed rapidly in the brain (Batty & Taylor, 2003; Eimer & Holmes, 2002). A growing body of research on the electrophysiological correlates of affective cue processing has emerged and has identified a number of early and late electrophysiological correlates, particularly for the processing of visual affective cues.

The most robust finding is that emotional stimuli enhance the amplitude of the Late Positive Potential (LPP). The LPP is a sustained wave broadly distributed over the dorsal scalp, in particular at posterior electrode sites, which emerges around 300 to 400 ms after stimulus onset and can stay present for several seconds (Cuthbert et al., 2000). The origin of this enhanced slow wave is believed to represent activity in a network of visual cortical structures, such as the lateral occipital, infero-temporal, and parietal visual areas (Sabatinelli et al., 2007). The LPP is a P3b-like wave capturing the later elaborative stages of stimulus processing and is thought to index increased attention to, and facilitated perceptual processing of motivationally relevant stimuli. Enhanced LPPs have been observed for high arousal unpleasant (e.g., mutilations) and pleasant images (e.g., erotic scenes; Cuthbert et al., 2000; Schupp et al., 2000) and this modulation is highly related to autonomic and self-reported indices of arousal (Cuthbert et al., 2000). Additionally, recent investigations have begun studying aberrations in LPP modulations as an index of emotion regulation deficits among clinical populations (e.g., phobias: Leutgeb et al., 2009; generalized anxiety disorder, MacNamara & Hajcak, 2010; depression: Foti et al., 2010). Such findings suggest that the LPP indexes the engagement of attentional resources by motivational systems and may be particularly well-suited for indexing the cognitive processes associated with emotion regulation.

In addition to later elaborative components, earlier ERPs also appear sensitive to emotional cues. Modulations occurring at shorter latencies (180-300 ms) and uniquely sensitive to emotional relative to neutral stimuli have been identified over posterior and anterior scalp locations related to earlier stages of attentional processing. While traditionally described as the Early Posterior Negativity (EPN), a growing body of research has also identified anterior modulations in the N2 time range (Feng et al., 2012), also referred to as the Early Anterior Positivity (EAP, Taake et al., 2009; Asmaro et al., 2012). Positive polarity frontal modulations for threat relative to neutral words have been described in a number of studies (Li et al., 2007; Pauli et al., 2005). It has been suggested that these early anterior ERPs reflect the fast and automatic processing of emotional salience through a forward direct projection from the amygdala to the medial PFC and rostral ACC (Taake et al., 2009). An even earlier fronto-centrally distributed positivity starting as early as 120 ms has also been linked to the processing of emotional faces compared to neutral ones (Eimer & Holmes, 2002; 2003). This early peak positivity has been proposed to reflect the initial rapid detection of face-specific emotional cues in prefrontal areas that play an important role in detecting emotionally relevant information (Eimer & Holmes, 2007).

Early effects over the visual scalp have also been described in the processing of visual affective cues. This includes the P1, which is a positive-going ERP that typically occurs around 100 ms after stimulus presentation. It is believed to index the mobilization of attentional resources and has been linked to perceptual information processing in extrastriate visual areas (Hopfinger & Mangun, 2001; Allison et al., 1999). P1 modulations may be affected by task demands such as task load (Taylor, 2002) and appear larger for attended compared to unattended stimuli (Hillyard et al., 1998). They may also be influenced by emotional content. For example, P1s appear enhanced for angry and fearful faces relative to neutral ones (Batty & Taylor, 2003). Additionally, enhanced P1s have been observed among clinical populations (e.g., obsessive-compulsive disorder, panic disorder), suggesting that the P1 reflects an attentional bias to threat (Thomas et al., 2013).

One of the most robust ERPs reported is the N170 component recorded over occipito-temporal sites around 170 ms post-stimulus, which is reliably triggered by faces but not other types of stimuli (e.g., Bentin et al., 1996). It is assumed to reflect pre-categorical perceptual encoding of faces in face-specific ventral visual areas, which provides structural representations that are utilized by subsequent face recognition stages (Bentin et al., 1996; Eimer, 1998; 2000). Since the N170 is considered to reflect structural encoding of facial features, traditionally it has been viewed as being unaffected by emotions and many studies support this perspective (e.g., Eimer & Holmes, 2007; Eimer et al., 2003). However, there have been some accounts of the N170 being modulated by emotional expressions (e.g., Batty & Taylor, 2003; William et al., 2006). Thus, a number of established early and later ERP components have emerged in the study of affective cues, some of which are particularly sensitive to faces.

2.6. Electrophysiology of Cognitive Control of Emotion

Electrophysiological studies have started identifying correlates of explicit cognitive modulation strategies. Using a cognitive reappraisal task, Hajcak and Nieuwenhuis (2006) observed LPP amplitude *reductions* to pleasant and unpleasant pictures and the degree of LPP modulation was positively correlated with reductions in self-reported emotional intensity. Similarly, Moser and colleagues (2006; 2009) reported *decreased* LPP amplitudes during active suppression of emotional responses to evocative pictures. On the other hand, cognitive enhancement of emotional responses resulted in *increased* LPP amplitudes (Moser et al., 2009). These findings suggest that the LPP is sensitive to the implementation of intentional emotion regulation strategies and is modulated in the intended direction.

Electrophysiological techniques may also be useful in the study of implicit emotion mechanisms. Using an eStroop paradigm, Thomas and colleagues (2007) observed early detection components to threat relative to neutral words in the P2 time range, regardless of whether the words were task-relevant or not. In contrast, they found that later elaborative components (P3) were differentially enhanced for *task-relevant* emotional words (Thomas et al., 2007). Of note, no corresponding behavioural Stroop effects were observed. Employing a similar task, Taake and colleagues (2009) described an enhanced EAP effect between 200 and 300 ms for *implicitly* presented physical threat words relative to neutral or positive words in the absence of reaction time slowing. Eimer and Holmes (2007) investigated the impact of attention on the processing of emotional facial expressions. They observed an early fronto-central positivity enhancement starting between 120 and 180 ms to facial expressions of affect relative to neutral expressions independent of the focus of attention, provided that the facial expressions were presented foveally (Eimer & Holmes, 2007). They also found that this effect was eliminated when faces were presented at unattended locations (Holmes et al., 2003), suggesting that early salience effects over the anterior scalp are to some degree attention-dependent. Although additional work is needed in order to clarify the mechanisms underlying implicit emotion processing, studies such as these show promise in terms of elucidating the processes involved.

2.7. Individual Differences & Clinical Applications

While the literature is broadly supportive of the fronto-limbic model of cognitive modulation, particularly for explicit emotion regulation such as cognitive reappraisal, investigations have recently shifted towards exploring individual differences in the functioning of the neural circuitry that supports this system. In an fMRI experiment (Campbell-Sills et al., 2010), anxiety-prone individuals showed altered functioning of neural substrates in an emotion regulation task compared to healthy controls. Specifically, during cognitive reappraisal of negative emotions, anxious individuals showed greater activation of brain regions implicated in effortful and automatic control of emotions (within the lateral PFC and subgenual ACC respectively). Similarly, Koenigsberg and colleagues (2009a) found that BPD patients displayed different neural dynamics while passively viewing social emotional stimuli and did not engage cognitive control regions to the extent that healthy controls did when employing a distancing strategy to regulate emotional reactions. Applying the fronto-limbic model of emotion regulation to individuals with emotion regulation difficulties can contribute important knowledge to our current understanding of this model, as well as yield valuable insights into emotion dysregulation.

Chapter 3.

Borderline personality disorder and emotion processing

3.1. Introduction

Borderline personality disorder (BPD) is a complex and serious mental disorder, characterized by a pervasive pattern of instability in the regulation of emotions, interpersonal relationships, self-image, and impulse control (American Psychiatric Association, 1994). It is estimated to occur in 1% to 2% of the general population (Torgersen et al., 2001). Approximately 80% of individuals with BPD have a history of self-harm (e.g., Bohus, et al., 2000), and 50% to 75% of those with BPD attempt suicide at least once (Fyer et al., 1988). In addition to self-injurious behaviour, BPD individuals also exhibit heightened levels of health-compromising behaviours, including risky sexual behaviour, substance misuse, and binge eating (American Psychiatric Association, 1994; Zanarini et al., 1998). Within the interpersonal domain, individuals with BPD report interpersonal conflict, frequent break-ups, and poor social problem-solving (Bray et al., 2007). Not surprisingly, the interpersonal and social costs associated with BPD are notable. Although great strides have been made to understand the disorder, the mechanisms underlying BPD, particularly the neurobiological mechanisms, are only starting to be understood.

Borderline personality disorder is a multidimensional heterogeneous condition. One common denominator of the various clinical phenotypes of BPD appears to be the dysfunctional regulation of emotions. Linehan (1993) proposed a biosocial theory of BPD where emotional vulnerability and emotion dysregulation represent key characteristics of the disorder. According to this theory, individuals with BPD would exhibit 1) a low threshold for emotional responding with high sensitivity to emotional stimuli, 2) intense and long-lasting responses to emotionally evocative stimuli with high emotional intensity and slow return of emotional arousal to baseline, and 3) an inability to control or modulate emotional experiences (Linehan, 1993). Impairments in emotion processing and affect regulation would help explain some of the maladaptive behaviours observed in BPD patients such as their strained interpersonal relationships (Wagner & Linehan, 1999).

3.2. Emotional Dysregulation in BPD

A growing body of research supports the notion of emotional dysregulation in BPD. On self-report measures, individuals with BPD report greater emotional lability and higher levels of anger and anxiety relative to other personality disorders (Koenigsberg et al., 2002; Henry et al., 2001). BPD individuals demonstrate prolonged anger reactions (Jacob et al., 2008) and report a longer duration and higher intensity of subjective perceived states of aversive internal tension compared with healthy controls (Stiglmayr et al., 2001). Additionally, their level of affect intensity and affect control correlates with the number of BPD traits they exhibit, even after controlling for level of depression (Yen et al., 2002). Field-based approaches, such as daily mood recordings, suggest the presence of heightened affective instability throughout the day (Cowdry et al., 1991; Stein et al., 1996). Such findings support the notion that individuals with BPD experience affect dysregulation; however, self-report methodology has some limitations.

While self-report measures can be widely distributed, they are highly subjective and prone to biases in responding. Moreover, they are limited by an individual’s willingness and/or ability to accurately describe their experiences. Evidence suggests that individuals with BPD exhibit deficits in emotional awareness and clarity (Levine et al., 1997). As such, they may be limited in their ability to accurately describe their emotional responses. BPD individuals also tend to avoid unwanted internal experiences such as unpleasant cognitions and emotions (Cheavens et al., 2005; Rosenthal et al., 2005), which may also impact their responses. Translational research, or the application of basic science methodologies to investigate clinically relevant phenomena, holds much promise in advancing the assessment and treatment of BPD (Rosenthal et al., 2008). In response to such limitations, researchers have been examining emotion processing in BPD using laboratory measures.

Facial emotion recognition has been a primary focus in the study of emotion dysregulation in BPD. The ability to accurately infer the emotional states of others from facial expressions is vital for adaptive social functioning and misinterpretations resulting from impaired facial emotion recognition are likely to result in dysfunctional relationships. Although there is converging evidence for altered emotion facial recognition abilities in BPD individuals, the findings concerning the pattern of alterations has been somewhat contradictory. Some studies (e.g., Levine et al., 1997; Unoka et al., 2011) have described deficits among BPD individuals in the recognition of facial expressions, in particular with increased errors in the discrimination of negative facial expressions. However, a growing number of studies suggest enhanced sensitivity towards facial affect among BPD individuals. Using a free-response format, Wagner and Linehan (1999) described reduced accuracy for the appraisal of neutral expressions with *heightened sensitivity* in the recognition of fearful facial expressions among BPD individuals, suggesting a negativity bias. Using a morphing paradigm where neutral faces morphed into emotional expressions, Lynch and colleagues (2006) described a hyper-sensitivity to facial expressions of anger, fear, sadness and happiness among BPD individuals relative to healthy controls. Domes and colleagues (2008) found no deficits among BPD individuals using a similar paradigm; however, they observed biases towards perceiving angry faces (but not fearful ones) when presented with blends of facial expressions (i.e., ambiguous cues). Dyck and colleagues (2009) also reported a negative bias among BPD individuals during a fast emotion discrimination task, though this effect disappeared when processing time was unlimited. Though the literature has been somewhat mixed, these latter studies suggest *enhanced sensitivity* to facial expressions among BPD individuals, particularly under conditions of reduced information or fast processing speed requirements.

Attempts to better understand the difficulties experienced in BPD have turned to studies of attentional bias. Effortful control, also known as executive or attentional control, is a self-regulatory dimension governed by the anterior attentional system, an executive system that regulates voluntary attentional functions to threat cues (Derryberry

& Reed, 2002; Rothbart et al., 2000). Using the eStroop task, Arntz and colleagues (2000) found that negative emotional words including BPD-specific words (i.e., negative views of others, sexual abuse-related words, and negative self-descriptors), as well as general negative words unrelated to BPD pathology resulted in an interference effect for BPD individuals, compared to healthy controls, suggesting hypervigilance to negative content in general as well as domain-specific negative content. Using an eStroop paradigm, Sieswerda and colleagues (2007) described an attentional bias for positive and negative cues among BPD individuals, who in particular showed hypervigilance for schema-related negative cues. These studies suggest that BPD individuals show biases towards affective cues, with some evidence suggesting biases towards domain-specific concerns.Interestingly, Gardner and colleagues (2010) found that low effortful control predicted poor affect labelling in BPD. Thus, investigating attention biases towards disorder-relevant cues may be relevant in better understanding emotion recognition abilities in BPD.

Psychophysiological studies have yielded mixed findings regarding emotional hyperactivity or hypersensitivity in BPD individuals. Herpertz and colleagues (1999) measured heart rate, skin conductance and startle responses in addition to self-report to neutral and negative pictures. Low electrodermal responses in BPD across all three stimulus categories suggested physiological underarousal. Interestingly, Ebner-Priemer and colleagues (2005) found that startle responses in BPD were modulated by dissociative symptoms. Specifically, patients with low dissociative experiences revealed enhanced startle responses whereas patients with high dissociative experiences showed reduced responses. Such findings support the cortico-limbic disconnection model of dissociation (Sierra & Berrios, 1998), which posits that affective dysregulation is associated with increased amygdala functioning, whereas dissociation is linked to inhibited processing of stimuli by the amygdala and dampened autonomic output.

3.3. Neural Bases of Emotion Processing in BPD

A growing number of studies have utilized neuroimaging techniques to examine emotional responding in BPD. Using such tools allows for the investigation of altered brain mechanisms which may account for the social and emotional processing difficulties observed in BPD. As discussed in Chapter 2, the interplay between limbic and prefrontal regions appears particularly relevant in emotion regulation among healthy individuals. As such, neuroimaging investigations in BPD have focused on alterations in these brain regions. A growing body of research employing structural and functional neuroimaging techniques provides evidence for a dysfunctional fronto-limbic network in BPD individuals (Schmahl & Bremner, 2006; Ruocco et al., 2013; Krause-Utz et al., 2014).

First, a number of structural differences have been identified among BPD patients. This includes volume loss in the amygdala and hippocampus (Driessen et al., 2000, Tebartz van Elst et al., 2003; Schmahl et al., 2003) with some evidence that early traumatic experiences may play a role in the observed hippocampal atrophy (Brambilla et al., 2004). While not as prominent, cortical volume loss has also been identified in some studies including the OFC (Tebartz van Elst et al., 2003) and the ACC (Tebartz van Elst et al., 2003; Hazlett et al., 2005). Thus, there is evidence for cortical and subcortical volume loss in BPD in regions important for emotion processing and regulation.

Of particular interest are findings of altered neural responses to affective stimuli among BPD individuals. Early fMRI studies in BPD suggested functional abnormalities in limbic structures including enhanced amygdala activations to negatively valenced pictures (Herpertz et al., 2001) and facial expressions of emotions (Donegan et al., 2003). Contrary to these early findings, a recent meta-analysis (Ruocco et al., 2013) suggests that rather than showing a hyper-responsivity within the amygdala, individuals with BPD show attenuated amygdala responses to negative emotions relative to healthy controls.

Additionally, those with BPD show less activation and responsiveness within frontal brain regions which are implicated in regulatory control processes including the ACC, medial frontal cortex, OFC, and DLPFC (Schmahl & Bremner, 2006; Ruocco et al., 2013; Krause-Utz et al., 2014). In particular, the ACC, which appears to be critically involved in the processing of emotional salience and conflict (e.g., Becker et al., 2001; Williams et al., 1996) has shown deactivation or failure of activation in BPD individuals during so-called “challenge studies” which use emotional, stressful, and sensory stimuli, such as personalized scripts related to memories of abandonment (Schmahl et al., 2003), traumatic events (Schmahl et al., 2004) or painful heat stimuli (Schmahl & Seifritz, 2003). In a recent fMRI study (Wingenfeld et al. 2009), BPD individuals also showed dysregulation in the ACC and frontal brain regions on an eStroop task compared to normal controls.

Together, the growing body of research shows converging evidence which suggests that the social and emotional disturbances of BPD may have a basis in the functional neuroanatomy supported by fronto-limbic circuitry. One hypothesis to explain emotional dysregulation in BPD is a failure of the ACC and of prefrontral brain areas to inhibit the amygdala (e.g., Minzenberg et al., 2007). Thus, the interplay between limbic hyper-reactivity and diminished recruitment of frontal brain regions may help explain the disturbed emotion processing and other core features of BPD such as impulsivity and interpersonal difficulties.

Despite emotional dysregulation being a core feature of BPD, few studies have investigated the neural bases of emotion dysregulation directly. In one study of explicit emotion regulation, Koenigsberg and colleagues (2009a) examined the neural correlates associated with distancing versus simply looking at pictures depicting social interactions. While both the BPD and control groups reported decreased affect ratings following the distancing strategy, BPD patients showed less signal change in the dorsal ACC and intraparietal sulcus, less activation in the amygdala, and greater activation in the superior temporal sulcus and superior frontal gyrus, showing a distinct pattern of neural dynamics. In a recent study using cognitive reappraisal of negative scripts, Lang and colleagues (2012) found reduced ACC activations in BPD individuals compared with healthy controls when down-regulating negative emotions. During the enhancement of negative emotions, healthy controls showed increased early activation in the PFC and amygdala. In contrast, BPD individuals showed early deactivation of the PFC, again showing a distinct pattern of neural dynamics, despite reporting similar changes in affect as the controls participants. While neuroimaging research can provide information regarding the neural structures which underlie emotion dysregulation, electrophysiological research can provide information regarding the timing of affect processing.

Despite the usefulness of EEG, a limited number of studies have utilized this technique to assess BPD-related difficulties. The EEG studies that have been performed among BPD individuals have generally focused on sleep patterns (Reynolds et al., 1985; De la Fuente et al., 2001; Asaad et al., 2002), error processing (Ruchsow et al., 2006), and self-injurious behaviour (Russ et al., 1999). Interestingly, BPD individuals show abnormal brain maturation, as evidenced by a failure to exhibit normal age-related reductions in P300 ERPs (Meares et al., 2005; Houston et al., 2005). Additionally, BPD individuals show reduced P3 amplitudes during response inhibition trials on Go/Nogo task (Ruchsow et al., 2008). In a recent study (Beeney et al., 2003), BPD individuals showed greater left hemisphere cortical activations following rejection, consistent with approach behaviour. In contrast, those with depression showed greater right hemisphere activation, consistent with withdrawal behaviour.

Only one known study to date has investigated the electrophysiological correlates associated with emotion processing in BPD. Marissen and colleagues (2010) observed larger LPPs to unpleasant pictures among a BPD group compared to a control group, indicating enhanced elaborative processing of unpleasant stimuli. Although they reported no group differences in LPP amplitudes following a cognitive modulation task, there was no direct comparison with their control task and as such it may be that neither group was able to down-regulate the impact of the high arousal images. A magnetoencephalography (MEG) study (Merkl et al., 2010) identified subtle deficits in early visual perception markers over the posterior scalp when facial expressions were processed by BPD individuals. However, no known studies to date have investigated early ERP components associated with more automatic emotion and regulation processes which may be aberrant in BPD. The lack of studies investigating the time course of emotion-related components, particularly during early processing stages is notable. This is particularly surprising given the large body of research which suggests biases in attention and potential hyper-reactivity in BPD. Given the current state of knowledge, further research into the electrophysiological correlates and the delineation of the time-course of emotion processing among those with BPD is much needed.

Chapter 4.

Study 1: Overt versus Covert Processing of Emotional Faces

4.1. Introduction

The present study employed a modified eStroop EEG paradigm to investigate group differences in the behavioural and electrophysiological correlates associated with the explicit and implicit processing of facial expressions of affect among females with high and low levels of BPD traits. By altering the focus of attention either *towards* the cognitive analysis of facial expressions (Overt condition), or *away* from the direct analysis of facial expressions (Covert condition), the current study intended to bias processing in a top-down versus bottom-manner manner respectively.

In order to shed light on the timeline of facial affect processing in BPD, the current study was interested in the early ERP components associated with the attentional capture of emotionally salient cues as well as the later ERP components associated with elaborative processes linked with more in-depth analysis of these cues. Early emotion-related ERP components were of primary interest given the lack of EEG data regarding affect cue processing during early stages among BPD individuals. Based on findings in the literature, the implicit processing of emotional cues involves greater limbic activity whereas the explicit processing of these cues involves greater prefrontal activity (e.g., Hariri et al., 2000; 2003; Ochsner et al., 2009). Moreover, greater limbic re-activity has been observed in emotional disorders during implicit emotion cue processing (Fu et al., 2004). Although the BPD literature on emotion processing has yielded mixed findings, differences between explicit and implicit processing of emotional cues were hypothesized. In line with research which finds attentional biases in BPD suggesting deficits in attentional or executive control (e.g., Arntz et al., 2000), ERP alterations associated with the voluntary allocation of attention were expected. As such, the findings of this experiment were intended to contribute to the current understanding of how individuals with BPD traits differ in their processing of facial expressions of affect when these were the intended focus of attention compared to when they were task-irrelevant.

The use of a non-clinical BPD sample offers a number of advantages. First, there has been much debate surrounding the conceptualization of BPD and many argue that it is best conceptualized as a dimensional disorder (Widiger, 1992). As such, individuals with high levels of borderline traits are believed to share commonalities with those diagnosed with BPD. In fact, individuals with elevated BPD traits in a non-clinical sample have been found to show pronounced deficits in emotional understanding and management demonstrating poorer subjective perception of emotion, management of their own emotions, and management of the emotions of others around them (Garder, Qualter & Tremblay, 2010). Other advantages of employing a non-clinical BPD group are the reduced confounds due to high comorbidity with depression, anxiety and other psychiatric disorders, medication status, overall severity and other non-specific illness-related effects that often accompany a BPD diagnosis. Thus, utilizing a non-clinical population is a practical and useful way of acquiring data which can offer helpful insights into emotion dysregulation difficulties in those with BPD.

A modified eStroop task consisting of facial expressions overlain with colour squares was utilized for this experiment. The demands for conscious processing of emotional content was manipulated by having participants identify facial expressions of affect while ignoring the colour squares (*Overt* emotion processing task) or having them identify the colour squares while ignoring the surrounding emotional faces (*Covert* emotion processing task). The explicit processing of emotions was expected to bias processing of the emotional content in a top-down manner with later ERP components indexing the more conscious processing of emotions. In contrast, the covert task was anticipated to bias processing of the emotional faces in a bottom-up manner with early ERP responses indexing more automatic processes associated with the salience of the emotional stimuli and as such index potential processing or attentional biases. Of note, the applied covert paradigm in the present study did not involve a lack of consciousness, but rather refers to processing of facial expressions without an explicit focus or intention to do so.

Given the exquisite temporal resolution of EEG, ERPs can be selectively averaged in response to different categories of rapidly occurring stimuli within the same experimental block allowing for the investigation of different emotions in a mixed trial design. As a result, processes associated with single events can be examined. In light of the special research focus in our lab on the regulatory processes associated with the frontal lobes, ERP responses to facial expressions of affect over the anterior scalp, in particular the early emotion-specific positive effects such as the EAP (Taake et al, 2009), were of particular interest.

Facial expressions of affect were selected for this experiment since faces are crucial for interpersonal communication, providing powerful and dynamic social feedback signals whose interpretation appears to be impaired among BPD individuals (e.g., Levine et. al., 1997; Unoka et al., 2011; Wagner & Linehan, 1999). Faces are also well-suited for EEG methodology since they are processed quickly and produce relatively early evoked responses. Based on previous findings in the BPD literature, facial expressions portraying five prototypical emotions consisting of angry, fearful, sad, happy, and neutral facial expressions were selected for this study. The electrophysiological responses to negative facial expressions, particularly hostile expressions (anger) were of particular interest. Angry faces typically convey a direct social threat to the individual, such as negative social feedback, disapproval, and social exclusion, which are areas of vulnerability among BPD individuals (Gunderson & Lyons-Ruth, 2008).

4.2. Hypotheses

The primary hypotheses for this study were centred on group differences. First, based on current knowledge regarding the social and emotional difficulties experienced in BPD, the HBT group was expected to show greater emotional reactivity to the emotional faces compared to the control group. It was hypothesized that relative to the control group, the HBT group would show 1) enhanced early salience markers (frontal positivities) indexing greater automatic capture and processing of emotion cues, and 2) enhanced later elaborative components (LPPs), consistent with greater processing and difficulty in disengaging attention from expressions of facial affect. Additionally, it was hypothesized that the HBT group would show 3) relatively more pronounced emotion reactivity effects in the covert condition, reflecting stronger bottom-up salience effects associated facial affect processing, and 4) stronger ERP effects for negative facial expressions, particular angry faces, consistent with predictions of greater sensitivity towards direct social threat cues. In light of the mixed trial design of this study, behavioural interference effects were not expected (see Taake et al., 2009 for discussion of blocked versus mixed trial effects). However, potential behavioural differences in accuracy and mood ratings were of interest.

