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Literature Reviews

Psychophysiological Research of Borderline Personality Disorder: Review and Implications for Biosocial Theory

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Abstract

According to the Biosocial theory, Borderline Personality Disorder (BPD) is developed by a biological predisposition to hyperarousal and hyperreactivity combined with an invalidating environment. Although widely supported by subjective measures, the impaired insight present in BPD may skew results, and thus psychophysiological measures have been suggested as an alternative method of examining possible biological differences in BPD. The current review aimed to critically assess psychophysiological research of BPD by electronic searching of relevant databases, with 22 articles meeting inclusion criteria. Results showed that in contrast to the hyperarousal proposed in the Biosocial theory, BPD was associated with hypoarousal and hyporeactivity to non-emotionally valenced stimuli. However, there was also evidence of BPD hyperreactivity towards negatively valenced stimuli, and impaired habituation during stressor tasks. As current psychophysiological results were inconsistent, it has been postulated that there may be possible subtypes of BPD. Further, evolutionary-based theories do not appear to adequately explain the complexity of emotion dysregulation in BPD, thus the Emotional Coherence theory has been proposed as an alternate method of conceptualising the role of psychophysiology in BPD. From the lack of clear or consistent findings, further research in the area appears necessary to determine the role of psychophysiology in BPD.

Keywords: Borderline Personality Disorder, psychophysiology, Emotion Dysregulation, arousal, reactivity

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The main theory which has dominated both academic and clinical spheres of the diagnosis, assessment and treatment of Borderline Personality Disorder (BPD) is the Biosocial theory by Linehan (1993), which has become the principal model of BPD and has spurred substantial research and clinical progress in the area. The Biosocial theory suggests that the core feature of BPD is emotion dysregulation, which is developed from a physiological vulnerability to hyperreactivity and hyperarousal, combined with an invalidating childhood environment where individuals were repeatedly invalidated by significant others, often through being ignored or punished for emotional expression. The Biosocial theory argues that individuals with BPD show emotion dysregulation in three key areas: a) high baseline arousal b) hyperreactivity, with a reduced threshold for emotional reactivity to environmental stimuli, and c) impaired habituation, with prolonged hyperarousal and a slower return to baseline arousal (Linehan, 1993).

The Biosocial theory's emphasis on hyperarousal, hyperreactivity and a slow return to baseline is widely supported by data from self-report measures (Chapman, Dixon-Gordon, Layden, & Walters, 2010; Chapman, Leung, & Lynch, 2008; Cheavens & Heiy, 2011; Domes et al., 2006; Ebner-Priemer & Sawitzki, 2007; Glenn & Klonsky, 2009; Kuo & Linehan, 2009; Links, Eynan, Heisel, & Nisenbaum, 2008; Meyer, Ajchenbrenner, & Bowles, 2005; Nigg, Silk, Stavro, & Miller, 2005; Reisch, Ebner-Priemer, Tschacher, Bohus, & Linehan, 2008; Russell, Moskowitz, Zuroff, Sookman, & Paris, 2007). However, as self-report measures are subjective, results can be skewed by multiple biases, such as mood state, accuracy of memories, and impression management (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005; Podsakoff et al., 2003). Particularly pertinent to research of BPD, self-report measures require the individual to be able and willing to verbally describe their emotional experience, and also be able to identify, recognise and accurately report a plethora of emotions, all of which is suspected to be impaired in those with BPD (Cole, Llera, & Pemberton, 2009; Putnam & Silk, 2005). Thus, objective measures of psychophysiological indicators have been considered as an alternate measure to investigate potential hyperarousal and hyperreactivity in BPD.

Therefore, the current review will explore whether the Biosocial theory is supported by psychophysiological research of BPD, through measures of baseline arousal, reactivity to both non-emotional and emotional stimuli, and the potential persistence of hyperarousal. This research will then be compared to self-report data, discussed in light of the Biosocial theory, and whether this theory provides a comprehensive conceptualisation of both the self-reported symptoms and psychophysiological characteristics of BPD.