4.3. Methods

The Simon Fraser University Research Ethics Board approved this experiment. All participants gave their written informed consent before participating in this study and received course credit or a token monetary incentive for their involvement.

4.3.1. Participants

Undergraduate students in introductory psychology classes at Simon Fraser University completed a web-based pre-screening survey which included the Personality Assessment Inventory - Borderline scale (PAI-BOR; Morey, 1991) and a demographic questionnaire. Following previously used standards in the field (e.g., Trull, 2001), individuals with scores of 38 or greater on the PAI-BOR, were designated as high BPD trait (HBT) individuals. Individuals with scores of 23 and lower on the PAI-BOR were designated as low BPD trait (LBT) individuals. To avoid the possible confound of gender differences on facial affect recognition (Hall & Matsumoto, 2004), the sample was restricted to females. In order to eliminate the possible confound of brain laterality differences and to ensure adequate visual acuity for the experimental tasks, the study was limited to right-handed participants who reported normal to corrected vision and had no colour-blindness. Participants meeting the cut-off scores for the two subgroups of interest and who met the inclusion criteria were contacted by email and invited to participate in the EEG experiment.

Forty females participated in this study. Four participants were excluded due to excessive noise in their EEG recordings and/or having too few trials to analyze (<30 trials/condition), four were excluded due to faulty recording or missing data, and two due to current psychoactive medication use. The final sample consisted of 15 HBT females and 15 LBT females who served as a control group. All participants reported no serious neurological issues, developmental disorders, or learning disabilities. Additionally, groups did not significantly differ in age, years of education, and reported hours of sleep ($p < .05$). See Table 4.1 for participant characteristics.

4.3.2. Measures

This study included a number of measures including the Personality Assessment Inventory-Borderline scale (PAI-BOR), Background and Medical History Questionnaire, Dissociation Tension Scale (DSS), Beck Depression Inventory- 2 (BDI-II), the Brief Symptom Inventory (BSI), and Mood and Psychological state ratings.

Borderline Traits

The Personality Assessment Inventory – Borderline scale (PAI-BOR; Morey, 1991) is part of the larger Personality Assessment Inventory (PAI), a 344-item self-report questionnaire designed to cover the constructs most relevant to a broad-based assessment of mental disorders. The PAI-BOR subscale consists of 24 Borderline items encompassing four core features of the disorder as defined in the DSM-IV (American Psychiatric Association, 1994). This includes affective instability, identity problems, negative relationships, and self-harm/impulsivity. Each item is rated on a 4-point scale (0 to 3) from “false” to “very true”, with possible scores on the PAI-BOR ranging from 0 to 72 where higher scores reflect a higher level of dysfunction. This subtest can be used as a stand-alone assessment of borderline features. A cut-off score of ≥ 38 represents a score of two standard deviations above the mean for community participants (Morey, 1991). A lower-level cut-off score of 23 represents the mean score for undergraduate students (Morey, 1991). The PAI-BOR is commonly used to assess BPD features among undergraduates (Trull, 1995; 2001) and demonstrates high internal consistency in a college sample (alpha = .92; Trull, 2001) and high test-retest reliability in a sample of men and women under 40 years old (r = .90; Morey, 1991). The scale converges with other BPD scales in clinical and college samples (Morey, 1991; Stein, 2007) and has recently been found to have a positive predictive power value of .97 with SCID-II diagnoses of BPD in a clinical sample (Jacobo et al., 2007).

Background and Medical History

The Background and Medical Questionnaire is a short self-report questionnaire that gathers participant's background information (e.g., age, education, handedness), and a brief medical history emphasizing neurological conditions (e.g., head concussion, seizures), mental health issues (e.g., depression, anxiety), developmental problems (e.g., learning disability, ADHD), and current medication use.

Dissociation

The Dissociation Tension Scale (DSS; Stiglmayr, Shapiro, Stieglitz, Limberger & Bohus, 2001) is a 21-item self-rating measure of dissociative symptoms that relate to psychological (e.g., derealization, depersonalization, amnesia) and somatic (e.g., perception of pain, vision, and hearing) dissociation. Higher scores relate to more severe dissociative symptoms. The scale demonstrates good psychometric properties and has high internal consistency (Cronbach's α = .92; Stiglmayr et al., 2010).

Depression.

The Beck Depression Inventory- 2 (BDI-II; Beck et al., 1996) is a 21-item self-report instrument intended to assess the presence and severity of symptoms of depression over the past two weeks including the day of testing. Higher scores indicate higher levels of depression. The BDI-II demonstrates excellent psychometric properties, with a high internal consistency for outpatients (Cronbach's α = .92) and college students (Cronbach's α = .93; Beck et al., 1996).

Psychopathology.

The Brief Symptom Inventory (BSI; Derogatis, 1993) is a 53-item self-report measure of clinical psychopathology. It is the shortened version of the Symptoms Checklist-90 encompassing nine symptom dimensions (Somatization; Obsession-Compulsion; Interpersonal Sensitivity; Depression; Anxiety; Hostility; Phobic Anxiety; Paranoid Ideation; and Psychoticism) and three global indices of distress (Global Severity Index, Positive Symptom Distress Index, and Positive Symptom Total). The global indices measure the overall level of distress and symptomatology, intensity of symptoms, and number of reported symptoms, respectively. Respondents rank each item on a 5-point scale ranging from 0 (not at all) to 4 (extremely). Rankings represent the intensity of distress over the past week. The BSI has adequate psychometric properties (internal consistency r = .71 to r = .85; test-retest reliability r = .68 to r = .91; Derogatis, 1993).

Mood and Psychological State Ratings.

Participants rated their current mood and psychological states for 7 different States (i.e., Sad, Anxious, Angry, Tired, Relaxed, Energetic, Happy) following each experimental block. They rated each state using a 5-point Likert scale (1 = not at all; 2 = a little; 3 = moderately; 4= quite a bit; 5 = extremely).

Experimental Stimuli.

Emotional face stimuli were selected from the standardized Karolinska Directed Emotional Faces database (KDEF; Lundqvist, Flykt, & Öhman, 1998). Twenty stimuli, consisting of two males and two females each portraying five facial expressions (Angry, Fearful, Sad, Happy, and Neutral) were selected for the study. To reduce the impact of extraneous information, the images were edited to mask the hair. Additionally, all images were centered onto a black background with facial features aligned across images. Finally, a small coloured square in one of five colours (Red, Green, Blue, Yellow, and Brown) was overlaid on the center of each nose. The stimuli for each task were the same; only the task instructions and desired responses differed between conditions.

4.3.3. Procedure

Participants were asked to come to the laboratory well-rested and with clean, dry hair. Each participant was informed about the nature of the study, gave their written informed consent and completed the Background and Medical History Questionnaire prior to beginning the experiment.

Participants sat 60 cm from a computer screen in a sound-attenuated booth, with ambient light standardized across participants. In order to minimize eye blinks, they were asked to keep their eyes focused on the central fixation marker ("+") on the computer screen throughout the experiment. In the *Overt* condition, participants completed an affect labelling task. As such, they were instructed to identify the *emotion* conveyed by each face as quickly and accurately as possible from five possible choices (i.e., angry, fearful, sad, happy, or neutral). In the *Covert* condition, participants completed a color discrimination task. As such, they were instructed to identify the *colour* of the squares superimposed on the faces as quickly and accurately as possible from five possible choices (i.e., red, green, blue, yellow, or brown). Prior to each task, participants completed practice trials to familiarize themselves with the task and to learn the response key configuration.

Each condition consisted of 4 blocks of 100 stimuli comprised of 20 images (five facial expressions portrayed by two males and two females) overlain by each of the five colour squares for a total of 400 *covert* presentations and 400 *overt* presentations. The stimuli were presented in pseudo-random order, constrained so that no more than three stimuli with the same emotion, gender or colour square were presented consecutively within any block. The presentation order for the two conditions was counterbalanced across participants. In order to eliminate potential laterality effects, the response key configuration was also counterbalanced across participants. Using E-Prime software (version 2.0), the experiment was programmed as follows: 100 ms central fixation marker "+" , 500 ms visual stimulus, and a1400-2400 ms jittered inter-stimulus interval with a central fixation marker "+" during which time the participants indicated their answer using a response pad. See Figure 4.1 for the time course of stimulus presentation. At the end of each block, participants completed the Mood and

Psychological State rating scales and were offered a short break. The total duration of the EEG task was approximately 35 minutes.

At the end of the experiment, participants completed the DSS, BDI-II, and BSI questionnaires before being thanked, debriefed and compensated for their participation.

EEG Data Recording and Processing

The EEG activity was recorded continuously from the scalp through 64 sintered Ag-AgCl electrodes embedded in an elastic cap (Electro-Cap International) which provided very low noise, low offset voltages and very stable DC performance. Electrodes were positioned in an equiradial layout relative to the vertex (i.e., each electrode was radially equidistant from Cz). Water-soluble conductive electrode gel (SignaGel) was used with no additional skin preparation given that active electrodes would make this redundant. Two reference electrodes were placed on the left and right mastoids. In order to monitor eye blinks, two lateral orbital and two inferior orbital electrodes were placed around the eyes. Electrode impedances were kept below 40 KOhm. EEG signals were amplified by BioSemi Active-Two amplifiers with a sampling rate of 512 Hz. Brain activity was recorded and analyzed offline using BESA (version 5.3) software. The EEG amplifier bandpass was 0.01 to 30 Hz and re-referenced to the common mastoid. Trials contaminated by eye movements over frontal channels were rejected from analyses (amplitude >120 µV). Bad channels (a maximum of six) contaminated by other artifacts surviving averaging were interpolated within BESA. Each participant maintained a minimum of 30 trials per condition after artifact rejection.

Distinct subject ERP averages were obtained for each group (HBT and LBT), for each condition (Covert and Overt), and for each emotion (Angry, Fearful, Happy, Sad, and Neutral), time-locked to stimulus onset. Averaged epochs included a 200 ms pre-stimulus baseline and a 1000 ms ERP time window. Grand-averages were computed by combining single subject ERP averages. ERP waveforms and topographical scalp maps were inspected for the components of interest. Time windows were selected around the peaks of interest, determined by the maximum amplitude. Mean voltage amplitudes in the selected time windows were extracted and employed as parameters in the ERP analyses.

Analyses

Behavioural Analyses

For each psychological measure administered, overall scores were computed for each participant. Group differences on psychological measures including the BSI, BDI-II, and the DSS were analyzed using independent samples t-tests. In order to analyze subjective mood and psychological state ratings, ratings for each state were averaged across blocks for each condition and participant. A repeated measures ANOVA with mean State (Angry, Anxious, Energetic, Relaxed, Happy, Sad, and Tired), Condition (Covert and Overt) and Group (HBT and LBT) as factors was computed. This was followed by separate ANOVAs for each mean state by Condition (Covert and Overt) and Group (HBT and LBT).

Accuracy was recorded as either correct (1) or incorrect (0) and averaged across blocks for each condition, emotion and participant. Mean accuracy was used as a parameter in the analysis. Error rates were not analyzed as there were too few errors recorded. Reaction time (RT) was measured in milliseconds (ms) from the time of stimulus presentation to the time that the participants indicated their responses via button press. Reaction times recorded as smaller than 150 ms and greater than1500 ms were excluded from the analyses. Mean reaction time for each emotion and condition was calculated for each participant and entered as a parameter in our analyses. For accuracy and reaction time analyses, a repeated-measures Analysis of Variance (ANOVA) was performed with Emotion (Angry, Fearful, Happy, Sad, and Neutral) and Condition (Overt and Covert) as repeated-measures factors and Group (HBT and LBT) as a between-group variable. In the event of significant interaction effects or for a-priori hypothesized differences, more restricted ANOVA analyses were conducted in order to clarify the effects. Bonferroni-corrected t-tests were used to correct for family-wise error.

Electrophysiological Analyses

In order to test the predicted enhanced early salience markers (Hypothesis 1), an early positivity over the anterior scalp [Early Anterior Positivity: EAP] was analyzed with a time window between 200 and 300 ms over midline and right fronto-central electrode sites (Fz, FCz, Cz, F2, FC2). In order to test predicted enhanced later elaborative components (Hypothesis 2), a posterior time window between 300 and 600 ms [Late Positive Potential: LPP] was selected over left (P1, P3, PO3), midline (POz, Pz, CPz), and right (P2, P4, PO4) electrode sites.

Additionally, a number of exploratory time windows were analyzed to supplement the main analyses. An early positivity between 130 and 170 ms [P150] over fronto-central electrode sites (Fpz, AFz, Fz, CFz) appeared to show similar group-specific modulations as the EAP effect, and was analyzed to help clarify the main findings. A corresponding time window over the posterior scalp (N170) was also analyzed between 130 and170 ms over posterior left (P9, PO7) and right (P10, PO8) electrode sites in order to rule-out the possibility that the P150 effect was the inverse of the N170 effect. Finally, to allow for comparison of findings between studies, a time window between 80 and 120 ms [P1] over the left (P7, PO7) and right (P8, PO8) occipital electrode sites was selected to assess P1 effects.

Repeated measures ANOVAs with Condition (Overt and Covert) and Emotion (Angry, Fearful, Happy, Sad, and Neutral) as repeated-measures factors and Group (HBT and LBT) as a between-subjects variable were performed for each effect of interest. In the event of significant interaction effects, subsequent more restricted ANOVA analyses were conducted in order to clarify the interaction with Bonferroni-corrected t-tests used to correct for family-wise error. To examine a-priori hypothesized differences, more restricted ANOVAs and t-tests were performed, even in the case of non-significant interaction effects. For all analyses, the threshold alpha was set to .05 and tests were adjusted for multiple comparisons and sphericity using the Greenhouse-Geisser epsilon method; however, uncorrected degrees of freedom are reported. Effect size estimates of repeated-measures ANOVA main effects and interactions were computed using partial eta squared (η^2_p). For t-tests, estimates of effect size were computed with Cohen’s *d*, using the pooled standard deviations. Effect sizes of .3 are considered small, .5 are considered medium, and .8 and above are considered large (Cohen, 1992).

Source Imaging Analyses

Post-hoc source localization was performed in order to explore a potential source for the EAP findings. Source localization was performed in BESA by employing the iterative 3D source imaging method CLARA (Classical LORETA Recursively Applied) during the EAP time window (200-300 ms). The CLARA approach iteratively localizes activity to the constrained regions identified from the previous solution. This technique allows for current density to be estimated and projected onto normalized MRI images of the brain. Source imaging analysis was performed on significant effects utilizing differences waves between conditions of interest.

4.4. Results

4.4.1. Behavioural Findings

Psychological Measures

The HBT group obtained higher scores on the BDI-II (t (28) = 5.55, $p < .001$, Cohen's *d* = 2.02) and the BSI Global Severity Index (t (28) = 5.01, $p < .001$, Cohen's *d* = 1.83) compared to the LBT group. No group differences emerged on the DSS (F (1, 22) = .772, p = .56). See Table 4.1 for group means on these psychological measures.

Subjective State Ratings

The overall ANOVA revealed a main effect of state ratings (F (6, 168) = 35.14, $p < .0001$, $\eta^2_p = .56$) and a state by condition interaction effect (F (6, 168) = 2.72, $p < .05$, $\eta^2_p = .09$). State-specific analyses revealed that the HBT group reported feeling more *Tired* than the LBT group (F (1, 28) = 5.85, $p < .05$, $\eta^2_p = .17$). Additionally, across groups the overt condition was associated with reduced *Relaxed* ratings compared to the covert condition (F (1, 28) = 9.67, $p < .01$, $\eta^2_p = .26$). All other state rating comparisons were non-significant between conditions and between groups ($p > .05$). See Table 4.2 for mean subjective ratings by mood state, group, and condition.

Accuracy

A main effect of emotion (F (4, 112) = 18.10, $p < .0001$, η^2_p= .39), a main effect of condition (F (1, 28) = 39.33, $p < .0001$, η^2_p= .58), and an interaction between emotion and condition (F (4, 112) = 11.53, $p < .0001$, η^2_p = .29) were observed. Overall, participants were more accurate in the Covert condition than the Overt condition, though performance in both conditions was excellent (88% or higher) overall. Group differences were non-significant (F (1, 28) = .16, p = .69, η^2_p= .00).

In the Overt condition, a main effect of emotion (F (4, 112) = 16.47, $p < .0001$, η^2_p = .37) was observed. Bonferroni-corrected t-tests revealed that participants identified Happy expressions more reliably than Angry (t (29) = 6.46, p = .000, Cohen's *d* = 1.39), Fearful (t (29) = 7.18, p = .000, Cohen's *d* = 1.36), Sad (t (29) = 6.76, p = .000, Cohen's *d* = 1.63), and Neutral (t (29) = 3.63, p = .001, Cohen's *d* = .91) expressions. Angry expressions were associated with lower mean accuracy relative to Fearful (t (29) = -3.26, p = .003, Cohen's *d* = -.57) and Neutral (t (29) = -3.38, p = .002, Cohen's *d* = -.84) expressions. Sad expressions were also associated with lower accuracy rates compared with Fearful (t (29) = -3.04, p = .005, Cohen's *d* = -.62) and Neutral (t (29) = -3.40, p = .002, Cohen's *d* = -.93) expressions. Group differences remained non-significant (F (1, 28) = .004, p = .95, η^2_p= .00), suggesting that accuracy in the Overt classification of facial expressions was similar across groups. See Figure 4.2 for mean percent accuracy in the Overt condition by emotions and group.

In the Covert condition, a group by emotion interaction effect (F (4, 112) = 3.05, $p < .05$, η^2_p= .10) emerged. Follow-up analysis within each group revealed a significant emotion effect within the HBT group (F (4, 56) = 2.59, $p < .05$, η^2_p= .16). Bonferroni-corrected t-tests revealed enhanced accuracy for colour classification associated with Fearful facial expressions relative to Neutral expressions (t (29) = 3.60, p = .003, Cohen's *d* = .67) in the HBT group. The LBT group revealed no significant differences in the accuracy of colour classification based on facial expressions (F (4, 56) = 1.97, p = .11, η^2_p= .12). See Figure 4.3 for mean percent accuracy in the Covert condition by group and emotions.

In summary, both groups showed similar accuracy rates in the overt condition, where Happy expressions were associated with the *highest* accuracy rates, and Angry and Sad expressions were associated with the *lowest* accuracy rates. A unique effect was observed in the HBT group where implicitly presented Fearful expressions were associated with *enhanced* accuracy relative to Neutral expressions, an effect not observed in the LBT group.

Reaction Time

A main effect of emotion (F (4, 112) = 54.28, p < .0001, η^2_p= .66), a main effect of condition (F (1, 28) = 73.77, p < .0001, η^2_p= .73), and an interaction between emotion and condition (F (4, 112) = 57.48, p < .0001, η^2_p= .67) was observed for mean reaction times. Overall, participants were faster in the Covert condition compared to the Overt condition. Group differences were non-significant (F (1, 28) = .04, p =.84, η^2_p= .00).

In the Overt condition, a main effect of emotion (F (4, 112) = 63.16, p < .0001, η^2_p = .69) was observed. Bonferroni-corrected t-tests showed that participants identified Happy expressions faster than Angry (t (29) = -10.84, p = .000, Cohen's *d* = -1.09), Fearful (t (29) = -12.74, p = .000, Cohen's *d* = -1.20), Sad (t (29) = -14.15, p = .000, Cohen's *d* = -1.92), and Neutral (t (29) = -6.23, p = .000, Cohen's *d* = -.85) expressions. Sad expressions were recognized slower than Angry (t (29) = 6.20, p = .000, Cohen's *d* =.80), Fearful (t (29) = 6.03, p = .000, Cohen's *d* =.73), and Neutral (t (29) = 7.27, p = .000, Cohen's *d* = 1.31) expressions. Fearful expressions were also associated with longer reaction times relative to Neutral (t (29) = 3.88, p = .001, Cohen's *d* = .57) expressions. Group differences remained non-significant (F (1, 28) = .137, p = .71, η^2_p = .00), suggesting that reaction time in the Overt labelling of facial expressions was similar across groups. See Figure 4.4 for mean reaction times in the Overt condition by emotions and group.

In the Covert condition, emotion did not significantly impact mean reaction time on the colour discrimination task (F (4, 112) = .79, p =.53, η^2_p = .03). Additionally, no differences were observed in mean reaction time between groups (F (1, 28) = .00, p=.98, η^2_p = .00). See Figure 4.5 for mean reaction time in the Covert condition by emotions and group.

In summary, both groups showed similar mean reaction times. In the Overt condition, Happy expressions were associated with the *fastest* reaction times, whereas Sad and Fearful expressions were associated with the *slowest* reaction times. No RT effects were observed in the Covert task.

4.4.2. Electrophysiological Findings

EAP Effect (200-300 ms)

An analysis of the EAP time window over the frontal scalp revealed a main effect of condition (F (1, 28) = 15.09, $p < .001$, $\eta^2_p = .35$) with more positive-going EAP amplitudes elicited in the Overt condition. A main effect of emotion (F (4, 112) = 4.07, $p < .05$, $\eta^2_p = .13$) and an interaction between condition, emotion and group (F (4, 112) = 2.57, $p < .05$, $\eta^2_p = .08$) were also found to be significant.

Within the Covert condition, a main effect of emotion (F (4, 112) = 3.07, $p < .05$, $\eta^2_p = .10$) and an interaction between emotion and group (F (4, 112) = 2.58, $p < .05$, $\eta^2_p = .08$) were observed. The HBT group showed a significant effect of emotions (F (4, 56) = 4.17, $p < .05$, $\eta^2_p = .23$). Bonferroni-corrected t-tests revealed that Angry expressions elicited more positive-going EAP modulations relative to Fearful expressions (t (14) = 4.00, p = .001, Cohen's *d* = .50). The difference between Angry and Neutral expressions (t (14) = 2.47, p = .027, Cohen's *d* = .29) did not survive correction for multiple comparisons. In contrast, no effect of emotion was observed among the LBT group (F (4, 56) = 1.48, p = .22, $\eta^2_p = .09$). See Figure 4.6 for mean EAP amplitudes within the Covert condition by emotions and group.

Group-specific analyses in the Overt condition revealed no significant effect of emotion in the HBT group (F (4, 56) = .72, p = .52, $\eta^2_p = .05$). In contrast, the LBT group showed a main effect of emotion (F (4, 56) = 3.02, $p < .05$, $\eta^2_p = .18$). Bonferroni-corrected t-tests revealed that Angry expressions elicited more positive-going EAP modulations relative to Fearful expressions (t (14) = 3.70, p = .002, Cohen's *d* = .16) and Sad expressions (t (14) = 4.89, p = .000, Cohen's *d* = .23). The difference between Angry and Neutral expressions (t (14) = 2.14, p = .05, Cohen's *d* = .24) and between Angry and Happy expressions (t (14) = 2.40, p = .031, Cohen's *d* = .26) did not survive

Bonferroni correction. See Figure 4.7 for mean EAP amplitudes within the Overt condition by emotions and group.

In summary, while the EAP showed overall enhanced mean amplitudes for Angry faces in both groups, this effect was differentially affected by condition as a function of group. In the HBT group, greater frontal responses were elicited by unattended, task-irrelevant Angry faces, while no such effect was present in the LBT group. In contrast, the LBT group showed greater frontal activity in response to explicitly attended Angry faces, while a similar frontal modulation was absent in the HBT group. See Figures (4.8, 4.9, 4.14 & 4.15) for waveforms for the EAP effect in the Covert and Overt conditions.

LPP Effect (300-600 ms)

An analysis of the LPP mean amplitudes revealed a main effect of condition (F (1, 28) = 9.28, $p < .05$, $\eta^2_p = .25$) with greater LPP amplitudes elicited in the Overt condition. An interaction between condition and emotions was also observed (F (4, 112) = 2.65, $p < .05$, $\eta^2_p = .09$).

Group-specific analyses revealed a main effect of condition (F (1, 14) = 7.29, $p < .05$, $\eta^2_p = .34$) and an interaction between condition and emotions (F (4, 56) = 2.94, $p < .05$, $\eta^2_p = .17$) in the LBT group only. Specifically, the LBT group revealed an effect for emotions in the overt condition (F (4, 56) = 2.83, $p < .05$, $\eta^2_p = .17$), but not the covert condition (F (4, 56) = .918, $p > .05$, $\eta^2_p = .06$). Bonferroni-corrected t-tests revealed greater LPP amplitudes for the explicit processing of Angry expressions relative to Sad expressions (t (14) = 3.40, p =.004, Cohen's *d* = .41), and for Fearful expressions relative to Sad expressions (t (14) = 3.43, p =.004, Cohen's *d* = .23). In contrast, the HBT group did not show any significant main effects ($p > .05$) or interaction effects between emotions and condition (F (4, 56) = .57, p = .69, $\eta^2_p = .04$). See Figure 4.10 for mean LPP amplitudes within the Overt condition and Figure 4.11 for mean LPP amplitudes within the Covert condition.

In summary, LPP mean amplitudes differentiated the HBT and LBT groups. While the LBT group showed enhanced LPPs for the overt condition, particularly for

Angry and Fearful expressions, the HBT group failed to show any modulations by condition or emotions.

EAP Source Imaging

Using the CLARA source localization technique, a main source for the HBT-specific EAP modulation for Angry relative to Fearful facial expressions in the Covert task was estimated in dorsal Anterior Cingulate Cortex (See Figure 4.8). A main source for the LBT-specific EAP modulation for Angry relative to Fearful facial expressions in the Overt task was estimated in ventral Prefrontal/Temporal pole (See Figure 4.9).