According to the current edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) (American Psychiatric Association [APA], 2000), BPD is an Axis II disorder characterised by a pattern of instability in mood, behaviour and interpersonal relationships, with a fragile/ unstable identity (Meares, Gerull, Stevenson, & Korner, 2011; Paris, 2005). It is primarily diagnosed in women (Friedel, 2006; Holm & Severinsson, 2008), and has a pervasive and severe impairment on psychosocial functioning (Anderson & Crump, 2004; Bender & Skodol, 2007; Hill et al., 2008; Holm & Severinsson, 2008), a high rate of comorbidity with Axis 1 diagnoses (Pantoularis et al., 2008; Zanarini, Frankenburg, Hennen, Reich, & Silk, 2004), increased psychiatric hospitalisation (Van Kessel, Lambie, & Stewart, 2002) and higher rates of suicide than other diagnoses from the DSM-IV-TR (Commons Treloar & Lewis, 2007; Friedel, 2006; Holm & Severinsson, 2008; Linehan, 2000).

BPD is typically evident by intense and rapid shifts of emotions, alternating between dysphoria, irritability, dissociation, anger, hostility, and panic (Hill et al., 2008; Kernberg & Michels, 2009; Trull et al., 2008). These emotions are experienced as extremely intense, with individual reporting heightened sensitivity and hypervigilance to both their internal and external realities, often displayed by behavioural impulsivity (Kernberg & Michels, 2009; Russell et al., 2007; Stanley & Wilson, 2006). In contrast to this impulsivity, BPD is often found alongside chronic Dysthymia, which is a dampening of mood and affect, and is related to the self-injurious and suicidal behaviours frequently found in BPD (Chapman et al., 2010). At its core, theorists assert that BPD is a distorted, fragile and fragmented sense of self with self-loathing, an excessive level of shame, and beliefs of malevolence (Bender & Skodol, 2007; Holm & Severinsson, 2008).

Although individuals with BPD report experiencing high emotional intensity (Links et al., 2008; Reisch et al., 2008), these emotional states are very transient, frequently fluctuating every few hours or days depending on environmental stimuli (Holm & Severinsson, 2008). Thus, in an attempt to cope with and control extreme emotional states, individuals with BPD often will engage in impulsive and maladaptive behaviours, such as being involved in abusive

relationships, using physical aggression and violence, misusing substances and engaging in frequent suicidal and self-injurious behaviours (Hill et al., 2008; Matsumoto et al., 2008; Trull et al., 2008).

The Physiology of Arousal and Reactivity

The Autonomic Nervous System (ANS) is the intrinsic evolutionary component of the nervous system responsible for responding to environmental stimuli, and is divided into the Parasympathetic Nervous System (PNS) and the Sympathetic Nervous System (SNS) (Ulrich-Lai & Herman, 2009). The PNS aims to conserve energy and maintain homeostasis; whilst the SNS aims to mobilise the body during activity. The process of neuroception occurs when the individual identifies a threat and activates the relevant system. Following neuroception, the SNS can initiate either defensive action, evidenced in fight-or-flight behaviours; or defensive immobility, where the individual 'freezes', and is automatically mobilised, hyperattentive, and primed to respond to threats. For some individuals, this freezing behaviour may occur when there is the absence of an escape option, as freezing can enhance survival (Lang, Davis, & Ohman, 2000; Roelofs, Hagenaars, & Stins, 2010).

Although all humans are believed to have evolved with these systems, the Biosocial theory argues that these systems are maladaptive in BPD. The theory argues that the SNS is overused, and therefore those with BPD report hypervigilance, impulsivity and frequent emotional lability (Linehan, 1993). Physiologically, it is postulated that compared to the general population, those with BPD have baseline hyperarousal, and hyperreactivity to stimuli. Individuals with BPD are also expected to show impaired habituation with persistent hyperarousal (Linehan, 1993). Thus, the Biosocial theory argues that the SNS is chronically overused and thus the individual is constantly in preparation of a fight-or-flight response.

Given the dominance of the Biosocial theory in both assessment and treatment, research has begun to study a potential biological basis for BPD. Research examining psychophysiological characteristics of BPD has focused on markers of arousal and patterns of reactivity. Psychophysiological measures are those which measure activity in the ANS and include: a) Heart Rate (HR), which refers to heart beats, with increased HR related to increased SNS activity; b) Skin Conduct Response (SCR), which measures skin conductance determined by the level of sweat secretion, with greater sweat secretion associated with increased SCR, and therefore increased SNS activity; c) Respiratory Sinus Arrhythmia (RSA), the measure of fluctuations in heart beats after respiration, with greater fluctuations indicating greater SNS activation; d) Eye blink, which appears raised during SNS activation, and is generally considered the most reliable measure of SNS activity (Lang et al., 2000); and e) Blood Pressure (BP), which measures the pressure from circulation of the blood in the arteries, and is generally elevated during SNS activation (Rosenthal et al., 2008).