P150 Effect (130-170 ms)

Analysis of the P150 effect over the anterior scalp revealed a main effect of emotion (F (4, 112) = 9.17, $p < .0001$, η^2_p= .25). Bonferroni-corrected t-tests showed enhanced P150 amplitudes for Angry (t (29) = -4.71, p = .000, Cohen's *d* =-.33), Fearful (t (29) = -3.28, p = .003, Cohen's *d* =-.22), Happy (t (29) = -4.44, p = .000, Cohen's *d* = -.27) and Sad (t (29) = -3.41, p = .002, Cohen's *d* = -.22) expressions relative to Neutral expressions. No effect of condition was present (F (1, 28) = .82, p = .37, η^2_p= .03) and the interaction between group and emotions did not reach significance (F (4, 112) = 1.49, p =.22, η^2_p= .05).

Exploratory group-specific analyses revealed a main effect of emotion in the HBT group (F (4, 56) = 6.42, $p < .0001$, η^2_p= .32). Collapsed across conditions, Bonferroni-corrected t-tests revealed significantly larger P150 amplitudes elicited by Angry (t (14) = 3.52, p = .003, Cohen's *d* = .32) and Happy (t (14) = 3.73, p = .002, Cohen's *d* = .32) expressions relative to Neutral ones. The difference between Sad and Neutral expressions did not survive Bonferroni-correction (t (14) = 2.61, p = .021, Cohen's *d* = .21). Interestingly, Fearful expressions did not elicit significantly different P150 modulations relative to Neutral expressions (t (14) = 1.62, p = .12, Cohen's *d* = .15) in this group.

Analyses within the LBT group also showed an effect of emotions (F (4, 56) = 4.14, $p < .05$, η^2_p = .23). Collapsed across conditions, Bonferroni-corrected t-tests revealed significantly larger P150 amplitudes elicited by Angry (t (14) = 3.03, p = .009, Cohen's *d* = .33) *and* Fearful expressions (t (14) = 3.29, p = .005, Cohen's *d* = .32) relative to Neutral ones. P150 modulations to Sad and Neutral expressions were not significantly different (t (14) = 2.13, p = .051, Cohen's *d* = .19), whereas differences in P150 modulations between Happy and Neutral expressions (t (14) = 2.65, p = .019, Cohen's *d* = .22) did not survive Bonferroni-correction. See Figure 4.12 for mean P150 amplitudes by group and emotions.

In summary, early frontal P150 modulations to emotional expressions were observed whether the emotional faces were attended (overt task) or unattended (covert task). Although both groups showed an effect of emotion, exploratory analyses suggest that what appears to distinguish the two groups is the lack of P150 modulation to Fearful faces in the HBT group.

N170 Effect (130-170ms)

An exploratory analysis of the N170 effect over the posterior scalp revealed a main effect of emotion (F (4, 112) = 4.25, p < .05, η^2_p= .13). Collapsed across conditions, Bonferroni-corrected t-tests revealed that none of the emotional expressions elicited significantly different N170 modulations compared to Neutral expressions (p < .0125). Instead, the pattern showed greater amplitudes elicited by Happy expressions relative to Angry (t (23) = -3.19, p = .004, Cohen's *d* = -.18) and Sad (t (23) = -4.74, p = .000, Cohen's *d* = -.29) expressions. Differences between Happy expressions and Neutral expressions (t (23) = -2.30, p = .031, Cohen's *d* = -.18) and Fearful expressions (t (23) = -2.24, p = .035, Cohen's *d* = -.17) did not survive Bonferroni-correction. No interaction effect between group and emotion was observed (F (4, 112) = .443, p =.74, η^2_p= .02); however, follow-up group-specific analyses were performed as with the P150 analysis.

The HBT group did not show a significant effect of emotions (F (4, 56) = 1.64, p = .18, η^2_p= .10). In contrast, the LBT group showed an effect of emotions (F (4, 56) = 2.79, p = .035, η^2_p= .17) with Happy expressions eliciting greater N170 modulations relative Sad expressions (t (11) = -4.59, p = .001, Cohen's *d* = -.42). See Figure 4.13 for mean N170 amplitudes for each group.

In summary, unlike the P150 effect, exploratory analyses of the N170 did not show modulations to emotional versus neutral faces. Instead, enhanced modulations for Happy expressions were observed, particularly within the LBT group. This pattern of findings suggests that the anterior P150 is distinct from the posterior N170 effect in this study.

P1 Effect (80- 120 ms)

An exploratory analysis of the P1 effect over the posterior scalp revealed no significant main effects or interactions ($p > .05$). Group differences were non-significant ($F(1, 28) = .65$, $p = .43$, $\eta^2_p = .02$). No further analyses were performed for the P1 effect.

4.5. Discussion

The present study employed a modified eStroop paradigm to investigate group differences in the behavioural and electrophysiological correlates associated with the implicit and explicit processing of facial affect among a group with high BPD traits and a control group with low BPD traits. In the Overt condition, which involved affect labelling, emotions were the *intended focus of attention* and as such the processing of facial expressions was biased in a top-down manner. In the Covert condition, which involved color discrimination, emotions were *not the intended focus of attention* and as such the processing of facial expressions was biased towards a bottom-up manner. The aim of the study was to examine group differences within early and late ERP components associated with the implicit and explicit processing of prototypical facial expressions in order to shed light on the mechanisms which may be aberrant in the processing of affective cues among individuals with BPD.

In light of the current knowledge regarding BPD and the social and emotional difficulties experienced by individuals who suffer from this severe psychological disorder, it was anticipated that the HBT group would show enhanced emotional reactivity to the emotional faces compared to the control group. In particular, it was hypothesized that individuals in this group would show 1) enhanced early salience markers (frontal positivities) indexing greater automatic capture and processing of emotion cues, and 2) enhanced later elaborative components (LPPs) indicating enhanced processing and difficulty in disengaging attention from expressions of facial affect. These effects were expected to be 3) relatively more pronounced in the covert condition, reflecting stronger bottom-up salience effects, and 4) relatively more pronounced for negative emotions, in particular angry expressions, consistent with heightened sensitivity towards social cues of personal threat in BPD.

Behavioural Effects

The subjective experiences of the participants throughout the experimental tasks, as measured by mood and psychological state ratings, suggested comparable mood states across groups save for the HBT group reporting feeling relatively more *Tired* than the LBT group. This difference was evident despite the lack of group differences in reported sleep. While such an effect was not predicted, one possible explanation is that HBT individuals expended relatively more cognitive resources in processing the emotional stimuli than did the control group, which may in turn have resulted in increased fatigue. Such an effect may also reflect the tendency for BPD to be associated with chronic fatigue (Selby, 2013). Similar state ratings were reported across tasks with the exception of reduced *Relaxed* ratings reported in the Overt task, which may be a reflection of the relatively greater cognitive demands required for affect labelling. The lack of additional differences in mood ratings between groups or conditions may result from the lack of sensitivity of subjective ratings. This may be particularly the case for a mixed trial study design where the effects of any particular mood state may be diminished.

Behavioural analysis of responses showed that participants identified happy faces faster and more accurately than other facial expressions. This is consistent with data showing that happy expressions are generally identified more accurately, earlier and faster than other facial expressions (Calvo & Lundqvist, 2008). This same body of research suggests that fearful faces are generally the least accurate, the latest, and the slowest to be identified. However, the current study found that sad faces were associated with the slowest reaction times, while angry and sad facial expressions were the least accurately identified facial expressions, though accuracy rates were high across emotions and conditions.

A surprising effect for accuracy was observed in the covert task. HBT participants demonstrated *enhanced* accuracy on the color discrimination task when the colors were superimposed onto fearful faces. Such a finding suggests that rather than demonstrating an interference effect, fearful facial expressions conferred an advantage in terms of cognitive processing among the HBT group when these faces were not the focus of attention. A similar benefit in accuracy (but not speed) associated with the implicit processing of fearful faces has previously been described in a healthy control group (Gonzalez-Garrido et al., 2009). Such an effect is believed to stem from the emotional content allocating greater neural processing resources in a more widespread network of participating regions, thus resulting in enhanced correct responses. Although unexpected, this finding suggests that HBT individuals process implicit affective cues differently from LBT individuals in this study.

No other group differences in reaction time or accuracy rates were observed, indicating that both groups were equally adept at identifying prototypical expressions of facial affect in the current experiment. Importantly, the lack of differences here does not appear to be an issue of power. The literature has been mixed with regard to the performance of BPD individuals in affect discrimination. Although explicit emotion recognition deficits have been described in some studies (e.g., Levine et al., Unoka et al., 2011), such deficits have not been consistently described. More often, studies have shown no group differences or have described enhanced sensitivity among BPD individuals, though the latter effects are generally observed using more sensitive paradigms and as such are more consistent with negative biases (e.g., Lynch et al., 2006;.Wagner & Linehan, 1999; Domes et al., 2008; Dyck et al., 2009). Thus, the lack of behavioural differences in the current study may simply reflect the forced-choice emotion discrimination paradigm, which is not well-suited for identifying biases in emotion recognition.

While eStroop tasks are intended to measure interference effects, reaction time differences were not anticipated given the mixed trial design of the current study.

Previous research suggests that reaction time effects in eStroop tasks are generally more pronounced in blocked design studies compared with mixed trial ones (Phaf & Kan, 2007; Taake et al., 2009). Moreover, a button-press variant of the Stroop task is said to produce less behavioural interference compared to a vocal response variant (Whalen et al., 1998). Importantly, the lack of behavioural differences does not preclude the presence of significant neural differences in eStroop paradigms (e.g., Whalen et al., 1998; Taake et al., 2009), which is the case here.

Early Frontal Effects

EAP Effect (200-300 ms)

Consistent with early salience markers (Hypothesis 1), early frontal positivity modulations to emotional facial expressions, maximal over right frontal scalp were observed between 200 and 300 ms (Early Anterior Positivity: EAP). Interestingly, the EAP was differentially modulated by facial expressions both within task (overt vs covert) and within each group, resulting in a significant three-way interaction. In the HBT group, angry facial expressions modulated the EAP relative to fearful expressions only within the *covert* condition, while no such differentiation was observed within the *overt* task. Among the LBT group, EAP modulations showed the opposite pattern of modulations. No significant modulations were observed for the *covert* condition; instead, they emerged when attention was directed *towards* the faces in the overt task. The latter result replicated previous findings in our laboratory using a similar task in an independent and unselected sample of healthy volunteers (Barrie et al., 2009). Thus, while the EAP appears to be differentially sensitive to facial expressions of affect during the explicit processing of emotions among healthy individuals, it is under conditions of implicit affect processing that such modulations appear among the HBT group. This implies that the implicit processing of facial expressions results in enhanced processing of angry expressions in the HBT group, an effect which is consistent with an attentional bias towards social threat cues. This effect also suggests abnormal bottom-up responding in the HBT group, when facial expressions were *not* the focus of attention. This finding is consistent with a previous study in high anxiety individuals (Taake et al., 2009) who showed positive enhancement for implicitly processed threat words during the same time range over the anterior scalp, suggesting that the EAP may reflect disorder-specific biases. These findings are also consistent with the prediction of greater salience effects for the covert processing of affective cues in the HBT group (Hypothesis 3), and with the prediction of stronger ERP effects for facial expressions conveying direct social threat cues in the HBT group (Hypothesis 4).

To better understand the EAP findings, exploratory source analyses of differences observed on the scalp were estimated using the CLARA source localization technique. For the anger-specific EAP effect in the HBT group, the analysis revealed a main source within the dorsal Anterior Cingulate Cortex (dACC). This region is strongly interconnected with prefrontal and parietal brain regions and has been implicated in a number of functions including the modulation of attention, complex motor control, error detection/conflict monitoring, integration of emotional and cognitive information, pain, and episodic memory retrieval (Bush et al., 2000; Leech & Sharp, 2013; Nielsen et al., 2005; Haas et al., 2006). In an fMRI experiment, Minzenberg and colleagues (2007) reported dissociation in the processing of angry and fearful facial expressions among BPD individuals when facial expressions were *unattended,* which is akin to the current covert condition. For fearful faces, they observed *increased* activations within the amygdala and *deactivation* within the ACC. In contrast, angry faces were associated with *greater* activation in the ACC with a concomitant *decrease* in amygdala activations. The current pattern of findings for angry versus fearful faces in the HBT group suggests a similar dissociation, though the electrical sources in subcortical structures like the amygdala do not produce electrical fields that are detectable on the scalp by standard EEG analysis. As such, subcortical findings which would presumably underlie the processing of fearful expressions cannot be replicated here. Nevertheless, there is a precedent for dissociable neural activations associated with the implicit processing of angry and fearful facial expressions among BPD individuals, though this effect has not been described using EEG techniques until now.

The EAP effect within the LBT group suggests enhanced modulations based on the emotional salience of the facial expressions, particularly when attention was directed *towards* the faces. The observed EAP modulations within the LBT group were limited to the overt condition, which is consistent with research findings showing that early anterior effects are generally sensitive to attentional deployment (e.g., Eimer et al., 2003; Holmes et al., 2003; Barrie et al., 2009). Interestingly, among healthy adults, Kesler and colleagues (2001) identified separate neural substrates involved in the overt processing of different facial expressions, which emphasized neocortical activations rather than limbic activations. Exploratory source analysis of the relative enhancement for explicitly processed angry versus fearful facial expressions in the control group was estimated within the ventral Prefrontal/Temporal pole region. The temporal pole is considered to be a part of the extended limbic system and has been found to play a role in the recognition of faces, as well as in social and emotional processing (see Olson et al., 2007 for review). The ventral prefrontal cortex generally plays a role in decision-making and learning and is considered important for maintaining appropriate emotional and social behavior (Hornak et al., 1996). Enhanced processing within prefrontal regions (e.g., OFC) is consistent with neuroimaging research which shows that the explicit analysis of facial expressions is associated with greater activations within these regulatory regions and decreased activity within subcortical regions (e.g., Hariri et al., 2000; 2003; Ochsner et al., 2009). Thus, the findings within the LBT group are consistent with the fronto-limbic model of emotion processing where the cognitive analysis of emotion cues engages pre-frontal regions, presumably associated with implicit down-regulation mechanisms. In contrast, the HBT group showed dampened modulations of emotional expressions when the processing of emotions was done overtly. A lack of emotion-specific modulations in this condition suggests abnormal implicit top-down cognitive control mechanisms among HBT individuals.

P150 Effect (130-170 ms)

While the most prominent differentiation between groups was observed during the EAP window, an earlier fronto-central positivity preceding the EAP showed findings in the same direction, although no condition effects were observed. This effect, which peaked at 150 ms, revealed enhanced modulations for emotional facial expressions relative to neutral ones, which showed distinct modulations from the posterior N170 effect. This suggests that the P150 acted as a “general detector” of emotion salience, which is consistent with previously described emotion-specific effects over the frontal scalp during this time range (Eimer & Holmes, 2002; 2003; 2007). Interestingly, exploratory within-group analyses revealed different patterns of modulations to facial expressions of affect. For control participants, the P150 showed the greatest ERP enhancements for *angry* and *fearful* faces relative to neutral ones, regardless of condition, suggesting sensitivity towards negative high salience cues. In contrast, for HBT participants the P150 showed the largest enhancements for *angry* facial expressions, followed by happy expressions. Particularly intriguing was the lack of modulation for *fearful* facial expressions relative to neutral expressions in this group, an effect which was present in the LBT group. Similar to the later EAP effect, this earlier frontal positivity suggests sensitivity to socially relevant cues in the HBT group, though no differentiation between conditions was observed during this earlier time window. Given the presence of differences occurring as early as 150 ms after stimulus onset, the findings suggest stronger bottom-up responses involving a potential automatic orienting mechanism towards angry faces. This finding provides preliminary evidence for *abnormal* facial affect processing in the HBT group occurring during early processing stages, suggesting a potential pre-attentive bias or hyper-vigilance towards socially relevant cues. However, given the exploratory nature of the P150 analyses, future studies are needed to confirm this finding.

LPP Effect (300-600 ms)

Group differences in the modulation of the late positive potential (LPP) were expected, with enhanced later elaborative components observed in the HBT group (Hypothesis 2). However, contrary to our predictions, the pattern of differences observed was somewhat surprising. The modulations observed in the control group showed enhanced LPP amplitudes associated with the identification of facial expressions, particularly for angry and fearful faces, and a prominent effect for the task manipulation, with enhanced LPP amplitudes associated with the overt processing of facial expressions. In contrast, the HBT group showed similar LPP amplitudes across conditions and emotions, indicative of an undifferentiated response, providing evidence for altered processing in the HBT group at this later stage of processing.

The LPP modulations in the LBT group are consistent with previous research which shows that the LPP is strongly modulated by the emotional intensity of a stimulus with larger and more positive-going LPPs elicited by positively and negatively valenced stimuli relative to neutral stimuli in healthy individuals (Cuthbert et al., 2000; Hajcak et al., 2010). In particular, motivationally relevant and high arousal stimuli typically elicit larger LPPs (e.g., Hajcak & Olvet, 2008; Duval et al., 2013). In this study, angry and fearful faces, which are both negative high arousal facial expressions, produced enhanced LPPs in the control group, a finding which has previously been reported among healthy participants (e.g., Foti et al., 2010). However, these emotion-specific modulations were only observed in the explicit processing of facial expressions, similar to the EAP findings, suggesting task-dependant effects. Moreover, the control group showed a prominent effect for task manipulation, with larger LPPs associated with the overt task. Such a finding may in part reflect relatively greater processing associated with affect labelling which requires the analysis of facial features before a decision can be made regarding the nature of the expressions portrayed. However, the findings are also in line with previous work that has found the LPP to be highly sensitive to spatial attentional deployment and task-relevance (e.g., Eimer et al., 2003; Holmes et al., 2003; Thomas et al., 2007). As such, it is not surprising that the overt condition, where facial expressions are task-relevant and involve greater cognitive processing, was associated with enhanced LPP amplitudes. Together, the LPP findings in the control group show LPP modulations with enhanced later elaborative processing for task-relevant high salience cues.

In contrast, the HBT group showed a lack of modulation for task or emotions within the LPP component. Based on previous research which has shown enhanced LPPs to unpleasant images in a BPD group (Marissen et al., 2010) and on theories suggesting that BPD individuals show enhanced processing and difficulty in disengaging attention from emotional content (Linehan, 1993), enhanced LPP modulations were expected in the HBT group. However, contrary to this prediction, such a finding was not evident in this study. Rather than showing enhanced LPP modulations, the current study showed a lack of differentiation to emotional stimuli associated with the explicit processing of facial affect. The lack of modulations to emotions within the overt condition is similar to the EAP effect which also showed a lack of differentiation to emotions when attention was directed *towards* the facial expressions. This suggests that the overt analysis of emotions and the underlying mechanisms involved are distinctly different from those involved in the implicit processing of facial affect within the HBT group. While the current study failed to replicate previously reported enhanced LPP modulations among BPD individuals, differences in the task design and stimuli used may explain the apparent discrepancy in findings. Marissen and colleagues (2010) used unpleasant images, which are generally considered to be more arousing than facial expressions. Additionally, the images were presented in a blocked format, which may have impacted associated ERP components. To date, no known studies have investigated the electrophysiological correlates associated with the processing of facial affect among individuals with borderline traits. As such, there is no direct comparison for the findings observed here.

An important difference between the conditions used in this experiment relates to the extent to which each task involves conscious processing of the facial expressions. In the covert task, processing was biased towards bottom-up affective responding with relatively small cognitive demands required to complete the task. In contrast, the overt task was biased towards top-down processing with a heavier cognitive load involved. One plausible interpretation for the LPP findings is that the HBT group experienced cognitive overload when required to attend to all facial expressions in this mixed trial study in order to complete the affect labelling task. By requiring direct attention towards facial expressions of affect, this may have exhausted their potentially limited cognitive resources and resulted in a lack of modulation to motivationally relevant facial expressions. In line with this view, in a study among healthy controls (Kellerman et al., 2012), *increased* cognitive demands during the *explicit* processing of emotional stimuli was associated with *reduced* neural responses associated with emotion processing (amygdala and OFC) and stronger activation in a widespread fronto-parietal network, thus supporting the notion that cognitive demands can modulate emotion-specific responses. The finding that the HBT group reported feeling more tired than the control group provides some support for this interpretation. While the LPP findings were not in the expected direction, they do provide evidence for altered ERPs to facial expressions at this later stage of processing consisting of undifferentiated responses, which may be subsequent to cognitive overload.

P1 Effect (80-120 ms)

Exploratory analysis of the visual P1 effect revealed no modulations for stimuli type or group membership in this experiment. P1 amplitude enhancements have previously been described for emotional stimuli relative to neutral stimuli (e.g., Li et al., 2007). However, these were generally described for blocks of stimuli of greater salience, suggesting that the enhanced sensory gain of perceptual processing requires advance knowledge of which blocks contain emotional stimuli, or where in space the emotion stimulus is going to be (e.g., Woldorff et al., 2002; see also P1 findings in current Study 2). The emotional and neutral stimuli were randomly intermixed in the current study; hence, it is not surprising that modulations in this early sensory gain marker were not captured here.

Summary and Implications

Early Frontal Effects Implications

The anticipated dissociation of EAP modulations between groups was confirmed. As predicted, greater early salience effects were observed in the HBT group relative to the LBT group (Hypothesis 1), with more pronounced effects observed during the covert processing of affective cues (Hypothesis 3). Thus, the EAP effect suggests that HBT individuals show greater salience effects when their attention is directed *away* from the explicit analysis of facial expressions. These findings suggest stronger bottom-up responses involving a potential automatic orienting mechanism, in particular to angry facial expressions, which is consistent with an attentional bias towards social threat cues. Although the P150 findings are preliminary at this time, the findings during this earlier time window show similar effects as the EAP, providing additional support for the early frontal modulations observed. In particular, sensitivity to threat cues was observed for the P150 across conditions, which raise the possibility for a pre-attentive bias or hyper-vigilance towards socially relevant cues, though replication of this finding is needed. Thus, it is proposed that HBT individuals exhibit abnormally *increased* bottom-up processing of social threat stimuli for implicit emotional presentations, which may occur pre-attentively. These findings are consistent with previously described attentional biases among BPD individuals to emotion words which are negative and/or represent BPD-specific concerns (e.g., Arntz et al., 2000; Sieswerda). They are also consistent with previous behavioural studies showing enhanced sensitivity to angry facial expressions under conditions of ambiguous visual cues (e.g., Domes et al., 2008).

While the covert effects were predicted and are consistent with the literature, the findings in the overt task were somewhat surprising since no group differences in the explicit processing of emotion cues were predicted. A failure of top-down emotional control in HBT individuals would presumably result in EAP salience effects persisting across both implicit and explicit processing of affective cues. However, since the overt processing of facial expressions was associated with a lack of EAP modulations, a different interpretation of the findings is required. A recent fMRI study (Dima et al., 2011), exploring *overt* face recognition in healthy participants reported emotion-specific effects (particularly for angry faces) in the right ventral prefrontal cortex (vPFC). They also conducted a functional connectivity analysis and determined that the vPFC modulation to attended angry faces was explained by similar changes in inferior occipital cortex without the mediation of the amygdala. They implicate a direct feed-forward cortico-cortical pathway from the visual system to the frontal cortex in the top-down attentional control of facial expressions without the mediation of the amygdala. This is in contrast to the reversed connection between the prefrontal cortex and amygdala which has previously been suggested by some fMRI studies comparing explicit and implicit emotional processing (e.g., Hariri et al., 2000; 2003). These findings may be relevant to the present study, since they suggest a different mechanism for interpreting the lack of an observed emotion response to attended angry faces in HBT individuals. It may be that blunted frontal responses here could reflect reduced top-down attentional control from other cortical areas rather than be the result of changes in functional cortico-subcortical connectivity. In the current study, it is proposed that HBT individuals, unlike control participants, appear to show an abnormal *decrease* of top-down cortico-cortical control resulting in dampened activation of right prefrontal cortex during the explicit processing of emotions. This latter finding is consistent with a recent study (Doll et al., 2013) of resting state fMRI networks in BPD patients and healthy individuals, suggesting an unbalance of activation of a limbic and paralimbic network of affective regions over a neocortical network of cognitive areas, which may help explain emotion modulation difficulties in BPD.

Social Threat Bias

In light of the enhanced processing associated with angry faces but not fearful ones, a social relevance dimension is suggested, where more personally relevant stimuli elicit enhanced ERPs. Angry faces have been described as signalling more direct and immediate threat by the aggressor and are considered more relevant to social interactions (Ohman, 1986). In contrast, fearful faces signal the presence of indirect threat or danger, for which the source or identity is undetermined. Furthermore, unlike fearful faces, angry faces provide negative social feedback signals, communicating disapproval, rejection or even punishment. Accordingly, facial expressions with potentially greater interpersonal impact, in particular angry expressions, may be automatically prioritized in HBT individuals as measured by enhanced modulations for the EAP, and possibly starting as early as 150 ms post-stimulus onset. In contrast, facial expressions with less social relevance or impact, including neutral and fearful facial expressions, receive relatively less attention. Interestingly, BPD individuals have previously been found to show a bias towards perceiving angry faces, but not fearful ones when the emotional cues were ambiguous (Domes et al., 2008). The authors proposed that such a bias may relate to an attributional style of anticipatory rejection in social situations.

Individuals with BPD are typically characterized by fears of abandonment and they exhibit instability in their close relationships (American Psychiatric Association, 1994). They tend to attribute untrustworthiness to neutral faces, a tendency which appears to be mediated by rejection sensitivity (Miano et al., 2013). Rejection sensitivity refers to a disposition to anxiously expect, readily perceive, and overreact to social rejection, a disposition which is often observed among BPD individuals (Downey & Feldman, 1996). This sensitivity presumably evolves as a result of repeated experiences of rejection, exclusion, and neglect during development and results in anxious expectations of rejection and hypervigilance to rejection cues (Downey & Feldman, 1996). Hypervigilance to angry faces may reflect this sensitivity to rejection since these facial expressions typically convey direct threat including negative social feedback such as disapproval and rejection. In light of the social interaction difficulties frequently observed in BPD, differential neural responses to facial expressions occurring early in the processing stream are not unexpected and may help explain the difficulties that BPD individuals experience in interpersonal relationships.