Psychophysiological measures are believed to be good indicators of SNS activity, arousal and reactivity to stimuli, and have been used with a variety of populations, including those with Axis I (Kuo & Linehan, 2009; Schmahl et al., 2004; Weber et al., 2009) and Axis II disorders (Herpertz et al., 2000; Lobbestael, Arntz, Cima, & Chakhssi, 2009). Research using psychophysiological measures in BPD is sparse and has only begun receiving attention in the last 15 years (Rosenthal et al., 2008).

Rosenthal et al (2008) provided an overview of psychophysiological, neuroimaging and self-report research to examine the possibility of a physiological predisposition towards hyperarousal and hyperreactivity in BPD. It was concluded that findings were mixed and that the research body was at an early stage of development, and thus further research was needed. Since Rosenthal and colleagues' (2008) review, the area of psychophysiological

indicators in BPD has steadily begun to increase, with a further 17 empirical studies published. Hence, it appears timely to provide a dedicated review of the physiological research examining a potential biological basis for BPD. Therefore, the purpose of the current review is to compare and contrast empirical research investigating biological hyperarousal and hyperreactivity to stimuli in individuals with BPD, and discuss these results in light of the Biosocial theory.

Method

This literature review was conducted through electronic searching of ProQuest, Medline, PsycINFO and EBSCO databases for relevant articles. Key words used in the search included: Borderline Personality Disorder, Psychophysiological response, Psychophysiology, Skin Response, Skin Conduct Response, Heart Rate, Startle response, Respiratory Sinus Arrhythmia, Eye blink, Blood Pressure and Emotional stimuli, which were used both separately and in combination with one another. A manual search of significant references in the topic area was also used.

Across these databases, 1,298 articles were found, which were then narrowed to publications that had been published in academic, peer-reviewed journals, and had used at least one psychophysiological measure. Participants included those who were diagnosed with BPD, reached criteria for a BPD diagnosis, or who had clinically significant BPD features. From this narrowing, 22 articles were included in this review, which have been tabulated in Appendix (Table A1). All research collected was critically assessed by the first author, in areas such as the sampling and recruitment of participants, reliability of assessment and data analysis and the validity of research conclusions and generalizations made, with final inclusion of articles dependent on the agreement of both authors. This method of review has been used in previous literature reviews of BPD (Holm & Severinsson, 2008).

Results

In the following section, the postulate of baseline hyperarousal will be reviewed, and it will be suggested that hypoarousal, rather than hyperarousal, is apparent in baseline levels of those diagnosed with BPD. From this, psychophysiological reactivity in BPD will be reviewed, with specific focus on whether the emotional valence of a stimuli affects reactivity. And lastly, it will be examined whether habituation may have a role in arousal and reactivity in BPD, followed by a discussion of the potential theoretical and research implications of these findings.

Baseline Arousal in BPD

Baseline arousal is the level of psychophysiological arousal before the presence of a stimulus, and is considered to reflect the overall resting physiological state of an individual (e.g., the baseline SCR before the presentation of a hypothesised emotionally-salient stimulus) (Ebner-Priemer et al., 2009). The Biosocial theory postulates that individuals with BPD have a higher baseline level of arousal, which from self-report measures has been widely supported (Bland, Williams, Scharer, & Manning, 2004; Cheavens & Heiy, 2011; Ebner-Priemer & Sawitzki, 2007; Jacob et al., 2010; Kuo & Linehan, 2009; Links et al., 2008; Meyer et al., 2005; Reeves, James, Pizzarello, & Taylor, 2010; Reisch et al., 2008; Russell et al., 2007; Selby, Anestis, Bender, & Joiner, 2009). Research has shown significantly greater overall self-reported baseline emotional intensity of individuals with BPD (Ebner-Priemer & Sawitzki, 2007; Links et al., 2008) compared to controls (Bland et al., 2004; Jacob et al., 2010; Kuo & Linehan, 2009; Reisch et al., 2008; Russell et al., 2007), and those with Axis I (Cheavens & Heiy, 2011; Kuo & Linehan, 2009; Stanley & Wilson, 2006), and Axis II disorders (Meyer et al., 2005). Thus self-report data lends support for the theorised biological vulnerability of those with BPD towards greater baseline arousal.