As discussed in Chapter 3, while delineating the precise emotion-related difficulties in BPD has remained elusive, the current consensus in the literature is that BPD individuals exhibit altered emotion processing and regulation abilities. Additionally, a number of studies have implicated dysfunction within the fronto-limbic system with hyper-reactivity observed within subcortical structures, particularly the amygdala, and reduced activation within frontal brain regions implicated in regulatory processes, particularly the ACC (Schmahl & Bremner, 2006; Ruocco et al., 2013; Krause-Utz et al., 2014). Bertsch and colleagues (2013) found that BPD individuals exhibited hypersensitivity to social threat in early reflexive stages of information processing as measured by amygdala activations and faster initial fixation changes to the eyes of angry faces compared to normal controls. Interestingly, they were able to normalize this abnormal response via the administration of oxytocin, a neuropeptide involved in social behaviour. Oxytocin has been known to reduce anxiety and stress in social situations (Heinrichs et al., 2003), enhance the recognition of facial expressions (Domes et al., 2007), and shift attention from negative to positive information in healthy individuals (Domes et al., 2012).

Summary and Study Contributions

Early neural differences observed between groups provides evidence of altered electrophysiological responses to facial expressions appearing over the frontal scalp. As previously noted, faces provide essential information for successful communication and interpersonal relationships. Accurate appraisal of facial expressions is vital; however, the extent that different facial expressions are processed and prioritized is also important and can help shed light on the social difficulties experienced in those with BPD. The findings in this study highlight group differences in the processing of facial expressions over the anterior scalp. The more robust EAP effect (200-300 ms) demonstrates that prioritized processing of angry facial expressions occurs primarily when these are not the focus of attention. This suggests that these expressions capture attention automatically in the HBT group, whereas directed attention is required among the control group to observe a similar enhancement of the EAP for angry expressions. The preliminary data obtained for the earlier P150 effect (130-170 ms), shows preferential responding among HBT individuals to facial expressions of social threat with a distinct lack of attention allocated towards fearful expressions, a finding which should be confirmed in future studies. The later LPP effect (300-600 ms) provides initial evidence for differences in the elaborative processes associated with the explicit analysis of facial expressions, suggesting a possible exhaustion of cognitive resources in the HBT group. Together, the current findings suggest that BPD individuals show more sensitivity to facial expressions at earlier stages of information processing, showing hypervigilance for expressions of social threat when these are covertly presented.

The current study is important as it sheds light on how individuals with BPD traits process emotional faces at an electrophysiological level. While a growing number of studies are taking advantage of neuroimaging techniques such as fMRI, the use of EEG, particularly in terms of delineating correlates associated with emotion processing in BPD is currently very scarce. This technique offers exquisite time resolution which can be informative with regard to the underlying processes associated with emotion dysregulation, particularly in terms of the processes occurring early in the processing stream. The use of ERP paradigms to measure neural activity during emotion processing has become a major approach in cognitive affective neuroscience, since this method captures the exact time course of the emotional information-processing cascade from early to later processing stages with a millisecond resolution (Luck et al., 2005). As such, this technique allows for the analysis of processes occurring quickly and very early on, as in the case of facial affect processing. The findings in the current study also support the use of a non-clinical sample of individuals with high BPD traits to help elucidate the processes linked to BPD-type behaviours. Moreover, detection of differences in a sub-clinical population lends support to the dimensional concept for personality disorders.

Limitations and Future Directions

The current study has a number of limitations. First, the selected sample represents a sub-clinical sample of BPD and the findings may not generalize to more severe forms of the disorder. As such, replication within a clinical population would be helpful. Nevertheless, the PAI-BOR has excellent psychometric properties and is highly predictive of BPD diagnoses (Jacobo et al., 2007), lending validity to this method of identifying individuals with BPD traits. Moreover, the use of a sub-clinical population with high levels of BPD personality traits to investigate BPD is not uncommon and has many advantages, particularly in light of the low prevalence of BPD in the general population (Torgersen et al., 2001).

Second, the study was limited to females. Not only have gender effects in emotion processing been found among healthy individuals (Hall & Matsumoto, 2004), a recent study (Snowden et al., 2013) described gender differences in the processing of emotional expressions among a high BPD trait group. Specifically, the findings showed a heightened level of performance in the processing of emotions which was specific to females. Thus, in order to rule-out possible effects of gender on facial affect recognition, the current experiment only included females. Future studies may wish to explore the electrophysiological correlates associated with implicit and explicit emotion processing among males and females in order to explore possible gender effects.

While a larger sample size (e.g., 20 participants per group) would have been preferable; the current findings with 15 participants are within the acceptable range for EEG studies. In ERP research, signal-to-noise is affected by factors such as number of trials in ERP averages, careful removal of artifacts, and number of sensors. Of note, highly significant and robust effects have been published in the ERP literature with sample sizes between 12 and15 participants (e.g., Pliszka et al., 2000; Holmes & Pizzagalli, 2010; Taake et al., 2009). Thus, while the sample size is relatively small, it remains typical for EEG experiments.

The experimental design allowed for the implicit and explicit processing of emotions while utilizing the same stimuli and the same number of responses. Such a design allows for the analysis of cognitive factors without the confound of changing stimuli, which offers strength to the experimental design used. However, the two tasks were not exactly matched for task difficulty; colour discrimination was easier than facial affect labelling. While task difficulty may have impacted differences between conditions, this would not explain group or emotion-specific differences within each condition. Where appropriate, this caveat is discussed as a possible interpretation for condition-specific findings. For example, faster and more accurate responses associated with the covert condition likely index differences in task difficulty, though both conditions were associated with very high accuracy.

It is important to consider that although individuals in the HBT group were selected based on self-reported BPD traits, those in the HBT group also reported greater symptoms of general psychopathology and depression. Thus, even though the BPD sample selected was sub-clinical, the HBT group showed signs towards potential comorbidity with depression and generally elevated levels of psychopathology. This resulted in a less “pure” sample of borderline traits than expected. If one considers that the group sampled represents a sub-clinical population of BPD individuals which may go on to be diagnosed with BPD, a disorder which is known to have a high comorbidity rate with other disorders including major depressive disorder and post-traumatic stress disorder (Zimmerman & Mattia, 1999; Skodol et al., 1999), the concurrence of self-reported difficulties across a number of psychological domains is not entirely surprising. Attempts were made to examine depression and general psychopathology as potential covariates. However, given the high overlap between borderline traits and other psychological symptoms, these analyses did not produce reliable results. Importantly, parallel studies among individuals with high and low symptoms of depression revealed similar EAP effects which were limited to concern-specific *sad* faces (Jaspers-Fayer et al., 2013). Given the lack of modulation to sad faces in the present study, the ERP results obtained do not appear to be driven by depression symptoms. Nevertheless, future studies may wish to utilize a group of individuals who exhibit high depression symptoms but low BPD traits as a comparison within the same study in order to help bolster the current findings and address the issue of specificity of these effects.

4.6. Conclusion

In conclusion, this study aimed to explore the behavioural and electrophysiological responses associated with explicit and implicit processing of facial expressions in order to bias processing in a top-down versus bottom-up manner among a group of females selected for high and low levels of BPD traits. The current study provided evidence of altered electrophysiological responses in the HBT group, primarily occurring during an early anterior time window, which supports the notion of hypervigilance to social threat among HBT individuals. The findings in the current study offer evidence for altered processing within early, possibly pre-attentive stages of information processing over the anterior scalp. The later elaborative ERP data showed a lack of modulation to emotions in the HBT group suggesting potential cognitive overload.

4.7. Tables Study 1

Table 4.1. Participant Characteristics and Mean Scores on Psychological Measures

Measures	LBT Group	HBT Group	P-value
Age (years)	20.47 (1.21)	19.60 (3.94)	.420
Education (years)	13.67 (1.66)	12.93 (.68)	.125
Current Sleep (hours)	7.03 (1.41)	7.53 (1.14)	.294
Typical Sleep (hours)	7.40 (.66)	7.36 (.95)	.912
PAI - BOR	17.73 (4.11)	42.73 (8.22)	.000*
DSS	43.67 (27.13)	49.40 (26.32)	.562
BDI-II	7.33 (3.94)	22.53 (9.86)	.000*
BSI	.62 (.38)	1.54 (.60)	.000*

Note: PAI-BOR = Personality Assessment Inventory – Borderline Scale; DSS = Dissociation Tension Scale; BDI-II = Beck Depression Inventory-2; BSI = Brief Symptom Inventory; Values represent means (standard deviation); p-values correspond to level of significance for group differences on each scale; *significant differences (p < .05).

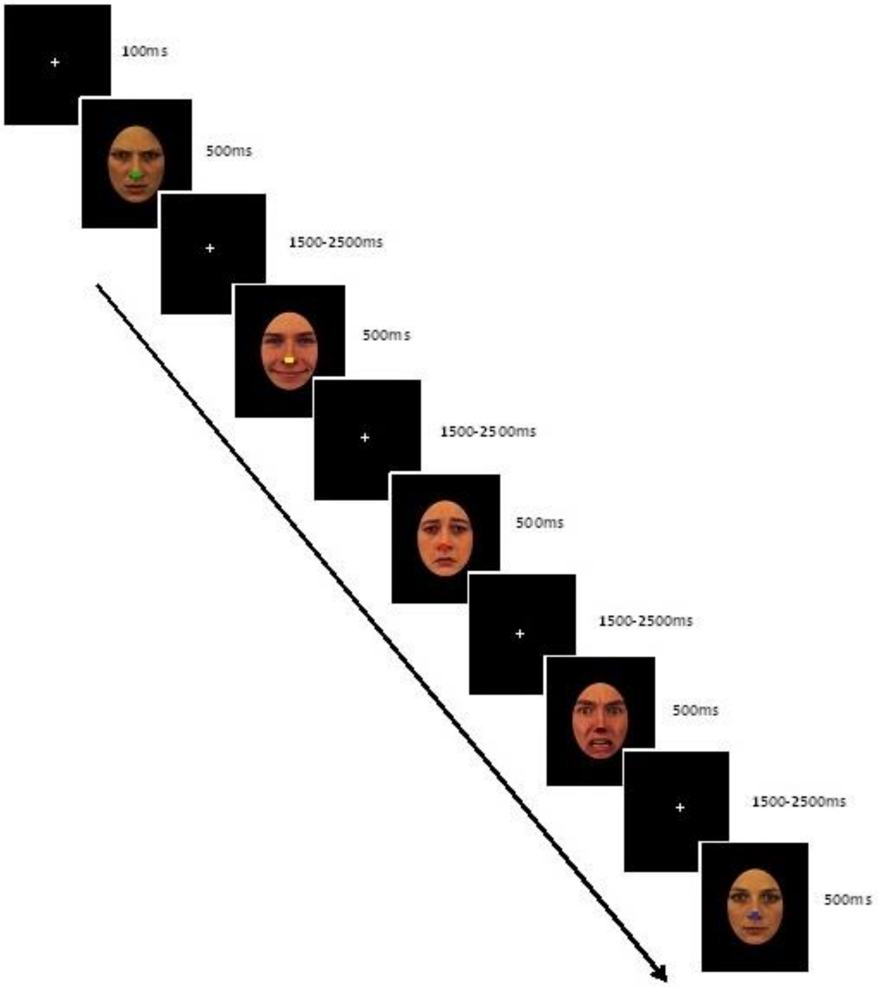
Table 4.2. Mean subjective ratings by mood state, group, and condition

	LBT Group		HBT Group	
Mood states	**Covert**	**Overt**	**Covert**	**Overt**
Angry	1.23 (.43)	1.27 (.57)	1.31 (.38)	1.35 (.36)
Anxious	1.81 (.62)	1.92 (.64)	2.10 (.78)	2.42 (.66)
Energetic	1.85 (.69)	1.77 (.60)	1.75 (.72)	1.83 (.44)
Happy	2.44 (.69)	2.42 (.73)	2.60 (.55)	2.54 (.84)
Relaxed	2.81 (.71)	2.75 (.77)	3.77 (.73)	2.40 (.52)
Sad	1.38 (.43)	1.58 (.58)	1.92 (.62)	1.79 (.41)
Tired	2.75 (.67)	2.63 (.73)	3.46 (.95)	3.31 (.77)

Significant differences (p < .05): Tired: HBT < LBT; Relaxed: Overt < Covert

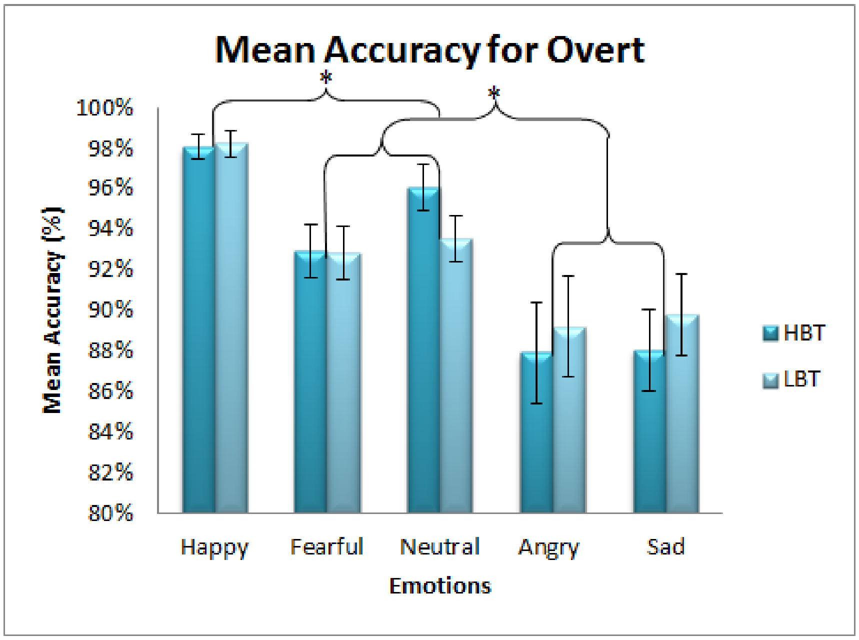
4.8. Figures Study 1

Figure 4-1. Illustration of the time course of stimulus presentation



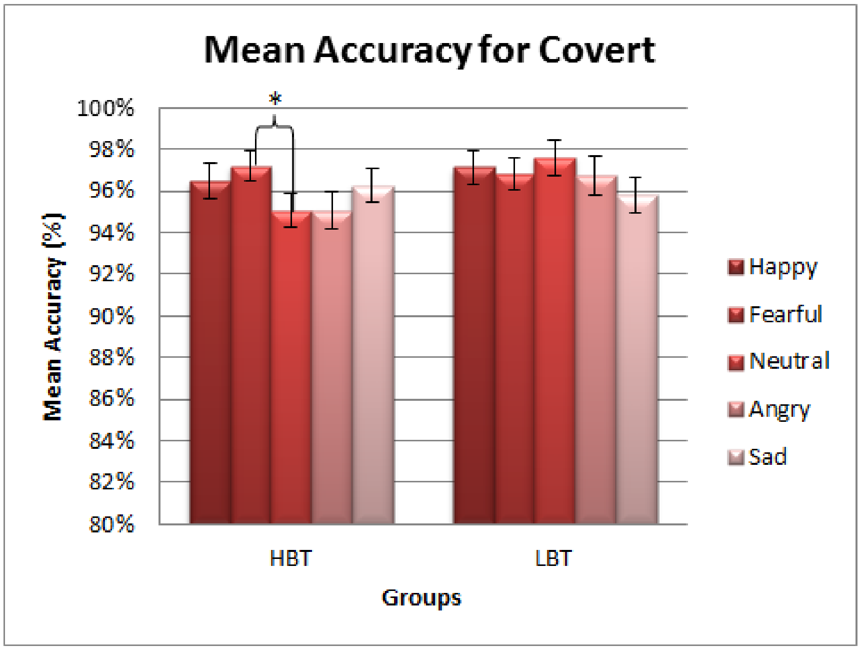
The time-course included a central fixation marker “+” (100 ms), visual stimulus (facial expression with coloured square on nose: 500 ms), and a jittered interstimulus interval (1400-2400 ms) during which time participants indicated their response (affect labelling for Overt condition; color discrimination for Covert condition).

Figure 4-2. **Mean percent accuracy in the overt condition by emotions and group**



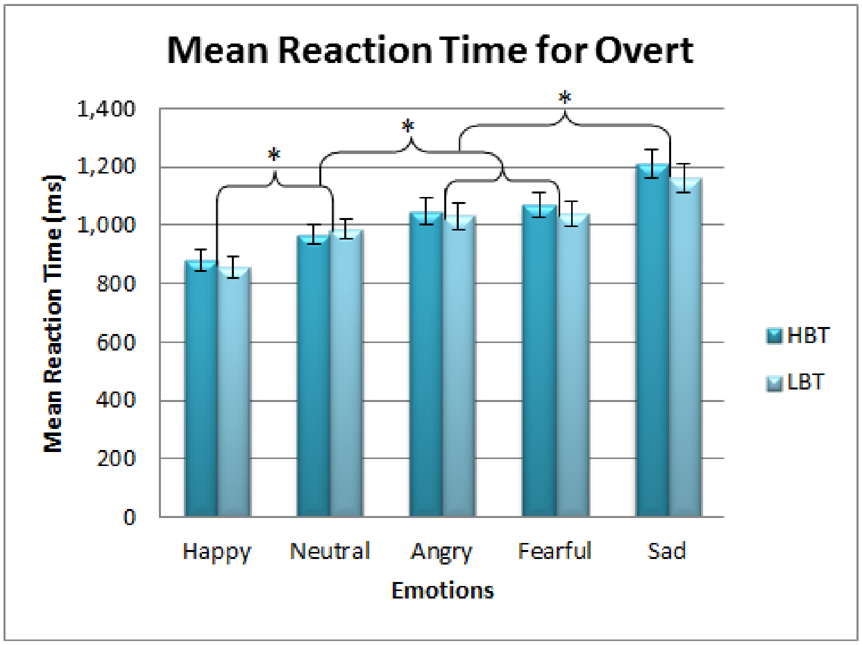
*Significant differences (p < .005) Happy > Fearful and Neutral > Angry and Sad

Figure 4-3. **Mean percent accuracy in the covert condition by group and emotions**



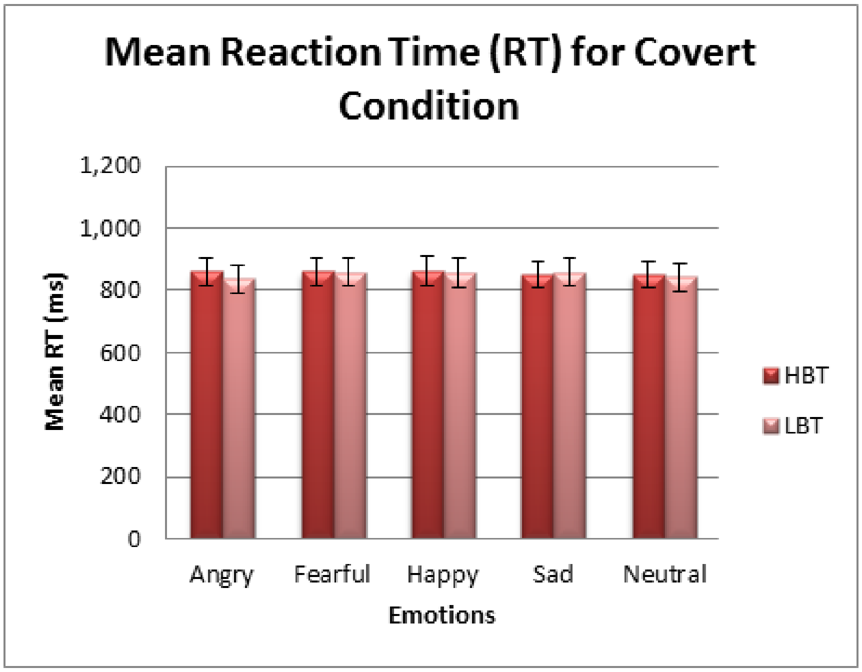
*Significant differences (p < .005): In HBT group: Fearful > Neutral

Figure 4-4. **Mean reaction time in the overt condition by emotions and group**



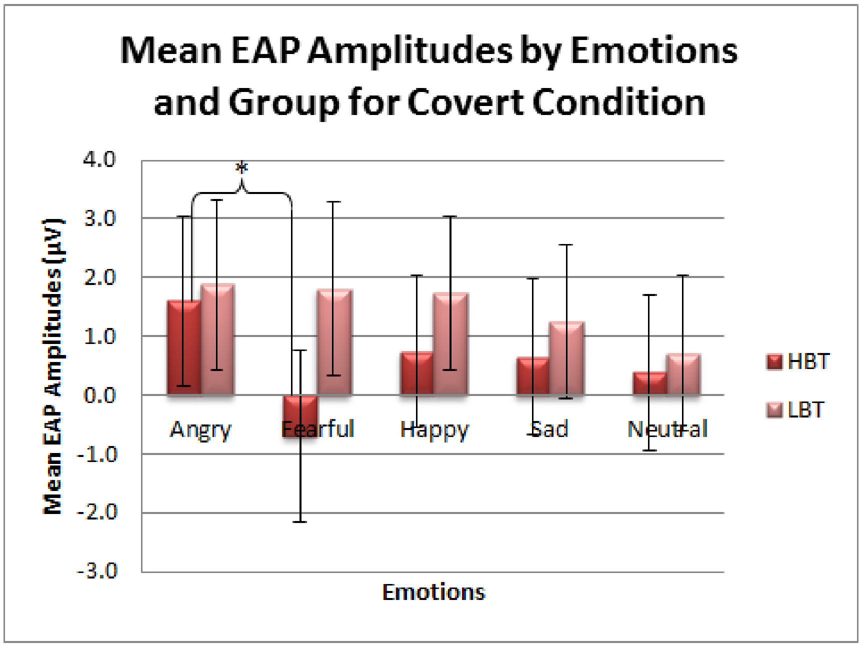
*Significant differences (p < .005): Happy < Neutral < Angry and Fearful < Sad

Figure 4-5. **Mean reaction time in the covert condition by emotions and group**



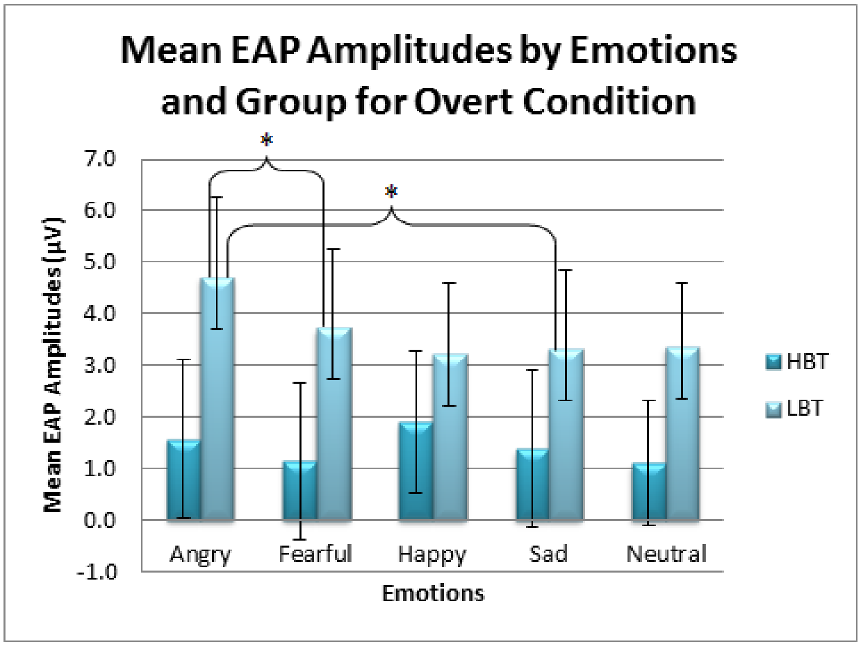
*No significant differences (p < .05)

Figure 4-6. Mean EAP amplitudes for covert condition by emotions and group



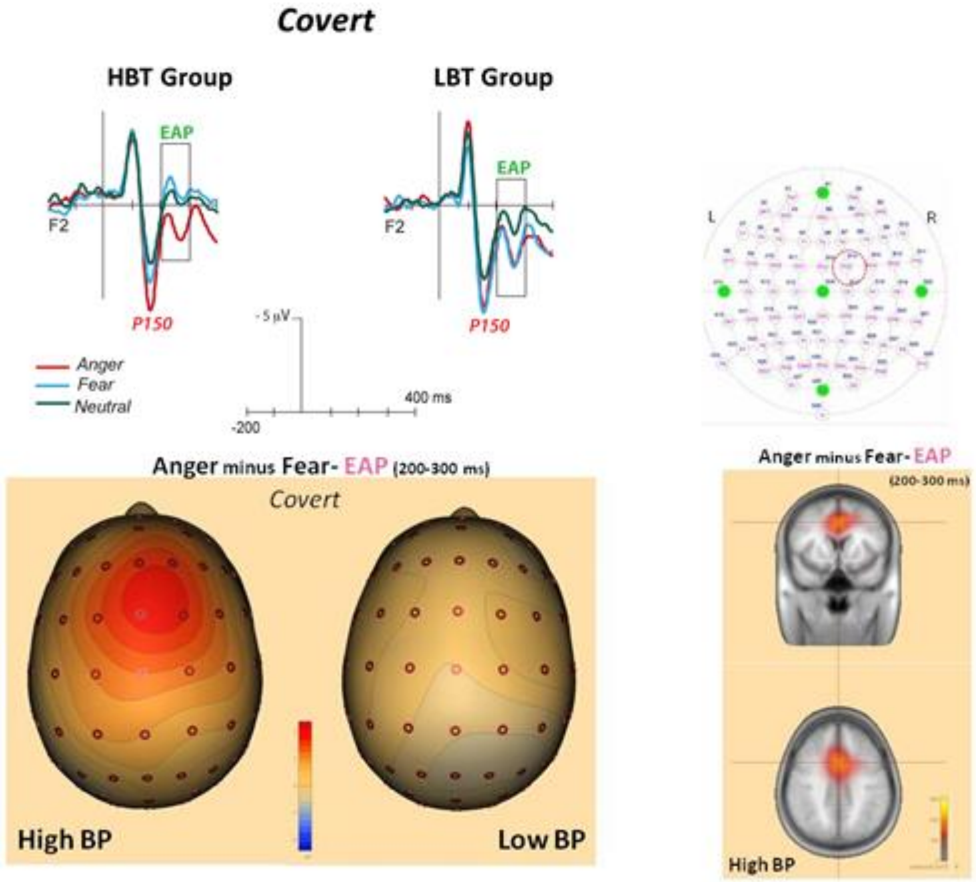
*Significant differences (p < .0125): In HBT group: Angry > Fearful

Figure 4-7. Mean EAP amplitudes for the overt condition by emotions and group



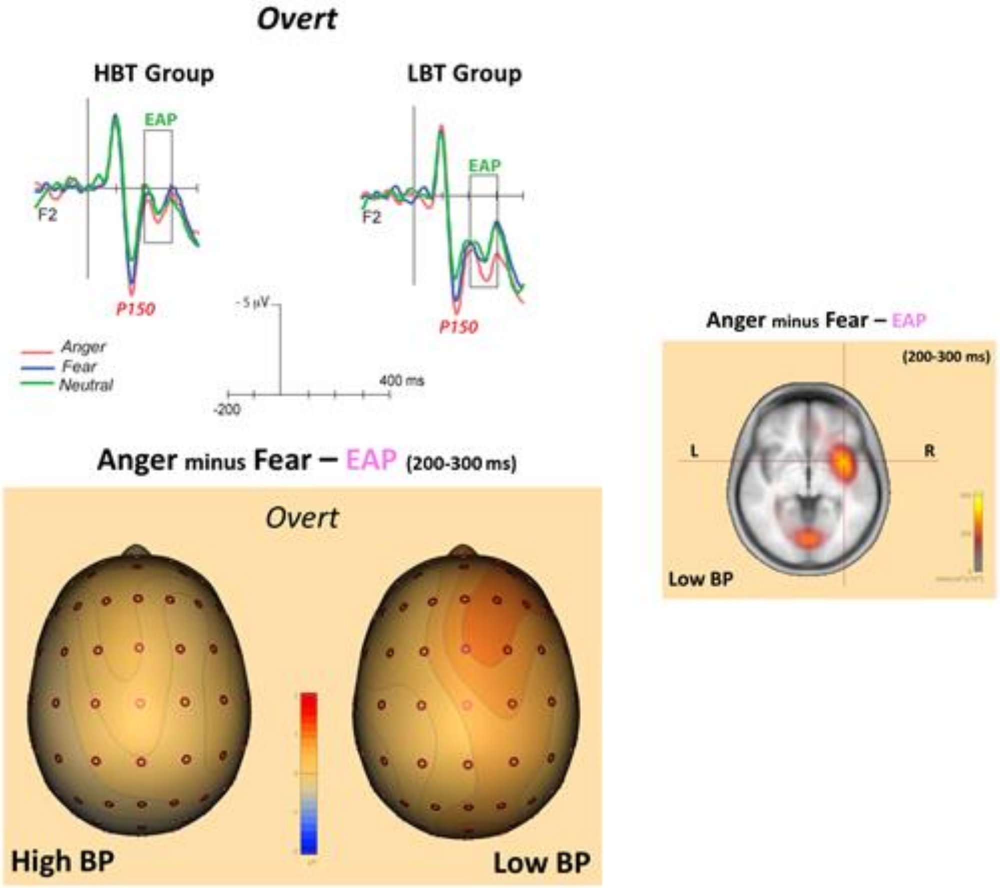
*Significant differences (p < .0125): In LBT: Angry > Fearful and Sad

Figure 4-8. **EAP effect in the Covert condition**



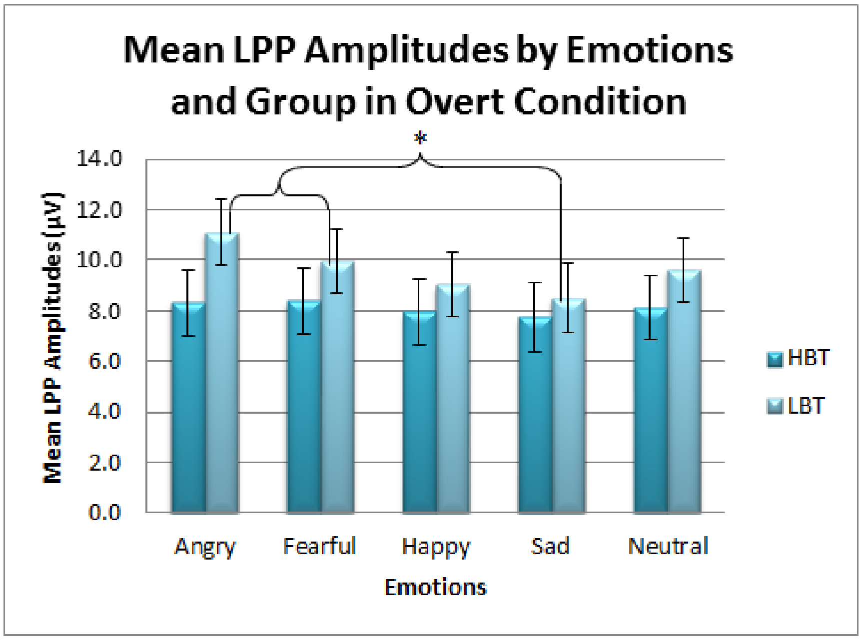
Waveforms for EAP effect in each group (top left); Topographical maps of the EAP difference wave for Anger minus Fear in each group (bottom left); Source imaging for EAP effect in the HBT group (bottom right).

Figure 4-9. EAP effect in the Overt condition



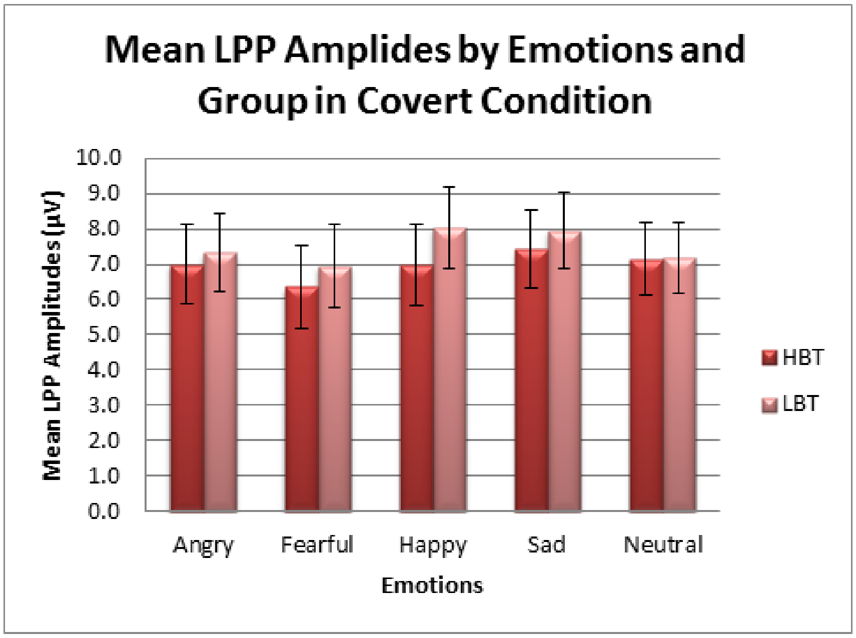
Waveforms for EAP effect in each group (top left); Topographical maps of the EAP difference wave for Anger minus Fear in each group (bottom left); Source imaging for EAP effect in the LBT group (right).

Figure 4-10. Mean LPP amplitudes for the overt condition by emotions and group



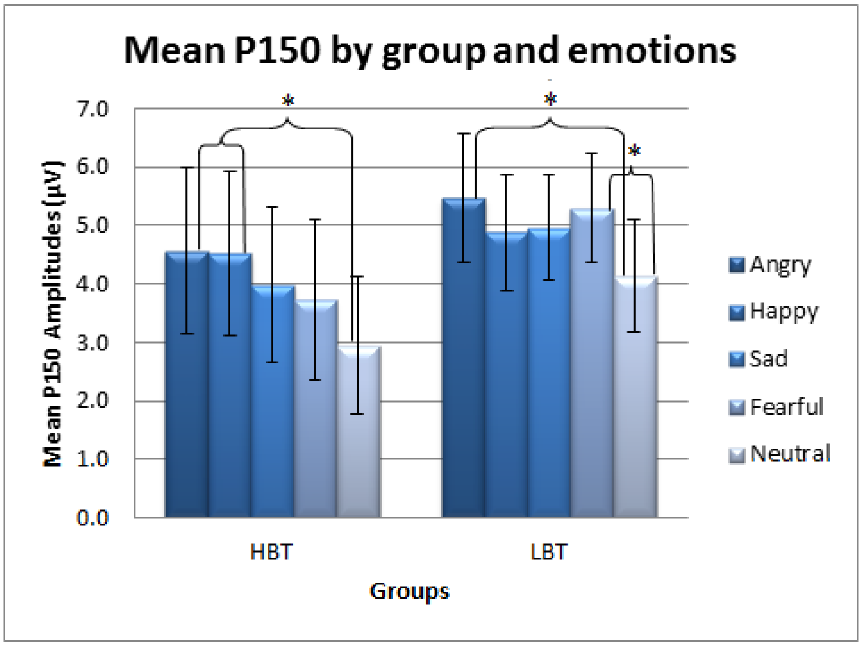
*Significant differences (p < .005): In LBT group: Angry and Fearful > Sad

Figure 4-11. Mean LPP amplitudes for covert condition by emotions and group



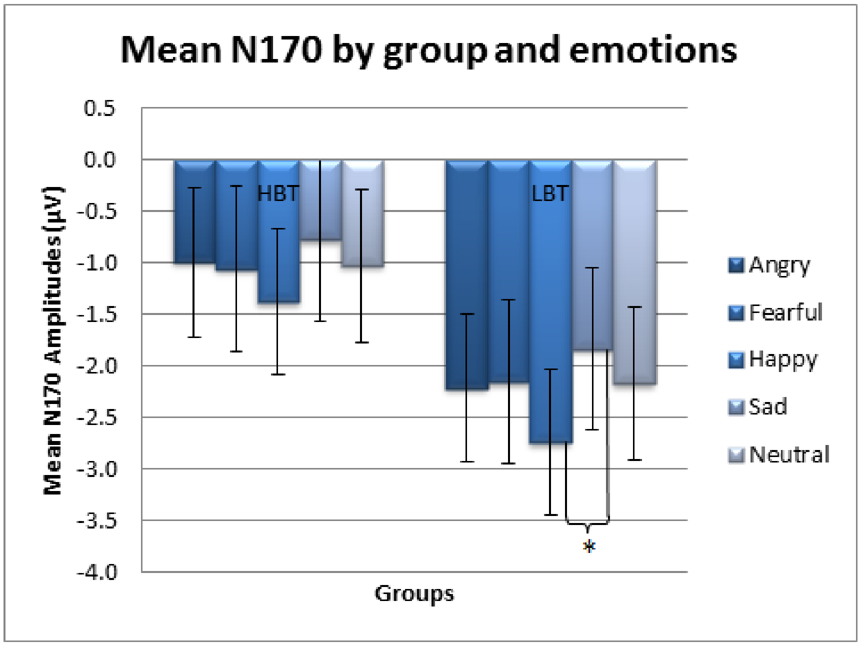
*No significant differences (p < .05)

Figure 4-12. Mean P150 amplitudes across conditions by group and emotions



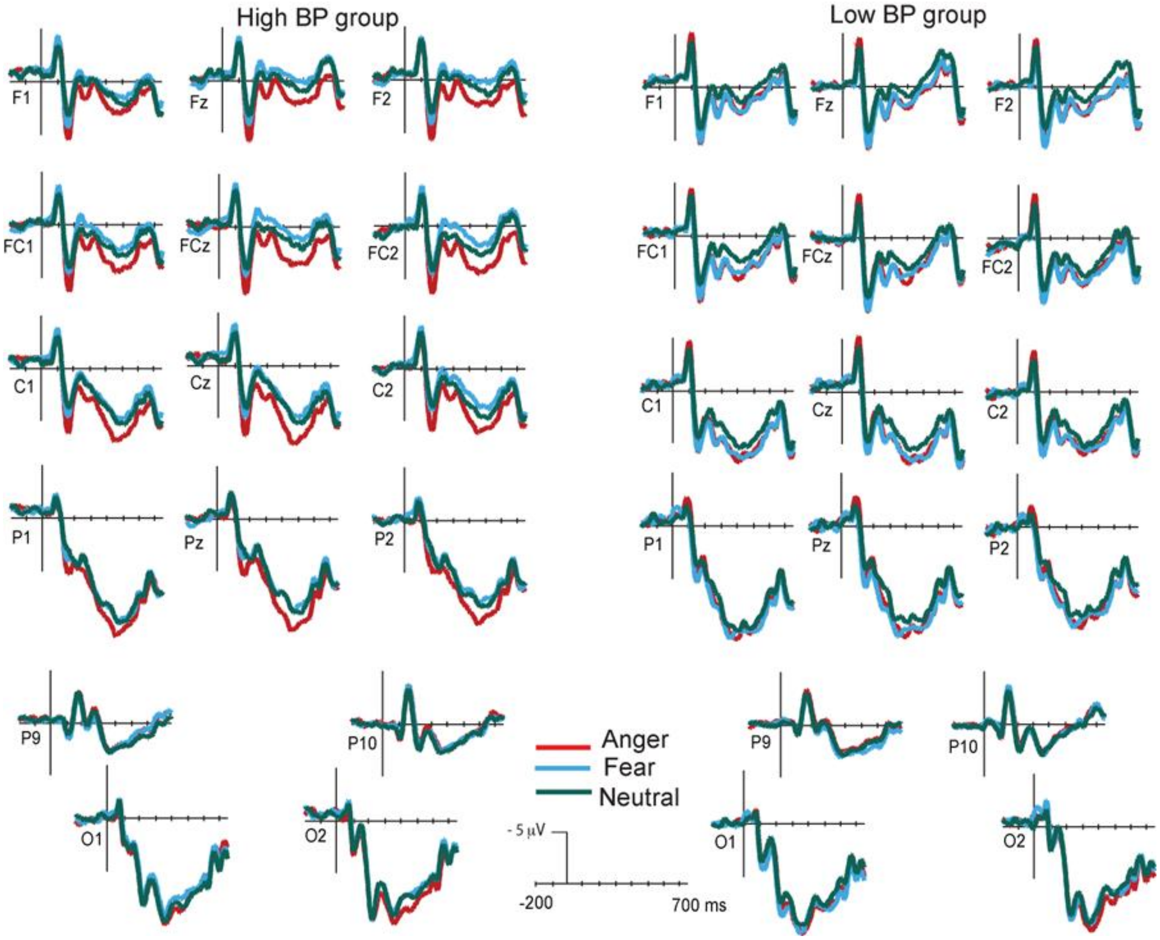
*Significant differences (p < .0125). In HBT group: Angry and Happy > Neutral; in LBT group: Angry and Fearful > Neutral

Figure 4-13. Mean N170 amplitudes for each group by emotions



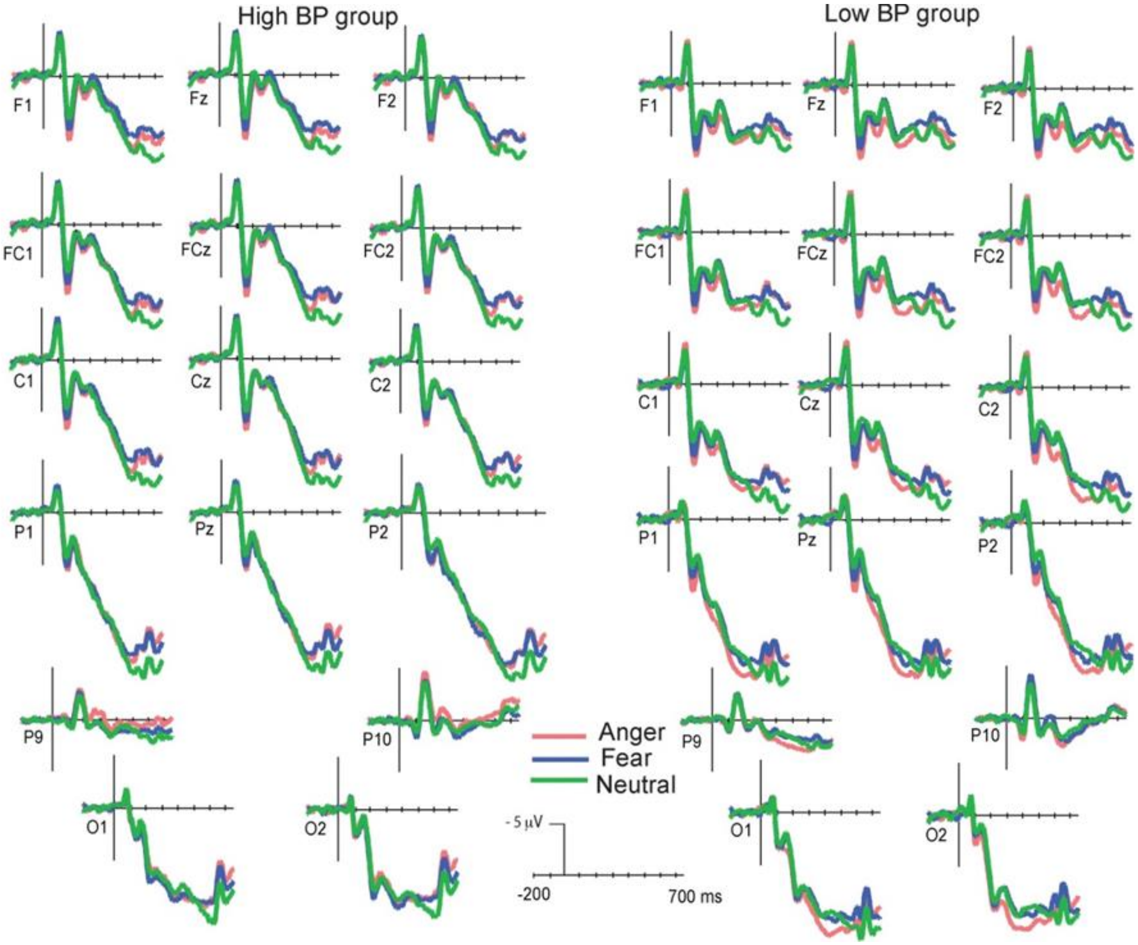
*Significant differences (p < .005): In LBT group: Happy > Sad

Figure 4-14. Waveforms within overt condition



Waveforms for 16 representative electrodes (-200 to 700 ms) in the HBT (left) and LBT (right) groups, shown for the covert processing of Angry, Fearful, and Neutral facial expressions. Effects of interest include: Frontal P150 (130 to 170 ms); EAP (200 to 300 ms); LPP (300 to 600 ms), and the P1 (80 to 120 ms).

Figure 4-15. Waveforms within covert condition



Waveforms for 16 representative electrodes (-200 to 700 ms) in the HBT (left) and LBT (right) groups, shown for the covert processing of Angry, Fearful, and Neutral facial expressions. Effects of interest include: Frontal P150 (130 to 170 ms); EAP (200 to 300 ms); LPP (300 to 600 ms), and the P1 (80 to 120 ms).

Chapter 5.

Study 2: Cognitive Modulation of Evocative Pictures

5.1. Introduction

As discussed in Chapter 3, a large body of research supports the notion of emotion dysregulation in BPD. Of special interest, BPD individuals have been characterized by the inability to control emotional experiences (Linehan, 1993). The bulk of findings are based on self-report data and behavioural measures. However, a growing number of studies have turned to neuroimaging techniques to investigate the altered brain mechanisms which may account for the social and emotional difficulties observed in BPD. Thus far, neuroimaging studies suggest dysfunction within a fronto-limbic neural network (Minzenberg et al., 2007; Schmahl & Bremner, 2006; Ruocco et al., 2013). Surprisingly, few studies have investigated the neural bases of emotion dysregulation in BPD directly using cognitive modulation paradigms. Even fewer studies have examined the ERP correlates associated with intentional down-regulation in BPD samples.

As discussed in Chapter 1, the processing of emotions involves bottom-up responses as well as top-down cognitive influences and the extent to which individuals are aware and consciously modulating their emotional responses may vary (Gyurak et al., 2011). Study 1 was focused on the more automatic mechanisms associated with the overt and covert processing of affective cues. To extend the current understanding of the underlying mechanisms involved in emotion processing and affect regulation which are aberrant in BPD, Study 2 focused on the intentional regulation of evocative cues among a high BPD trait group. Intentional cognitive modulation of emotional stimuli can provide insights into the healthy and dysfunctional modulation of affective cues, which may be particularly relevant in providing information regarding the treatment of emotional dysregulation among BPD individuals (Campbell-Sills & Barlow, 2007; Mennin et al,. 2005). In line with the view that affective instability in BPD is in part derived from a dysfunction in the neural mechanisms underlying emotion regulation, Study 2 investigated emotion-related ERP components associated with top-down control mechanisms by having participants intentionally down-regulate their emotional responses to affective cues varying in arousal levels.

Utilizing a cognitive modulation EEG paradigm, the current study compared females with high and low levels of BPD traits in their ability to intentionally modulate their responses to evocative (low and high arousal unpleasant) images and neutral images while applying one of two prescribed strategies. Participants either *reduced* their emotional responses to the presented images using top-down emotion regulation strategies, or they *allowed* their natural emotional responses to occur. The primary aim of the study was to examine the behavioural and electrophysiological markers associated with intentional down-regulation in order to better understand the emotion regulation processes which may be dysfunctional in BPD. Consistent with the aim of providing information regarding the time-course of affect processing in BPD, the current experiment was focused on both early and late ERP components and delineating potential group differences across processing stages. Late positive potentials (LPPs), which are thought to index more conscious stages of processing of emotional stimuli and generally respond to down-regulation attempts (e.g., Hajcak & Nieuwenhuis, 2006), were of particular interest in this study. Although previous studies have reported alterations in later components in BPD individuals (e.g., Marissen et al., 2010; Ruchsow et al., 2008), the extent to which arousal level plays a role is unclear. As such, stimuli varying in arousal level were included here. Moreover, differences occurring early in the processing stream have been generally lacking in the field of affect cue processing in BPD, despite the presence of attentional biases described in BPD (e.g., Arntz et al., 2000; Sieswerda et al., 2007; current Study 1). To this end, the current study aimed to examine early anterior modulations (e.g., EAPs) to unpleasant stimuli, which were expected to index greater attention towards the processing of self-relevant cues.

5.2. Hypotheses

The primary hypotheses for this study were centered on group differences. It was predicted that the HBT group would show greater dysregulation in their affect and would exhibit greater difficulties in down-regulating the impact of affective cues relative to the control group. It was hypothesized that the HBT group would show 1) *enhanced* LPP amplitudes overall, reflecting greater attention towards and enhanced processing of emotional cues, 2) smaller differences in LPP components elicited within the *Reduce* and *Allow* conditions reflecting relatively greater difficulties in intentionally down-regulating the impact of evocative cues in this group, 3) relatively greater difficulty in down-regulating the impact of high arousal images, as measured by enhanced LPP amplitudes for this stimuli type, 4) smaller differences in early anterior modulations (e.g., EAPs) elicited within the *Allow* and *Reduce* conditions, reflecting greater salience effects associated with viewing evocative stimuli and failure of top-down cognitive control mechanisms to attenuate the impact of early effects, and 5) smaller changes in self-reported mood and distress scores between conditions, indexing less subjective success in utilizing the prescribed emotional regulation strategies in the HBT group.

5.3. Methods

The Simon Fraser University Research Ethics Board approved this experiment. All participants gave their written informed consent before participating in this study and received course credit or a monetary incentive for their involvement. Additionally, participants were informed that the top two reducers, as measured by brain activity, would be awarded $20 in bonus money at the completion of the study.

5.3.1. Participants

Participants were recruited using the same web-based pre-screening survey available to psychology undergraduate students and had to meet the same inclusion and exclusion criteria as in Study 1 in order to be invited to participate in this study. None of the participants were the same as in Study 1. Thirty-six females participated in the current study. Four participants were excluded from EEG analyses due to excessive noise in their EEG recordings and/or having too few trials to analyze (<30/condition). The high BPD trait (HBT) group consisted of 16 females with high levels of borderline traits (PAI-BOR ≥ 38) and the low BPD trait (LBT) group served as the control group and consisted of 16 females with low levels of borderline traits (PAI-BOR ≤ 23). As with

Study 1, all participants were right-handed females, with normal to corrected vision, and with no neurological disorders, developmental disorders or learning disability. Additionally, groups did not significantly differ in age, years of education, and reported hours of sleep ($p < .05$). See Table 4.1 for participant characteristics.