In contrast to self-report data, psychophysiological data of arousal have shown that during baseline, those with BPD show a significantly lower HR than controls (Austin, Riniolo, & Porges, 2007; Kuo & Linehan, 2009; Lobbestael et al., 2009; Weinberg, Klonsky, & Hajcak, 2009; Schmahl et al., 2004). They also show significantly lower RSA (Kuo & Linehan, 2009; Weinberg et al., 2009), and BP when compared to controls during baseline (Lobbestael et al., 2009; Schmahl et al., 2004). Thus, data using HR, RSA and BP measures indicate a trend towards lower baseline arousal, in contrast to both self-report data and the Biosocial theory.

Although research using baseline measurements of HR, RSA and BP suggest hypoarousal in BPD, results of baseline SCR are mixed. Kuo and Linehan (2009) measured physiological arousal and reactivity of 20 individuals diagnosed with BPD, to that of 20 individuals diagnosed with Social Anxiety Disorder and 20 controls, who were all age-matched. Participants engaged in a 5 minute baseline, during which the BPD group showed a significantly higher baseline SCR compared to controls (Kuo & Linehan, 2009), suggesting increased SNS activity during baseline.

However, other studies using SCR during baseline have found no significant differences between those with BPD and controls (Herpertz et al., 2000; Herpertz et al., 2001; Lobbestael et al., 2009; Schmahl et al., 2004; Taylor & James, 2009), and those with Axis I (Schmahl et al., 2004), and Axis II disorders (Lobbestael et al., 2009; Taylor & James, 2009). There are multiple potential reasons for this inconsistency. Firstly, Kuo and Linehan's (2009) sample included participants who were taking psychoactive medications, and comorbid anxiety disorders were also permitted in the BPD group. Both psychoactive medications and comorbid anxiety disorders could potentially influence psychophysiological measures, particularly anxiety disorders which are associated with hyperarousal (Kuo & Linehan, 2009), which could confound psychophysiological results, with findings unlikely to be a true representation of BPD.

In summary, although Kuo and Linehan's study (2009) reported SCR hyperarousal, other research using SCR has consistently found no significant differences in baseline SCR (Herpertz et al., 2000, 2001; Lobbestael et al., 2009; Schmahl et al., 2004; Taylor & James, 2009). Thus, overall it appears that research measuring baseline arousal indicates those with BPD have a significantly lower baseline arousal than either controls, or those with Axis I or Axis II disorders. Interestingly, these results are in contrast to the hyperarousal postulated in the Biosocial theory, and findings from self-report measures. Hence, although self-report data suggest BPD is associated with hyperarousal, physiologically BPD is associated with baseline hypoarousal. Hence, the divergence between subjective and objective measures of baseline arousal in BPD requires further investigation.

Psychophysiological Reactivity in BPD

Given the level of impulsivity in BPD, the Biosocial theory considers that individuals with BPD not only are hyperaroused, but are also highly reactive to environmental stimuli. Hyperreactivity has been indicated in BPD samples through both self-report (Bland et al., 2004; Cheavens & Heiy, 2011; Ebner-Priemer & Sawitzki, 2007; Jacob et al., 2010; Links et al., 2008; Reisch et al., 2008; Russell et al., 2007) and also laboratory studies using decision-making and learning tasks (Chapman et al., 2008, 2010; Domes et al., 2006; Nigg et al., 2005). However, psychophysiological indicators are less clear.

Reactivity to Non-Emotionally Valenced Stimuli — Stimuli can be either non-emotionally valenced, (e.g., aversive noise), or emotionally valenced with stimuli linked to prior memories (e.g., scripts featuring abandonment). Research using non-emotional stimuli (e.g., auditory stimuli) has found no significant differences in reactivity using

measures of SCR (Ebner-Priemer et al., 2009; Herpertz & Koetting, 2005; Mauchnik, Ebner-Priemer, Bohus, & Schmahl, 2010; Taylor & James, 2009), HR (Taylor & James, 2009) or eye blink (Herpertz & Koetting, 2005).

Research using aversive auditory stimuli (e.g., startling tones), has shown that individuals with BPD have increased SCR to stimuli (Grootens et al., 2008), and increased eye blink responsivity (Ebner-Priemer et al., 2005). However in contrast to these findings, other studies which also used auditory stimuli found that the BPD group showed delayed SCR, although no significant differences in SCR amplitude when compared to controls, indicating that although their response was delayed, this response was not significantly different to controls (Williams, Sidis, Gordon, & Meares, 2006). This suggests that although those with BPD showed a delayed response to stimuli, they did not show any greater or lesser level of reactivity than controls.