5.3.2. Measures

As in Study 1, this study employed the Personality Assessment Inventory-Borderline scale (PAI-BOR), Background and Medical History Questionnaire, Dissociation Tension Scale (DSS), Beck Depression Inventory- 2 (BDI-II), and the Brief Symptom Inventory (BSI). Participants also completed Mood and Psychological State ratings following each block. Please refer to the Measures section in Study 1 for descriptions and details relating to these measures. Additionally, participants completed the following:

Emotion Regulation Strategies

The Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) is a 10-item measure designed to assess individual differences in the habitual use of two emotion regulation strategies: 1) Cognitive Reappraisal (ERQ-Reappraisal) and 2) Expressive Suppression (ERQ-Suppression). Respondents answer each item on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The ERQ has been found to have acceptable internal consistency among community adults (Cronbach's $\alpha = .82$ Cognitive Reappraisal; $\alpha = .76$ Expressive Suppression; Wiltink et al., 2011).

Distress Ratings.

In order to assess subjective distress associated with each task an stimuli type, participants rated their current distress following each mini-block of 10 trials using a 5-point Likert scale (1 = not at all; 2 = a little; 3 = moderately; 4= quite a bit; 5 = extremely).

Effectiveness Ratings.

In order to assess subjective success at completing each task, participants rated their task effectiveness after each experimental block using a 5-point Likert scale (1 = not at all; 2 = a little; 3 = moderately; 4= quite a bit; 5 = extremely).

Experimental Stimuli.

The stimuli consisted of colour images taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999), a standardized stimulus set, which is considered to be the most reliable and valid system in the experimental study of emotions and deemed well-suited in evoking strong emotional reactions (Jayaro et al., 2008). The IAPS is widely used in neuroimaging research and is a valuable tool in the experimental investigation of attention and emotions. IAPS images are rated with respect to their valence category (unpleasant to pleasant) and arousal level (low to high) on a nine-point scale by both female and male young adults (Lang et al., 1999). For this study, thirty unpleasant low arousal (LA) images (e.g., child crying, man smoking, drug paraphernalia), thirty unpleasant high arousal (HA) images (e.g., burning building, pointing gun, assault), and thirty neutral (NT) low arousal images (e.g., crackers, stairs, ironing board) were selected. No nudity or sexual content was included. The images were selected based on normative ratings, such that low and high arousal images differed in arousal ratings but were matched for negative valence. The selected neutral images were rated as neither positive nor negative in valence and had low arousal ratings. See Table 2.2 for mean valence and arousal ratings for selected images within each stimuli type. Additionally, Appendix A includes the evocative images included in this study. All images were centred onto a black background and included a small white central fixation marker (“+”) in order to minimize eye movements.

5.3.3. Procedure

Participants were asked to come to the laboratory well-rested and with clean, dry hair. Each participant was informed about the nature of the study, gave their written informed consent and completed the Background and Medical History Questionnaire prior to beginning the experiment.

Participants sat 60 cm from a computer screen in a sound-attenuated booth, with ambient light standardized across participants. In order to minimize eye movements, they were asked to keep their eyes focused on the central fixation marker (“+”) on the computer screen throughout the experiment and to minimize their eye blinks. Participants received detailed instructions for each task (i.e., *Allow* and *Reduce* tasks), which were adapted from Moser et al. (2006) as they were found to be effective in modulating physiological responses to unpleasant pictures. The instructions for each task can be found in Appendix B. Briefly, for the *Allow* task, participants were instructed to allow their natural emotional response to occur to the images presented. For the *Reduce* task, participants were instructed to actively reduce their natural emotional response to the images presented. The instructions described methods for down-regulating one’s emotional responses which largely focused on simply reducing one’s emotional reactions to the images presented. Of note, participants were told not to generate thoughts and images that were completely unrelated to the presented stimuli or to replace their initial emotion with a different one. Participants completed several practice trials and had the opportunity to ask questions in order to familiarize themselves with the experiment and to ensure understanding of the two tasks prior to beginning the experiment.

The experimental design included two blocks for each task for a total of 4 experimental blocks (i.e., 2 *Allow* blocks and 2 *Reduce* blocks), presented in alternating sequence. The presentation order of the tasks/blocks was counter-balanced across participants. Each *Allow* block included 180 stimuli (60 LA, 60 HA, and 60 NT images), whereas each *Reduce* block included 120 stimuli (60 LA and 60 HA images). Following analogous cognitive modulation paradigms (e.g., Jackson et al., 2000), neutral images were excluded for the *Reduce* task, since such a condition has been deemed to be confusing for participants. All stimuli were presented in mini-blocks of 10 images from the same condition. Additionally, a catch trial was included in each mini-block which consisted of a randomly repeated image to which participants were required to respond via a button press. The catch trial was intended to ensure active engagement and attention to the stimuli. The mini-blocks as well as the images within each mini-block were presented in random order. Using E-Prime (version 2.0), the experiment was programmed as follows: 2500 ms visual reminder of the task (i.e., either “ALLOW your natural emotional response” or “REDUCE your natural emotional response”, depending on the block), 300 ms central fixation marker “+”, 2000 ms visual stimulus, and a 1000-2000 ms jittered inter-stimulus interval with a central fixation marker “+”. See Figure 5.1 for the time course of stimulus presentation. After each mini-block, participants completed the Distress Rating scale. At the end of each experimental block participants completed the Mood and Psychological State Rating scales and the Effectiveness Rating scale. A two-minute continuous performance test which involved matching 1s and 2s was used a distracter task in between experimental blocks. Each block was followed by a short break. The total duration of the EEG tasks was approximately 40 minutes.

At the end of the experiment, participants completed the DSS, BDI-II, BSI, and the ERQ before being thanked, debriefed and compensated for their participation.

EEG Data Recordings and Processing

The EEG data recording and processing procedure was identical to Study 1. Distinct subject ERP averages were obtained for each group (HBT and LBT) and for each task and stimuli type. ERPs were time-locked to stimulus onset. Averaged epochs included a 200 ms pre-stimulus baseline and a 1000 ms ERP time window. Grand-averages were computed by combining single subject ERP averages. ERP waveforms and topographical scalp maps were inspected for the components of interest. Time windows were selected around the peaks of interest, determined by the maximum amplitude. Mean voltage amplitudes in the selected time windows were extracted and employed as parameter in the ERP analysis.

Analyses

Behavioural Analyses

For each psychological measure administered, overall scores were computed for each participant. Group differences on psychological measures including the BSI, BDI-II, DSS, ERQ-Reappraisal and ERQ-Suppression were compared using independent samples t-tests. Participant self-reported effectiveness ratings were pooled together for each task to assess their subjective success at completing each task. A two-way

ANOVA with Condition (Allow and Reduce) and Group (HBT and LBT) as factors was compared for mean effectiveness ratings. To assess hypothesized group differences in state ratings and distress ratings between conditions (Hypothesis 5), subjective mood and psychological state ratings were averaged across blocks for each condition and participant. A repeated measures ANOVA with mean State Ratings (Angry, Anxious, Energetic, Relaxed, Happy, Sad, and Tired) Condition (Allow and Reduce) and Group (HBT and LBT) as factors was computed. This was followed by separate ANOVAs for each mean state by Condition (Allow and Reduce) and Group (HBT and LBT). Participant distress ratings following each mini-block were pooled together for each stimuli type within each task to assess predicted group differences in subjective distress associated with the task manipulations. A two-way ANOVA with Stimuli Type (Allow LA, Allow HA, Allow NT, Reduce LA, and Reduce HA) and Group (HBT and LBT) was computed for mean distress ratings. Reaction time (RT) for catch trials was measured in milliseconds (ms) from the time of stimulus presentation to the time that participants indicated their response via button press. Mean RT for each condition and block was calculated for each participant in order to assess attentiveness throughout the experiment. A repeated measures ANOVA with Condition (Allow or Reduce), Block (First or Second) and Group (HBT and LBT) as factors was computed. In the event of significant interaction effects or for a-priori hypothesized differences, more restricted ANOVA analyses were conducted in order to clarify the effects. Bonferroni-corrected t-tests were used to correct for family-wise error.

Electrophysiological Analyses

In order to test the predicted modulations within later elaborative components (Hypothesis 1, 2 and 3), a posterior time window between 400 and 700 ms [Late Positive Potential: LPP] was selected over left (P1, P3, PO3), midline (POz, Pz, CPz), and right (P2, P4, PO4) electrode sites. In order to test the hypothesized early anterior modulations (Hypothesis 4), an early positivity over the anterior scalp [Early Anterior Positivity: EAP] was analyzed with a time window between 200 and 300 ms over right fronto-central electrode sites (FP1, FPz, FP2, AF8, AF4, AFz, F4, F6, F8).Additionally, an exploratory time window was selected between 90 and 130 ms [P1] over left (PO7, PO3, O1) and right (PO8, PO4, O2) occipital electrode sites in order to assess P1 differences between groups.

Repeated measures ANOVAs with Condition (Allow and Reduce) and Arousal (HA and LA) as repeated-measures factors and Group (HBT and LBT) as a between-group variable were performed for each effect of interest. In the event of significant interaction effects, subsequent more restricted ANOVA analyses were conducted in order to clarify the interaction with Bonferroni-corrected t-tests used to correct for family-wise error. To examine a-priori hypothesized differences, more restricted ANOVAs and t-tests were performed, even in the case of non-significant interaction effects. Secondary analyses using the Neutral images as a baseline comparison were performed as a manipulation check for the EAP and LPP time windows, consisting of a two-way ANOVA with Stimuli Type (Allow LA, Allow HA, Allow NT, Reduce LA, and Reduce HA) and Group (HBT and LBT) as factors. For all analyses, the threshold alpha was set to .05 and tests were adjusted for multiple comparisons and sphericity using the Greenhouse-Geisser epsilon method; however, uncorrected degrees of freedom are reported. Effect size estimates of repeated-measures ANOVA main effects and interactions were computed using partial eta squared (η^2_p). For t-tests, estimates of effect size were computed with Cohen’s *d*, using the pooled standard deviations.

5.4. Results

5.4.1. Behavioural Findings

Psychological Measures

The HBT group obtained higher scores on the BDI-II (t (30) = 3.98, p = .000, Cohen’s *d* = 1.41) and the BSI Global Severity Index (t (30) = 6.57, p =.000, Cohen’s *d* = 2.32) relative to the LBT group. Group differences on the DSS did not reach significance (t (30) = 2.02, p = .053, Cohen’s *d* = .71).Group differences were non-significant on the ERQ-Reappraisal (t (30) = -1.51, p = .14, Cohen’s *d* = -.53) and the ERQ-Suppression (t (30) = -.045, p =.96, Cohen’s *d* = -.02). See Table 4.1 for group means on these psychological measures.

Subjective State Ratings

The overall ANOVA revealed a main effect of state ratings (F (6, 180) = 15.80, p = .000, η^2_p= .35) and a condition (F (1, 30) = 23.40, p = .000, η^2_p= .44) with the Allow condition being associated with greater mean subjective ratings relative to the Reduce condition. A state by condition interaction effect (F (6, 180) = 5.27, p = .000, η^2_p= .15) was also observed. The condition by group interaction effect did not reach significance (F (1, 30) = 3.04, p = .09, η^2_p= .16).

State-specific analyses revealed significantly lower subjective state ratings within the Reduce condition for mean Angry (F (1, 30) = 5.87, p < .05, η^2_p= .16), Anxious (F (1, 30) = 7.98, p < .01, η^2_p= .21), Happy (F (1, 30) = 8.87, p < .01, η^2_p= .23), Sad (F (1, 30) = 17.07, p < .0001, η^2_p= .36), and Tired (F (1, 30) = 6.70, p < .05, η^2_p= .18) ratings. No significant group differences emerged for any of the state ratings (p > .05). Table 2.3 includes the means for each mean state rating by condition.

Effectiveness Ratings

No significant effects were found for mean subjective effectiveness ratings between groups (F (1, 29) = .13, p =.72, η^2_p= .00) or between conditions (F (1, 29) = .02, p =.90, η^2_p= .00).

Distress Ratings

A main effect of stimuli type (F (4, 120) = 34.19, p < .0001, η^2_p = .53) was observed. Bonferroni-corrected t-tests revealed mean distress ratings associated with each stimuli type as follows: Allow NT < Reduce LA (t (31) = -4.04, p = .000, Cohen's *d* = -.87); Reduce LA < Reduce HA (t (31) = -2.64, p = .012, Cohen's *d* = -.26); Reduce HA< Allow LA (t (31) = -3.99, p = .000, Cohen's *d* = -.72); Allow LA < Allow HA (t (31) = -2.77, p = .009, Cohen's *d* = -.17). Group differences were not significant (p < .05). Figure 5.2 displays mean distress ratings by stimuli type and group.

Catch Trial Reaction Time

A main effect of condition (F (1, 31) = 4.16, p = .05, η^2_p= .12) was observed with faster mean catch trial RTs occurring in the Reduce condition compared to the Allow condition. A block effect was also observed (F (1, 31) = 5.78, p = .025, η^2_p= .16) with faster mean RTs in the second block compared to the first block. Group differences were not significant (F (1, 30) = .85, p = .36, η^2_p= .03). See Figure 5.3 for mean catch trial reaction times by condition, group, and block.

5.4.2. Electrophysiological Analyses

LPP Effect (400-700 ms)

The primary analysis for the LPP revealed a main effect of arousal level (F (1, 30) = 24.55, p < .0001, η^2_p = .45) with HA images eliciting larger mean LPP amplitudes compared to LA images. The interaction between condition, arousal, and group did not reach standard levels of significance (F (1, 30) = 3.23, p = .082, η^2_p = .10).

Group-specific analyses revealed a main effect of arousal within the LBT group (F (1, 15) = 6.81, p < .05, η^2_p = .31) and the HBT group (F (1, 15) = 19.02, p = .001, η^2_p = .56), with greater LPP amplitudes elicited for HA images relative to LA images. The LBT group also showed a main effect of condition (F (1, 15) = 6.16, p < .05, η^2_p = .29), with smaller LPP amplitudes elicited in the Reduce condition relative to the Allow condition, though follow-up analyses revealed that this effect was only evident for LA images (F (1, 15) = 16.06, p = .001, η^2_p = .52), but not for HA images (F (1, 15) = .74; p = .40, η^2_p = .05). In contrast, no effect of condition was observed within the HBT group (F (1, 15) = .15, p = .71, η^2_p = .01). See Figure 5.4 for mean LPP amplitudes by condition, arousal level, and group.

Secondary analyses for the LPP effect using the baseline (neutral images) as a comparison revealed a main effect of stimuli type (F (4, 120) = 9.31, p < .0001, η^2_p = .24). Bonferroni-corrected t-tests revealed smaller LPP amplitudes elicited for Neutral relative to Allow HA images (t (31) = -7.16; p = .000, Cohen's *d* = -.74) and Reduce HA(t (31) = -4.15, p = .000, Cohen's *d* = -.62). Comparisons between Neutral and Allow LA did not survive Bonferroni correction (t (31) = -2.20, p = .035, Cohen's *d* = -.31) and the difference between Neutral and Reduce LA was non-significant (t (31) = -1.14, p = .26, Cohen’s *d* = -.17). See Figures 5.7 to 5.9 for waveforms and scalp topography for effects of interest.

In summary**,** LPP amplitudes differed as a function of group, condition and arousal level. For the LBT group, Low Arousal images in the Reduce condition elicited smaller LPPs relative to the Allow condition suggesting appropriate down-regulation in this group. In contrast, no effect of condition was present in the HBT group; LPPs had similar amplitudes independent of Allow or Reduce instructions. Only the effect of arousal level was present for the HBT group, with greater LPPs elicited by High Arousal images relative to Low Arousal ones.

EAP Effect (200-300 ms)

The primary analysis for the EAP revealed a main effect of condition (F (1, 30) = 4.59, p < .05, η^2_p= .13), with more positive-going EAP amplitudes elicited within the Allow condition relative to the Reduce condition. Additionally, a significant three-way interaction between condition, arousal, and group was observed (F (1, 30) = 4.40, p < .05, η^2_p= .13).

Within the Allow condition, a significant interaction between arousal and group was observed (F (1, 30) = 7.36, p < .05, η^2_p= .20). Group-specific analyses revealed a main effect of arousal within the HBT group (F (1, 15) = 5.70, p < .05, η^2_p= .28) with more positive-going EAP amplitudes elicited for the HA images relative to the LA images. In contrast, no significant effect of arousal was observed within the LBT group (F (1, 15) = 2.41, p = .14, η^2_p= .14), with HA and LA images eliciting comparable EAP amplitudes. Analyses within the Reduce condition revealed no significant effects of group or arousal level (p > .05).

Analyses restricted to the LA stimuli revealed a significant effect of condition in the LBT group (F (1, 15) = 4.71, p < .05, η^2_p = .24) with more positive-going EAP amplitudes elicited in the Allow condition relative to the Reduce condition. In contrast, no effect of condition was observed in the HBT group (F (1, 15) = .029, p = .86, η^2_p= .00). Analyses restricted to the HA stimuli revealed no main or interaction effects (p > .05). See Figure 5.5 for mean EAP amplitudes by condition, arousal, and group.

Secondary analyses for the EAP effect using the baseline (neutral images) as a comparison revealed a main effect of stimuli type (F (4, 120) = 19.36, p < .0001, η^2_p= .20); however, no group or interaction effects were observed (p > .05). Bonferroni-corrected t-tests revealed smaller (less positive-going) EAP amplitudes elicited for Neutral relative to Reduce LA (t (31) = -2.92, p = .006, Cohen's *d* = -.25), Reduce HA (t (31) = -3.20, p = .003, Cohen's *d* = -.34), Allow LA (t (31) = -3.22, p = .003, Cohen's *d* = -.37), and Allow HA (t (31) = -5.51, p = .000, Cohen's *d* = -.41) images.

In summary, the EAP showed a significant interaction effect between condition, arousal and group. Condition was a more prominent factor for the LBT group, with less positive-going EAPs elicited for Low Arousal images in the Reduce condition relative to the Allow condition. In contrast, arousal level was a more prominent factor for the HBT group, with more positive-going EAPs elicited within the Allow task for High Arousal images relative to Low Arousal ones.

P1 Effect (90-130 ms)

An exploratory analysis of the P1 effect revealed a significant three-way interaction between condition, arousal and group (F (1, 30) = 10.09, p < .005, η^2_p= .25). Within the HA stimuli, a significant condition by group interaction (F (1, 30) = 8.68, p < .05, η^2_p = .22) was observed. Follow-up within-group analyses revealed a significant effect of condition for the HBT group (F (1, 15) = 7.64, p < .05, η^2_p= .34) with greater P1 amplitudes observed in the Allow condition relative to the Reduce condition. In contrast, the LBT group did not show a similar effect for condition for HA stimuli (F (1, 15) = 2.69, p = .12, η^2_p= .15). Analyses limited to the LA stimuli revealed no significant effects of group or condition (p > .05). See Figure 5.6 for mean P1 amplitudes by stimuli type, condition, and group.

In summary, preliminary analyses of the P1 effect showed a significant interaction effect between condition, arousal and group, driven by larger P1 amplitudes elicited for High Arousal images within the Allow condition relative to the Reduce condition, for the HBT group only.

5.5. Discussion

The present study employed a cognitive modulation EEG paradigm to investigate the behavioural and electrophysiological correlates associated with the processing of evocative images varying in arousal levels among females selected for high and low levels of BPD traits. Using unpleasant (high and low arousal) and neutral images as a comparison, participants were instructed to either allow their natural emotional responses to the images to occur (*Allow* condition) or to intentionally reduce their emotional responses to evocative images (*Reduce* condition). The aim of the study was to examine group differences within early and late ERP components associated with the processing and intentional modulation of affective cues in order to shed light on the mechanisms involved in emotional processing and regulation that may be altered in BPD.

In light of the current knowledge regarding BPD and their emotion regulation difficulties, it was anticipated that the HBT group would display relatively greater difficulty in down-regulating the evocative images compared to the control group. Specifically, the HBT group was expected to show 1) *enhanced* LPP amplitudes overall, reflecting greater attention towards and enhanced processing of emotional cues, 2) smaller differences in LPP components elicited between experimental conditions reflecting relatively greater difficulties in intentionally down-regulating the impact of evocative cues in this group, 3) relatively greater difficulty in down-regulating the impact of high arousal images, as measured by enhanced LPP amplitudes for this stimuli type, 4) smaller differences in early salience markers between conditions, indexing greater hyper-responsivity towards affective stimuli and failure of top-down cognitive control mechanisms to attenuate the impact of early effects, and 5) smaller changes in self-reported mood and distress scores between conditions, indexing less subjective success in utilizing the prescribed emotional regulation strategies in the HBT group.

Behavioural effects

Self-report ratings were gathered throughout the experiment in order to provide insights into the subjective experiences of the participants during each task. Both groups reported similar levels of task effectiveness across experimental conditions. Thus, the

HBT group did not report feeling *less effective* at either task compared to the control group. Importantly, participants reported significantly *lower mood ratings*, specifically with regard to feeling Angry, Anxious, Happy, and Sad during the Reduce condition. They reported *less distress* when intentionally reducing their emotional responses to the stimuli presented and also indicated feeling *less tired* during this condition. In contrast, allowing one's emotions to remain unregulated was associated with *higher* self-reported mood ratings, levels of distress, and fatigue. As such, these mood and psychological state ratings provide validity to the study design and experimental manipulations. Self-reported reduction in experienced mood and distress following intentional emotional down-regulation is consistent with previous research which shows that cognitive strategies such as reappraisal and suppression reduce the intensity of negative experiences in healthy individuals (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006). These findings suggest that participants experienced a subjective decrease in mood associated with attempts to down-regulate the impact of the evocative images. While subject to the limitations of self-report measures, these findings offer initial support for the study design and success of the participants in implementing the prescribed strategies to modulate their emotional responses.

Contrary to predicted differences between groups in self-reported mood and distress ratings (Hypothesis 5), the HBT participants reported similar reductions in mood and distress as the control group. Although self-reported measures are subject to known limitations (see Chapter 3), the findings replicate earlier work where a distancing strategy was associated with comparable decreases in affect ratings between a BPD group and a healthy control group in the context of observed neural differences between groups (Koenisberg et al., 2009a). Thus, while self-reported reductions in mood were similar across groups, the lack of group differences based on subjective ratings does not preclude the presence of group differences in neural correlates associated with emotion processing and modulation, which is exactly what was observed in the current study.

An interesting effect of task manipulation was observed with regard to speed of processing. Specifically, allowing one's emotional responses resulted in *slower* reaction times on catch trials. This type of effect is akin to the interference effects observed in many eStroop studies where the emotional content of words is associated with a slowing of reaction time in naming the colour of the ink the words are printed in (Gotlib & McCann, 1984). Thus, the observed reaction time difference may reflect a *behavioural interference effect* stemming from allowing one's emotional responses to remain unregulated in the Allow condition. Consistent with this interpretation, reaction time interference effects during eStroop tasks are more robust during block presentations of the same emotion, rather than in mixed-trials presentations, suggesting that it is a "slow" effect building up over the course of the block with an impact on subsequent trials (such as the catch trial) rather than the current trial (McKenna & Sharma, 2004; Waters et al., 2005). Alternatively, the reaction time difference may also represent *faster* reaction times associated with intentional emotion down-regulation. Research suggests that reduction of emotional responses can confer a cognitive advantage. For instance, memory for pictures and emotional conversations was enhanced under reappraisal instructions (Richards & Gross, 2000). Similarly, enhanced memory for unpleasant pictures on a surprise recall trial was observed under conditions of cognitive reappraisal in a different study (Dillon et al., 2007). Moser and colleagues (2010) found that cognitive reappraisal primed cognitive resources as measured by reduced reaction times on subsequent eStroop trials, suggesting that intentional modulation of emotion cues heightens cognitive control. These findings raise the possibility that the reaction time differences between conditions observed in the current study may reflect a *priming effect* associated with intentional down-regulation reflecting greater cognitive control in the Reduce condition. Taken together, the observed reaction time differences most likely reflect a combination of behavioural interference and priming effects. While the current study design does not allow for the differentiation between possible contributing factors, the findings support the notion that regulating one's emotions through cognitive down-regulation strategies is associated with positive effects as indexed by faster processing speed. In contrast, allowing one's emotional responses to remain unregulated was linked with reduced processing speed. The lack of group differences on reaction times suggests that contributing factors impacted both groups in a similar fashion. Thus, based on behavioural findings alone, individuals with high levels of BPD traits behaved just as the control group did, showing no evidence of emotional dysregulation or difficulty in completing the experimental tasks. Moreover, the HBT group showed a similar benefit on processing speed associated with down-regulating the impact of evocative images as did the control group.

LPP Effect (400-700 ms)

A late positive potential (LPP) effect between 400 and 700 ms was observed across posterior scalp locations. In line with the predictions, the LPP was modulated by the experimental manipulations in the expected direction; however, this effect was dependent upon group membership and arousal level of the stimuli. For the control participants, LPP amplitudes for Low Arousal images were *decreased* in the Reduce condition relative to the Allow condition consistent with successful down-regulation of the emotional stimuli when instructed to do so. This finding is consistent with previous reports describing decreased LPP amplitudes associated with intentional down-regulation strategies such as reappraisal and suppression among healthy participants (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006; 2009).

The current findings suggest that arousal level of the stimuli impacted the extent to which control participants were able to successfully down-regulate the impact of evocative images in the time allotted. Although they showed significant reductions in LPP amplitudes following cognitive down-regulation for Low Arousal images, they were not successful in down-regulating the impact of High Arousal images. While previous studies using high arousal unpleasant images have shown significant reductions in LPP amplitudes associated with explicit down-regulation instructions, discrepancies in findings may stem from differences in study design. For example, Moser and colleagues (2009) observed significant LPP reductions for highly arousing unpleasant images; however, a cue word (e.g., “DECREASE”) was presented prior to each stimulus. Such a cue likely impacted the ERP responses observed. In fact, the authors found that cue instructions were associated with enhanced orienting and anticipation of the upcoming unpleasant image, suggesting that the processes associated with intentional down-regulation can begin prior to the onset of the emotional content and enhance differences between conditions.

In line with the predicted down-regulation difficulties in the HBT group as measured by smaller differences in later elaborative components elicited between conditions (Hypothesis 2), individuals in this group exhibited difficulties in intentionally down-regulating the impact of affective cues in this study. Since neither group was successful in modulating the impact of HA images, the lack of successful down-regulation for LA images in the HBT group is of particular interest since the LBT group showed evidence of successful down-regulation for this stimuli type. These findings are consistent with neuroimaging studies which have found that BPD patients failed to show typical neural markers associated with reducing the impact of negative emotional cues, in particular within pre-frontal regions (Koenigsberg et al., 2009a; Lang et al., 2012). Only one known study to date has investigated the electrophysiological correlates associated with intentional down-regulation in a BPD sample. Marissen and colleagues (2010) observed no group differences in LPP amplitudes following reappraisal instructions, although relative to healthy controls, the BPD group showed enhanced LPPs during a viewing task, suggesting enhanced elaborative processing for unpleasant stimuli. These findings are very similar to the findings obtained for HA images in the current study, which found that the HBT group showed *enhanced* processing of highly arousing images and a lack of group differences in attempts to down-regulate this image type.

Interestingly, the HBT group showed a stronger differentiation in LPP amplitudes elicited by HA and LA stimuli relative to the control group, suggesting that highly arousing images are particularly motivationally important for the HBT group. In contrast, LA images did not appear to capture the same attentional resources among the HBT group when compared to the control group. This finding provides indirect support to the prediction of greater difficulty for HBT individuals in down-regulating the impact of high arousal images (Hypothesis 3). Previous findings in the literature suggest that greater LPP modulations are found for emotional stimuli, in particular high arousal unpleasant images (e.g., Haycak & Olvet, 2008; Duval et al., 2013; Eimer, Holmes, & McGlone, 2003), and modulations in LPP amplitudes have been found to reflect emotional dysregulation in different disorders (e.g., MDD; Foti et al., 2010). The current findings suggest that HBT individuals allocate greater cognitive resources in the processing of highly arousing negative and likely threatening stimuli, but not necessarily all negative stimuli. This enhanced processing of highly evocative cues is likely to result in greater difficulties in down-regulating the impact of such cues and thus result in greater emotion dysregulation.

EAP Effect (200-300 ms)

An early anterior positivity (EAP) effect between 200 and 300 ms was observed over right fronto-central electrode sites. The EAP effect showed an overall positive enhancement for all emotional image types relative to the baseline (neutral) images, providing evidence for early anterior modulation to affective images. These findings are consistent with previous findings which show positive enhancement for emotional stimuli relative to neutral stimuli during the N2 time range over the anterior scalp (e.g., Taake et al., 2009; Li et al., 2007; Pauli et al., 2005; Eimer & Holmes, 2007). Thus, the current findings provide further evidence that this early ERP is sensitive to affective cues.

Importantly, the EAP in the current study was modulated by the task manipulation; however, this effect was dependent upon group membership and arousal level of the stimuli, thus partially supporting the predicted group differences in earlier salience markers (Hypothesis 4). In the control group, intentional down-regulation resulted in *reduced* (less positive-going) EAP amplitudes for LA images, an effect not observed among the HBT group. This finding suggests that this early anterior evoked response is sensitive to cognitive control mechanisms and may index down-regulation effects. EEG studies that have investigated explicit emotion regulation have generally focused on later ERP components, in particular the LPP (Haycak & Nieuwenhuis, 2006; Moser, 2006; 2009), although some recent studies have started to acknowledge modulation of earlier ERPs to cognitive modulation strategies, observed over the posterior scalp (e.g., EPN: Bletchert et al., 2012). The current EAP findings suggest that early evoked responses over the anterior scalp may be sensitive to conscious top-down regulation input in healthy individuals, particularly when the affective content is not too highly evocative. The lack of a similar task effect in the HBT group provides initial evidence for difficulties in the intentional down-regulation of emotional responses in a sub-clinical BPD group as measured by early ERPs over the anterior scalp.

Another group difference for the EAP effect consisted of positive enhancements among the HBT participants for HA images relative to LA images during the Allow condition, an effect not seen among the control participants. The HBT group exhibited *increased* attention towards and processing of high arousal unpleasant images, particularly when their emotional responses remained unregulated. The observed pattern of EAP modulations provides evidence for altered electrophysiological responses among those with elevated BPD traits with neural processing being prioritized based primarily on arousal level. This indicates that high arousal negative cues are particularly relevant for this group. Interestingly, this effect was not observed during the Reduce task, suggesting that this effect likely reflects more automatic processing in the HBT group. Since the Allow condition is more likely to elicit automatic bottom-up responses to affective cues, the presence of altered ERP responses in this condition presumably reflects normal processes that take place in HBT individuals when they encounter affective cues in everyday life. This finding is consistent with the EAP findings in Study 1, which showed a hypervigilance for Angry facial expressions among HBT participants associated with greater bottom-up responses in the covert processing of these cues.

P1 Effect (90-130 ms)

An exploratory analysis of the visual P1 effect (90-130 ms) revealed an interaction effect, which was driven by enhanced P1 amplitudes identified in the HBT group. This effect was specific to High Arousal images in the Allow condition, suggesting enhanced attentional gating for highly evocative images among HBT individuals, particularly when their emotional responses remained unregulated. Altered P1 amplitudes to threat words in panic disorder and OCD patients relative to healthy controls have previously been described (Thomas et al., 2013) and attentional biases have been shown to play a crucial role in the etiology and maintenance in various disorders, in particular anxiety disorders (Williams et al., 1997). Findings in the current study suggest similarly altered P1 responses among HBT individuals, which may explain the attention biases that have previously been described in BPD such as biases for negative and concern-specific words (Arntz et al., 2000) or current personally relevant events (Wingenfeld et al., 2009), though this latter finding was also observed among those with post-traumatic stress disorder. Given the scarcity of studies looking at the time-course of affective cue processing in BPD, this type of effect has not been described as of yet, although an MEG study (Merkl et al., 2010) did describe subtle differences in early visual perception markers among a BPD group.

Although a similar P1 effect was not present in Study 1, a number of possible factors may explain the difference between experiments such as the design (mixed versus blocked design) and stimuli used (facial expressions versus evocative images). High arousal IAPS pictures are designed to produce strong ratings of arousal, while prototypical facial expressions usually lack arousal ratings norms. Thus, evocative scenes may be intrinsically more arousing than faces and as such produce stronger automatic responses. Nevertheless, this effect is preliminary at this time and should be replicated in future studies.

Summary and Implications

The current study highlights early ERPs over the anterior scalp, as well as later elaborative ERP components which differentiated groups in this cognitive modulation study. First, in line with the predictions, the HBT group demonstrated difficulties in down-regulating their emotional responses to evocative images. While both groups reported similar reductions in affective ratings associated with the intentional down-regulation task, only the LBT participants showed ERP markers associated with successful down-regulation of the evocative images as measured by decreased EAP positivity over the right anterior scalp and decreased LPP modulations over the posterior scalp, though these effects were limited to the low arousal images. These findings highlight the difficulties that individuals with high levels of BPD traits experience when attempting to cognitively modulate the impact of affective cues. Moreover, the current study replicates the disparity between self-report ratings and neural correlates previously reported among BPD individuals (e.g., Koenisberg et al., 2009a), which may help explain the mixed findings described in the literature (see Chapter 3). As such, the use of translational research and multi-method assessments in examining clinically relevant phenomena may be particularly useful in understanding the different aspects which may be contributing to the emotional difficulties observed in BPD.

Additionally, the current findings show altered electrophysiological responses with preferential processing for highly evocative negative images throughout the processing stream. Early positive modulations over the anterior scalp between 200 and 300 ms, and later elaborative components over the posterior scalp starting around 400 ms showed preferential processing for HA stimuli, which likely reflects the motivational relevance of these images for HBT individuals. Additional analyses revealed preliminary evidence for enhanced attention allocation (visual gating system) around 110 ms after stimulus onset, reflecting attention biases towards high threat cues. The enhanced attentional and cognitive resources allocated towards high arousal negative images appears to be to the detriment of allocating appropriate resources towards less arousing, but nevertheless important affective cues. Low arousal unpleasant images were associated with relatively less attention and processing in the HBT group, most evident during early processes stages, though the finding was also observed during later elaborative stages.

Arousal level is the primary dimension differentiating the current stimuli (HA vs. LA). However, based on the findings in Study 1 and attentional bias studies in the literature (e.g., Sieswerda et al., 2007), HBT individuals appear to prioritize affective stimuli which are more schema-related and potentially more personally relevant. Thus, it may be that HA images (e.g., gun pointing, violence/attack, snake fangs) were perceived as more personally relevant and threatening whereas the LA images (e.g., prisoner, alcohol/drug use, cemetery) were perceived as relatively less personally relevant or threatening. The IAPS pictures are based on a dimensional continuum of arousal and valence (Lang et al., 1999) and as such do not allow for an easy categorical distinction between emotions. Moreover, they do not include other possibly relevant dimensions such as approach and withdrawal which may be relevant among BPD individuals (e.g., Beeney et al., 2003). Nevertheless, assessment of the images included in this study shows that fearful and aggressive pictures are predominant among the HA unpleasant images. In contrast, sad and depressive images dominate the LA unpleasant images used in this study. Therefore, it is possible that the arousal effects observed among the HBT individuals may reflect differential processing of emotions such as sadness and threat. According to this interpretation, HBT individuals would show enhanced processing for threatening images and diminished processing for sad images. However, such an interpretation would not account for the processing differences observed between Angry and Fearful facial expressions in Study 1. Given the limited number of stimuli used in the present experiment, no attempts were made to break up the stimuli into anger versus fear provoking stimuli in this study.

The lack of attention to potentially threatening stimuli at low arousal levels may represent an impediment to healthy emotional responding in BPD. Failure to recognize more subtle cues can result in missing important information such as hints which may point to the possible escalation of threat. In this way, individuals with BPD traits may be surprised when more dramatic or serious situations arise, perceiving these events as arising “out of the blue”. Thus, rather than conferring an advantage, selective responding to environmental cues could impair one’s ability to recognize a pertinent situation or problem early on. Furthermore, this also raises the possibility that borderline individuals may not have recourse to low arousal methods for addressing difficulties in their own lives. Thus, they may not consider utilizing milder emotional expressions themselves and as such may resort to more dramatic expressions instead. A failure to attribute sufficient attention towards milder forms of threat may help explain the difficulties experienced in BPD and the tendency for such individuals to respond in an extreme fashion. Individuals with BPD have a tendency to evaluate one's experiences with extreme polarity (i.e., feeling all good or all bad; Beck et al., 2004; Linehan, 1993; Coifman et al., 2012). The findings in the current study provide some insights into why individuals with BPD may respond in such an extreme manner. Additionally, the lack of normal evoked responses to low arousal cues may also be relevant for their ability to empathize with others. While BPD individuals are highly responsive to the feelings of others, they show impairment in identifying and describing their feelings and in taking the perspective of others around them (New et al., 2012). As such, the absence of normal ERP modulation to sad/depressive images which make up a large portion of the LA images may help explain why individuals with BPD struggle to respond appropriately in their interactions with others. Thus, the findings may be relevant to the interpersonal difficulties that BPD individuals experience.

Given that the observed ERP differences present themselves likely as early at 100 ms after stimulus onset suggests that these differences are neurally-based, rather than representing excessive cognitive processing such as rumination. According to cognitive-behavioural theories, early childhood traumas constitute a learning environment which results in specific trauma-related cognitive schemas and these schemas may bias information processing (Arntz, 2004). Since individuals with BPD often have traumatic experiences, one possible explanation is that such experiences confer changes in the processing of affective stimuli, which in turn may impact their affective responding and interpersonal relationships.

The findings in this study lend some support to the biosocial theory of emotional dysregulation in BPD proposed by Linehan (1993), with evidence for HBT individuals demonstrating difficulties in modulating their emotional experience as measured by a lack of LPP and EAP reductions when attempting to down-regulate the impact of evocative images. Also, consistent with the theory is the finding that HBT individuals show selective attention to highly arousing negative stimuli, as measured by enhanced early evoked responses specific to this image type. These findings suggest that HBT individuals may show a processing bias towards highly arousing cues which are likely perceived as particularly relevant and personally threatening. Concurrently, HBT individuals appear to show a lack of attention and processing for less arousing negative stimuli which may pose less imminent threat to them, but are nevertheless important for relationships and interpersonal success. This challenges the view that BPD individuals have a low threshold and high sensitivity to *all* negative stimuli. Rather, this study suggests that enhanced processing appears specific to stimuli which are highly arousing.

Limitations and Future Directions

The current study has similar limitations as Study 1, including the use of a sample with high BPD traits rather than a BPD clinical sample, use of an all-female sample, and a limited sample size (although most of the predicted effects were significant). Thus, in order to extend the findings, the study would benefit from replication in a larger sample, with males and females, and among BPD patients.

As with Study 1, this study is also limited by the presence of elevated general psychopathology and depression symptoms among the HBT group. Unfortunately, due to a high overlap between these symptoms and BPD symptoms, analysis of depression and general psychopathology as covariates did not produce reliable results. However, it is worth noting that Study 1 included Sad faces and in Study 2 LA negative images were predominantly sad scenes. Sad faces in Study 1 and LA unpleasant images in Study 2 produced much *smaller* effects on ERP indices of emotion. Instead, Angry faces and HA stimuli were more salient for HBT individuals rather than Sad faces and LA negative scenes. Furthermore, parallel studies in our laboratory using similar overt/covert face and face eStroop tasks in subjects with high and low depression symptoms revealed similar EAP effects limited to concern-specific *sad* faces (Jaspers-Fayer et al., 2013). This suggests that the current findings were unlikely to be driven by depression symptoms.

Both groups exhibited difficulties in down-regulating the impact of HA images in the short amount of time allotted, essentially showing a floor effect. This is perhaps not surprising given that the IAPS images were designed with the intent of evoking strong emotional reactions (Jayaro et al., 2008). Provision of additional time and more frequent cue reminders similar to previous studies (e.g., Moser et al., 2009), would be expected to enhance the success of down-regulating the impact of these stimuli among healthy participants. While the use of HA images was not particularly fruitful in investigating the differences between groups in their ability to intentionally down-regulate their emotional responses, the inclusion of these images did offer insights into the automatic and preferential processing that HBT individuals allocate to these highly evocative cues.

The use of cognitive modulation as an experimental manipulation presents inherent limitations due to its subjective nature. Since no behavioral output is required for emotion regulation to take place, participants may disengage from the task at hand. For this reason, catch trials were included in this study to ensure adequate attention and engagement in the tasks. Additionally, in order to capture the participants' subjective experiences, current mood and distress ratings were gathered throughout the experimental tasks. The use of multiple methods of assessment, including behavioural measures (e.g., RTs), subjective mood ratings, and ERP components, offers strength to the present paradigm. Based on these multiple sources of data, evidence suggests that healthy participants were able to down-regulate the impact of the unpleasant images. In contrast, HBT participants showed dysregulated ERP responses, despite reporting similar reductions in mood and distress on self-report ratings.

Participants were generally instructed to reduce the impact of the emotional stimuli. While self-reported use of different emotion regulation strategies did not yield reliable differences in the current sample, previous studies suggest that healthy controls generally report use of cognitive reappraisal to manage emotions in their everyday life, whereas BPD traits are associated with forms of experiential avoidance (e.g., Chapman, et al., 2005; Vollrath et al., 1998). Moreover, the use of cognitive reappraisal has generally been associated with psychological health and healthier patterns of affect, social functioning, and well-being when compared to the use of suppression methods, in part because cognitive reappraisal results in changes earlier in the processing stream (John & Gross, 2004). Thus, it may be that the control group experienced success in emotional down-regulation because they utilized cognitive reappraisal techniques, whereas the HBT group failed because they were attempting to utilize expression suppression techniques. In the current study, LBT participants showed ERP responses to down-regulation strategies appearing relatively early in the processing stream (200-300 ms after stimulus onset), which suggests that they implemented a more cognitively-based approach similar to cognitive reappraisal. Additional methods aimed at ascertaining the methods implemented by the participants would help determine potential differences in the approach taken which might help explain the observed group differences.

In light of the differences in processing between LA and HA images among the HBT group, it may be that this group failed to show successful down-regulation for LA images since this image type was not perceived as emotionally evocative in the first place. Thus, reducing the impact of stimuli which are not perceived as evocative within this group would also result in similar findings with a lack of observed differences in LPP modulations observed between tasks. Further studies are needed to clarify this finding.

The current study does not address whether the hyper-responsivity observed in the HBT group is specific to high arousal *negative* images or whether such a response would be observed for pleasant or positive high arousal images as well. Although some have noted that extreme cheerful mental states might occasionally occur among BPD patients (Herpertz et al., 1997), findings to date suggest stronger reactivity to unpleasant stimuli. For example, Marissen and colleagues (2010) observed enhanced ERPs to unpleasant images, but not pleasant or neutral ones among a BPD sample. Given that the nature of affect in BPD is predominantly of a dysphoric nature, only negative stimuli and neutral stimuli were included in the current study. Nevertheless, future studies may want to confirm this by using high arousal *pleasant* images which may potentially impact one’s well-being (e.g., erotic scenes).

5.6. Conclusion

In conclusion, this study aimed to explore the electrophysiological and behavioural responses associated with intentional cognitive modulation to evocative images among females with high and low levels of BPD traits. The current study provided evidence of altered electrophysiological responses in the HBT group, during early and late time windows, demonstrating enhanced attention and processing for High Arousal unpleasant images, but not Low Arousal unpleasant images. Additionally, while the control group showed ERP evidence for down-regulation of their emotional responses to Low Arousal images, with the EAP over the frontal scalp, and the LPP over the posterior scalp, the HBT group failed to show similar effects, providing evidence of emotion regulation difficulties among a sub-clinical sample of BPD females.

5.7. Tables Study 2

Table 5.1. Participant Characteristics and Mean Scores on Psychological Measures

Measures	LBT Group	HBT Group	P-value
Age (years)	19.5 (1.79)	18.8 (1.78)	.284
Education (years)	13.56 (1.48)	12.91 (.55)	.108
Current Sleep (hours)	6.94 (1.14)	7.16 (1.33)	.620
Typical Sleep (hours)	7.38 (1.44)	7.38 (.81)	1.00
PAI-BOR	17.13 (3.85)	42.50 (4.31)	.000 *
DSS	25.13 (10.20)	39.19 (25.97)	.053
BDI-II	8.13 (5.64)	18.13 (8.32)	.000 *
BSI	29.19 (12.97)	68.56 (20.17)	.000 *
ERQ-Reappraisal	31.38 (5.91)	27.88 (7.16)	.142
ERQ- Suppression	15.69 (3.65)	15.63 (4.13)	.964

Note: PAI-BOR = Personality Assessment Inventory – Borderline Scale; DSS = Dissociation Tension Scale; BDI-II = Beck Depression Inventory-2; BSI = Brief Symptom Inventory; ERQ = Emotion Regulation Questionnaire – Reappraisal = Cognitive Reappraisal and Suppression = Expressive Suppression; Values represent means (standard deviation); p-values correspond to level of significance for group differences on each scale; *significant differences ($p < .05$).

Table 5.2. Normative ratings for images selected for each stimuli type

	Low Arousal (LA)	High Arousal (HA)	Neutral (NT)
Valence ratings	3.19 (.61)	2.83 (.63)	5.06 (.30)
Arousal ratings	4.22 (.44)	6.20 (.42)	2.99 (.58)

Values represent means (standard deviation) across images selected for each image type.

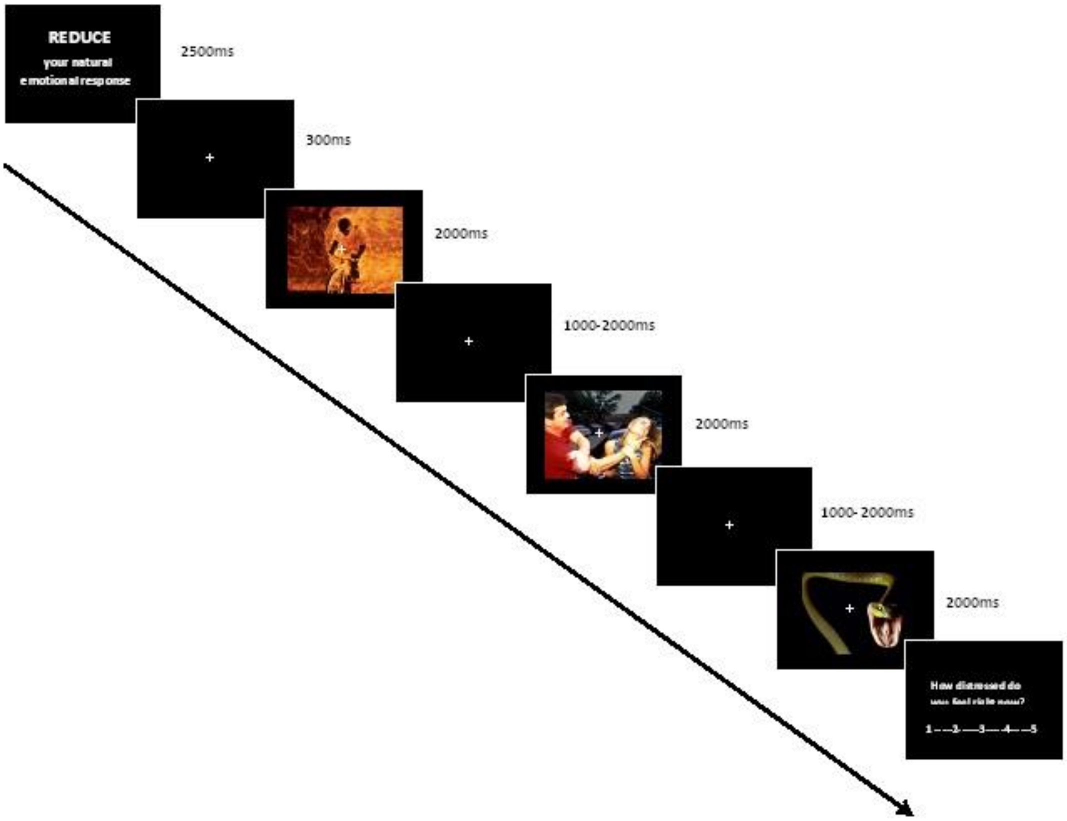
Table 5.3. ***Mean subjective ratings by mood state and condition***

Mood States	Allow	Reduce	P-value
Angry	1.47 (.72)	1.19 (.30)	.022*
Anxious	1.84 (.88)	1.53 (.61)	.008*
Happy	2.42 (.78)	1.86 (.90)	.006*
Sad	2.20 (.86)	1.58 (.66)	.000*
Energetic	1.58 (.56)	1.63 (.54)	.443
Relaxed	2.42 (.78)	2.52 (.85)	.315
Tired	2.73 (.93)	2.47 (1.00)	.015*

Values represent means (standard deviation); p-values correspond to level of significance for condition differences for each state; * significant differences ($p < .05$).

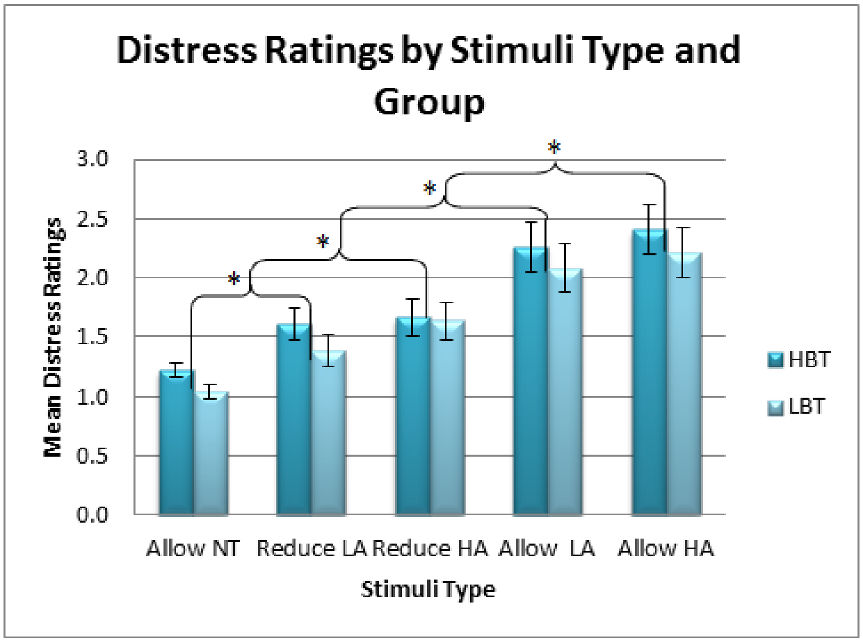
5.8. Figures Study 2

Figure 5-1. Illustration of the time course of stimulus presentation



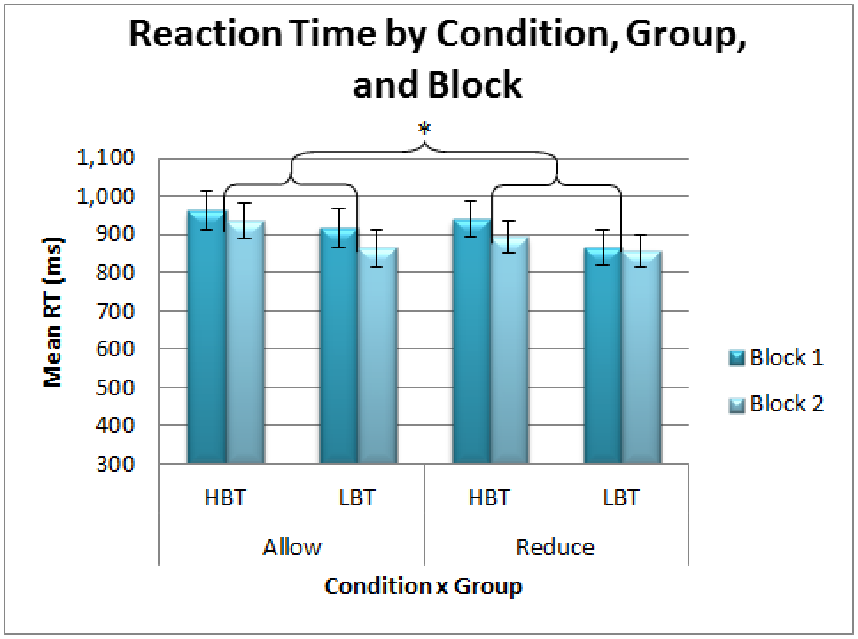
The time-course included a visual reminder of the task (2500 ms), central fixation marker "+" (300 ms), visual stimulus (2000 ms), and a jittered interstimulus interval (1000-2000 ms). At the end of each mini-block (10 trials plus 1 catch trial) participants completed distress ratings.

Figure 5-2. **Mean distress ratings by stimuli type and group**



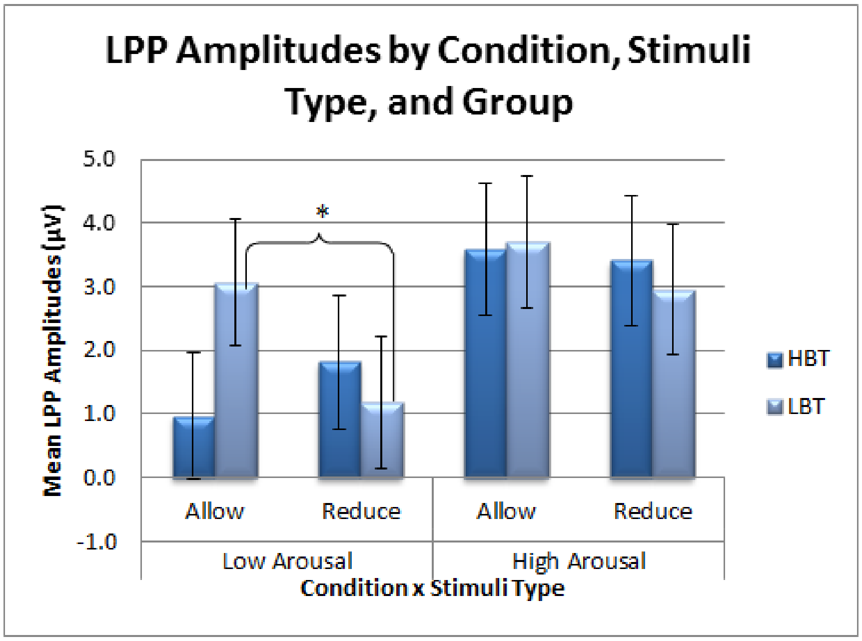
*Significant differences (p < .0125) Allow NT < Reduce LA < Reduce HA < Allow LA < Allow HA

Figure 5-3. **Mean catch trial reaction times by condition, group, and blocks**



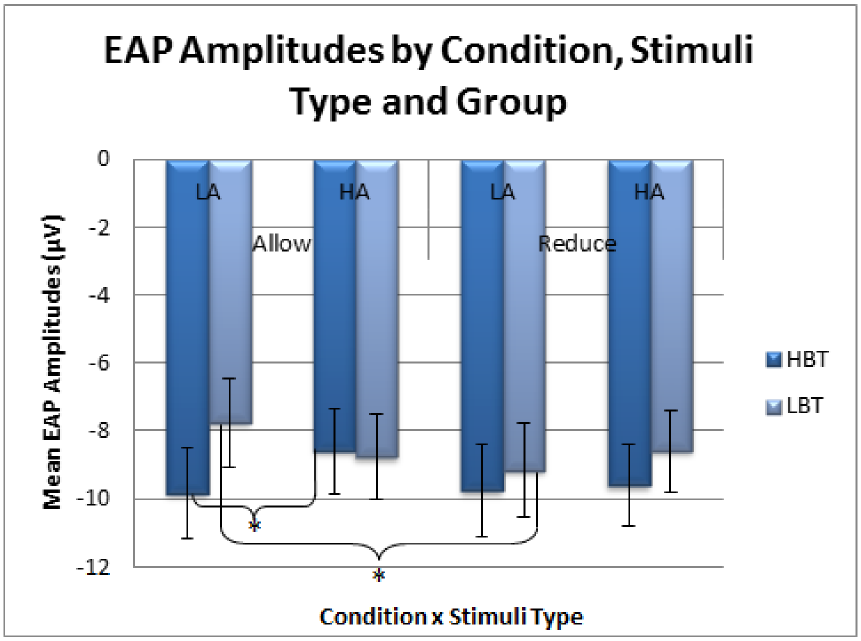
*Significant differences (p < .05): Reduce < Allow; Block 2 < Block 1

Figure 5-4. **Mean LPP Amplitudes by condition, stimuli type, and group**



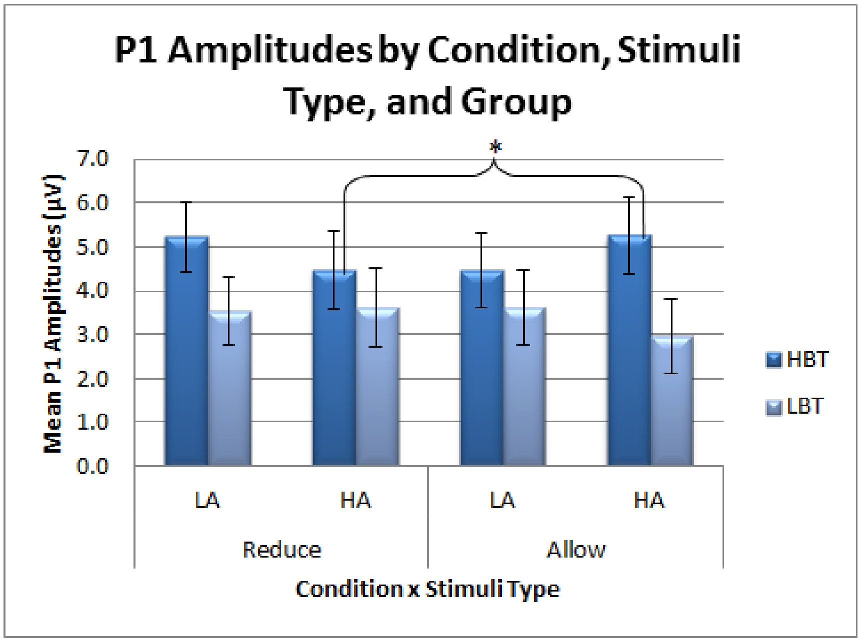
*Significant differences (p < .05): In LBT group: Reduce LA < Allow LA; For both groups: HA > LA

Figure 5-5. **Mean EAP amplitudes by condition, stimuli type, and group**



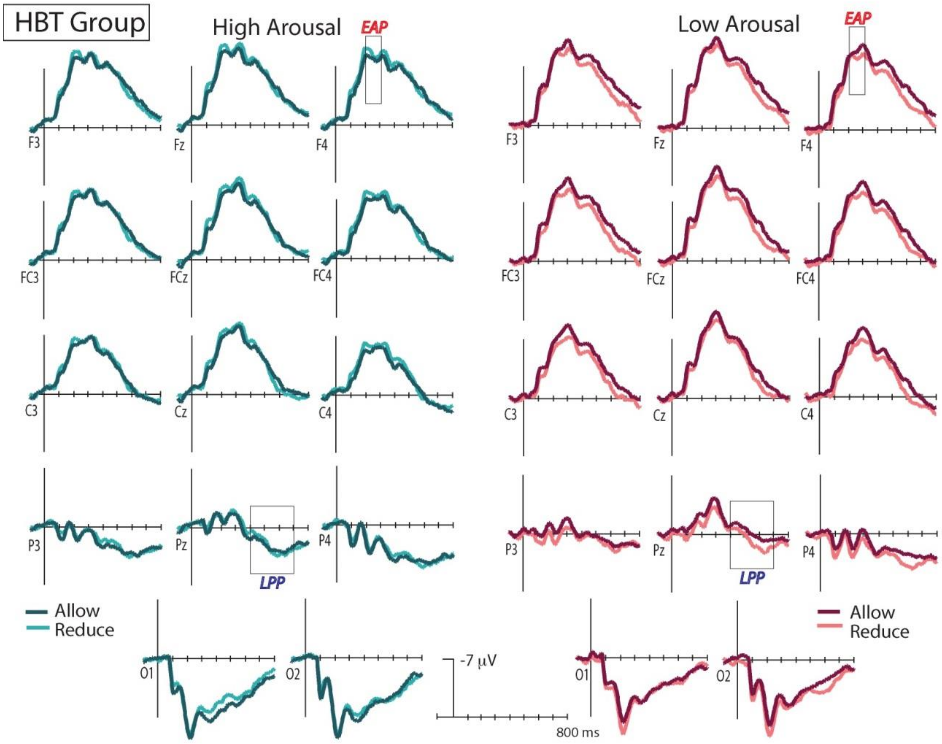
*Significant differences (p < .05): In HBT group: Allow HA < Allow LA; In LBT group: Allow LA < Reduce LA

Figure 5-6. Mean P1 amplitudes by condition, stimuli type, and group



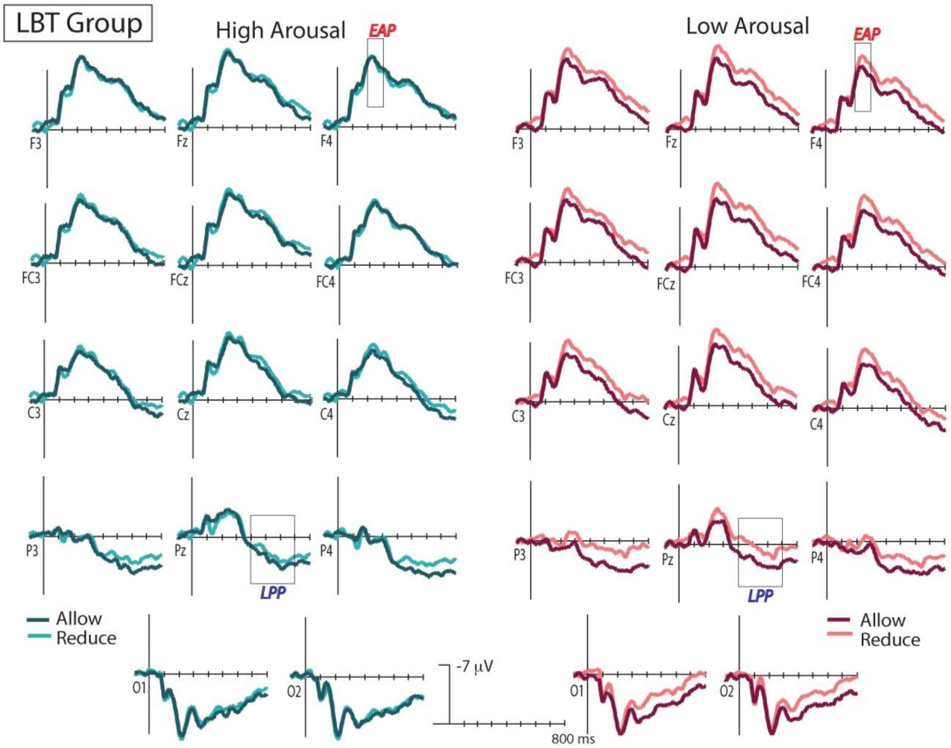
*Significant differences (p < .05): In HBT group: Allow HA > Reduce HA

Figure 5-7. Grand Average waveforms for HBT Group



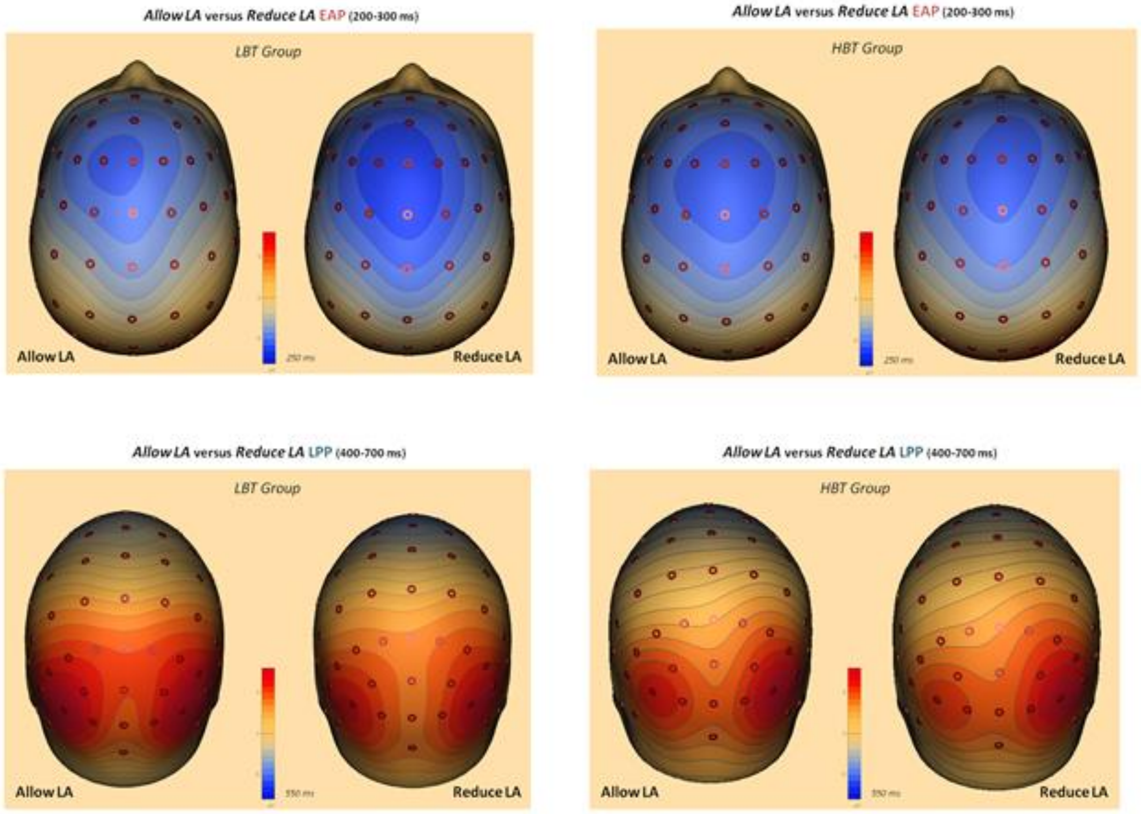
Includes grand average waveforms for 14 representative electrode sites for HBT group for High Arousal (left) and Low Arousal (right) images.

Figure 5-8. Grand Average waveforms for LBT Group



Includes grand average waveforms for 14 representative electrode sites for LBT group for High Arousal (left) and Low Arousal (right) images.

Figure 5-9. EAP and LPP scalp topography for Low Arousal images



Top panels: Scalp topography at 250 ms for LBT group (left) and HBT group (right)
Bottom panels: Scalp topography at 550 ms for LBT group (left) and HBT group (right).

Chapter 6.

Overall Discussion

Borderline personality disorder (BPD) is a complex and serious mental disorder. A core feature of BPD relates to emotional dysregulation (American Psychiatric Association, 1994). Although great strides have been made to understand this disorder, the mechanisms underlying BPD, particularly the neurobiological mechanisms, are only starting to be understood. Given the vast personal and social repercussions individuals with BPD face in light on their emotional problems, a better understanding of how borderline individuals process and regulate affective cues is much needed. The studies included here were intended to contribute to the current understanding of emotion processing and regulation mechanisms in BPD by studying the behavioural and electrophysiological correlates associated with the processing and modulation of affective cues among a sample of sub-clinical BPD. Study 1 aimed to examine the explicit and implicit processing of affective cues by altering the focus of attention towards or away from the analysis of facial expressions of affect in an attempt to bias processing in a top-down versus bottom-up manner, respectively. Study 2 was focused on the mechanisms involved in the intentional down-regulation of affective cues consisting of unpleasant images varying in arousal levels.

Electrophysiological methods were applied to investigate the neural markers associated with the processing and modulation of affective cues among female samples selected for high and low BPD traits. Early as well as later processes which may be associated with disturbed emotional responding in BPD were examined. Few studies have utilized ERPs to examine altered emotion processing and regulation in BPD individuals; however, the current findings support the use of this methodology in investigating emotion-related difficulties in BPD. Across the reported studies, altered electrophysiological responses to affective cues in HBT individuals were observed in the context of mostly absent behavioural differences (e.g., self-report ratings, accuracy, reaction time) between groups. This disparity, while previously noted in some BPD research (Koenigsberg et al., 2009a) highlights the utility of brain imaging techniques and the use of multi-method assessment when studying emotional responding in BPD.

Findings across the present studies described here show that individuals with high levels of BPD traits differ from those with low levels of BPD traits in their electrophysiological responses across affective stimuli, including faces and emotion-laden scenes. Specifically, evidence for attentional biases as indexed by enhanced modulation of early ERP responses was evident among HBT individuals. This hyper-responsiveness appears specific to certain types of stimuli, including facial expressions bearing greater social or personal relevance, particularly angry expressions, as well as high arousal negative images, which may also be perceived as personally threatening. These findings also suggest that individuals with BPD traits show dampened cortical responses to affective cues which are less arousing and may not pose an immediate or direct personal threat (e.g., fearful faces and low arousal/sad scenes). Preliminary evidence suggests that these modulations may be present early in the processing stream and impact automatic attentional capture mechanisms. It is proposed that the types of affective cues that HBT individuals respond to are likely motivationally relevant and reflect domain-specific concerns such as social relevance and interpersonal threat. These may be particularly relevant given that individuals with BPD are generally sensitive to rejection (e.g., Miano et al., 2013). Such concern-specific biases have been observed in other clinical disorders such as depression and anxiety (Williams et al., 1996), though the concerns are specific depending on the disorder. The current studies not only provide electrophysiological evidence to support findings of attentional biases in BPD (e.g., Arntz et al., 2000; Sieswerda et al., 2007), but they also expand on the literature in showing evidence for biases in a sub-clinical BPD group using facial expressions and evocative images.

These findings highlight the importance of acknowledging different types of affective cues which are experienced as threatening or personally relevant among HBT individuals. The current findings raise the possibility of implementing treatment strategies which focus on identifying and recognizing affective information which they currently fail to attend to in an appropriate manner. This includes learning to recognize and appreciate more subtle cues (low arousal information) and facial expressions which may not pose an immediate personal threat (e.g., fearful faces), but remain important for social communication and interpersonal success. These findings also speak to the continued need for developing strategies that will help individuals with BPD cope with their emotional sensitivity, particularly their hyper-responsiveness to cues of high personal threat.

With regard to specific ERP components, the early anterior positivity (EAP) effect showed a differential response to affective stimuli and task depending on group membership. For control participants, the EAP appears sensitive to top-down cognitive influences and conscious attentional deployment towards affective cues. Consequently, the EAP indexes more conscious processes associated with affective stimuli processing and is modulated in the intended direction with greater EAP positivity enhancements observed for emotional cues deemed relevant to the task at hand. In contrast, for HBT individuals, the EAP appears more sensitive to automatic bottom-up responses to personally relevant affective cues. As such, greater EAP positivity enhancements were observed in conditions where the emotional cues were not subject to top-down cognitive control mechanisms.

One possibility is that the EAP and its brain source in prefrontal cortex reflects a stage in emotion processing where bottom-up affective responses and top-down cognitive responses are integrated and may reflect biased processing towards the former in the HBT group, and towards the latter among the control group. Potential regions identified which may contribute to the effects observed include the ACC, which is known for integrating emotional and cognitive information (Bush et al., 2000). Additionally, the ventral PFC/Temporal pole regions, which play important role in the social and emotional processing of information, as well as a learning and decision-making (Olson et al., 2007; Hornak et al., 1996), may be relevant, particularly with regard to the regulatory processes involved in emotion regulation. The frontal regions in particular have been identified as showing abnormal functioning in a number of imaging studies (e.g., Lang et al., 2012; Koenigsberg et al., 2009a; Schmahl & Bremner, 2006).

Later elaborative components, specifically the late positive potential (LPP) evoked responses, were helpful in indexing the success of intentional down-regulation of affective cues. As such, control participants showed successful down-regulation of LPP amplitudes for LA stimuli, while HBT individuals demonstrated difficulties in reducing their emotional response to these cues. In Study 1, the LPP showed an undifferentiated response to stimuli type among the HBT group, possibly indexing the exhaustion of cognitive resources. While both studies show group differentiation within the LPP, providing evidence for altered processing in the HBT group, the later elaborative effects appear milder compared to the earlier saliency effects observed. These findings highlight the importance of not only examining explicit emotion processing and intentional down-regulation, but also highlight the benefits of investigating the implicit mechanisms involved in emotion processing which are more susceptible to automatic, bottom-up processes. As such, covert processing of affective cues can reveal attentional biases and preferential processing towards particular types stimuli, as was observed across the two studies described here.

The current studies were focused on emotion processing within the visual domain. As such, visual affective cues were manipulated with the intent of capturing relevant ERPs associated with emotion processing, in particular with effects associated with emotional salience among individuals with high and low levels of BPD traits. Though the focus of this work was not on linguistic factors, it is possible that early and late ERP effects may reflect, at least in part, underlying levels of linguistic or conceptual analysis of the stimuli rather than the processing of emotional salience per se. Future studies may wish to explore the contribution of language factors in the processing of emotion cues among BPD individuals.

While studies using ERPs among BPD have been limited thus far, the few existing studies have focused on later elaborative ERP components (e.g., LPP). The current studies highlight the importance of not only looking at the later components associated with the cognitive processing of affective cues, but also suggest that examining early ERPs over the frontal and posterior scalp which can provide insights into the more automatic processes occurring among HBT individuals, which would be missed with other less time-sensitive tools such as fMRI.

The current studies suggest hyper-responsiveness to high arousal negative cues, which are presumably particularly personally relevant and convey a personal threat. However, further delineating the types of information that BPD individuals are particularly sensitive to is warranted. Moreover, combining functional neuroimaging with electrophysiological techniques would be particularly helpful in elucidating the neural substrates associated with the altered ERPs observed here. The evidence of ERP differences in our sample is interesting as it provides evidence for differences which are already present in a sub-clinical population. However, replication in these findings within a BPD group will help extend these findings within a clinical population.

6.1. Final Conclusion

In conclusion, the studies described here support the use of electrophysiological tools in studying affect processing and dysregulation in high BPD trait individuals. Both experiments provide support for a model of abnormal functioning of a neural network sensitive to personally threatening information in BPD and offer evidence for altered processing within early, possibly pre-attentive stages of information processing over the anterior scalp. These findings provide important clues for the understanding of neural mechanisms underlying emotion dysregulation difficulties in BPD. The observed ERP findings occurred in the context of mostly absent behavioural findings in this sub-clinical group of BPD, highlighting the benefits of utilizing multi-method assessment. Together, these studies contribute to the limited data currently available on the time-course of emotion processing and regulation mechanisms which may be aberrant in BPD.

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Appendix A.

Experiment Images

High Arousal Images

Low Arousal Images

Appendix B.

Emotion Modulation Instructions

Allow Instructions

During this block, you will see only negative (or only neutral) pictures and be instructed to allow yourself to feel the emotion you are currently experiencing in response to the picture. Before each picture, the word **ALLOW** will be presented on the screen to remind you what to do. By allow we mean allow your natural response to the picture to take place. Don't try to minimize or enhance the emotion. Simply allow yourself to feel it. For example, if you are asked to allow your responses to a picture of a car accident, you would allow your natural, instinctive reaction of shock to take place without attempting to alter it. Do not think of something unrelated that alters your experience. Don't think, just feel. So, when you see the word **ALLOW**, prepare yourself to feel the emotion as it invoked by the pictures that you see. Prepare yourself to allow your natural emotional reaction to take place.

Reduce Instructions

During this block, you will see only negative pictures and be instructed to reduce the emotion you are currently feeling in response to the picture. Before each picture, the word **REDUCE** will be presented on the screen to remind you what to do. By reduce we mean that we would like you to decrease the intensity of the emotion you feel in response to the picture. Try to feel the emotion less strongly. For example, think how a doctor enters an emergency room. The doctor knows that he/she will be entering a negative environment and prepares him/herself to deal with that by decreasing the negative emotions he/she might feel when he/she enters the room. So, when you see the word **REDUCE**, prepare yourself to decrease the intensity of whatever negative emotion you might feel in response to the picture. Prepare yourself to feel the negative emotion less strongly. Reduction of an emotion is not equivalent to replacing that emotion with a different one. Do not generate thoughts and images that are completely unrelated to the presented stimulus in order to produce a different emotion to compete with or replace your initial emotional response to the picture. For example, if you are asked to reduce fear in response to a picture of a poisonous snake, do not think of something unrelated that generates a positive emotion (e.g., the end of finals week and beginning of winter holiday). However, feel free to focus on a positive aspect of the picture or on a possible positive outcome of the situation in the picture. For example, you can imagine that the poisonous snake is about to be killed, which may help decrease fear you may feel in response to the picture.