This inconsistency between findings using auditory stimuli could be partially explained by the nature of Williams et al.'s study (2006). In Williams and colleagues (2006) study, an auditory discrimination task was used, and thus over time individuals with BPD could become habituated to the auditory stimuli, unlike research (Ebner-Priemer et al., 2009; Grootens et al., 2008) which used aversive intermittent or startling tones as stimuli. Thus, aversive auditory stimuli are likely to have different results to that of an auditory discrimination task, where psychophysiological reactivity is likely to be influenced by habituation.

These results suggest that in general, individuals with BPD do not show significant differences in reactivity to non-emotional stimuli when compared to controls, although this is limited only to auditory stimuli, and therefore further research is needed to investigate reactivity to other non-emotional stimuli.

Reactivity to Emotionally Valenced Stimuli — Given the mixed findings of non-emotionally valenced stimuli, some researchers have queried whether the type of stimuli and its emotional salience may impact the psychophysiological reactivity of individuals with BPD. Picture slides from the International Affective Picture System (IAPS) have been used to examine whether those with BPD show differences in reactivity to different types of photographic slides (Herpertz et al., 1999). In the IAPS, standardized slides are categorised into pleasant (e.g., smiling infant, food), unpleasant (e.g., snakes, violent deaths) or neutral slides (e.g., common household objects), and have been used with both Axis I (Weber et al., 2009) and Axis II (Herpertz et al., 2000) disorders.

The IAPS was first used in BPD research that examined psychophysiological arousal and reactivity in BPD compared to controls (Herpertz, Kunert, Schwenger, & Sass, 1999). Psychophysiological measures included SCR, HR and eye blink. Research found that when compared to controls, those with BPD showed no significant differences in either SCR or HR reactivity when aggregated across the task. However, when results were analysed based on the emotional valence of stimuli, the BPD group showed significantly greater SCR and HR when viewing unpleasant slides, above and beyond that of the control group. This suggests that in BPD the level of physiological reactivity is dependent on the emotional valence of a stimulus (Herpertz et al., 1999). This result has been replicated in a number of studies using IAPS in those with BPD, using measures of eye blink reactivity (Dziobek et al., 2011; Hazlett et al., 2007). Similar results using RSA as a measure of reactivity have also been found in research of adolescent females who engaged in frequent self-injury and who showed early signs of BPD (Crowell et al., 2005).

Following Herpertz and colleagues (1999) study, Herpertz et al. (2000) administered the IAPS to 70 females; 24 diagnosed with BPD, 23 with Avoidant Personality Disorder (AvPD), and 27 controls. Psychophysiological measures included HR, SCR and eye blink, with results showing no significant differences on any psychophysiological measures between the BPD group compared to either the AvPD or control group when aggregated across the

study, consistent with previous research (Herpertz et al., 1999). However, when the stimuli's emotional valence was analysed, individuals with BPD did not show any significant hyperreactivity to unpleasant slides, contradictory to previous research (Herpertz et al., 1999). Interestingly, significant differences between the groups became evident during pleasant slides, with the BPD group showing significant deceleration when viewing pleasant slides, in opposition to the HR acceleration of both the control and AvPD groups (Herpertz et al., 2000). This lowered SNS activity during pleasant slides was consistent with self-report data, with the BPD group reporting significantly lower levels of arousal during pleasant slides, which was consistent with previous self-report data of BPD (Herpertz et al., 1999).

From these results, it appears that individuals with BPD are no more reactive in general than controls (Dziobek et al., 2011; Hazlett et al., 2007; Herpertz et al., 1999), or those with Axis II disorders (Herpertz et al., 2000), although when data are analysed via the stimuli's emotional valence, those with BPD show significantly greater psychophysiological reactivity to unpleasant stimuli, as measured by eye blink, RSA and SCR (Dziobek et al., 2011; Hazlett et al., 2007), and significantly lower reactivity to pleasant stimuli (Herpertz et al., 1999, 2000). From these findings, it could be argued that individuals with BPD appear primed to focus on negative stimuli, consistent with research showing those high in BPD features more accurately interpret negative facial expressions than controls, with a bias towards over attributing negativity in non-negative stimuli (Scott, Levy, Adams, & Stevenson, 2011). This preoccupation with negatively emotionally valenced stimuli, and impaired in enjoyment of pleasant stimuli may be implicated in the self-reported chronic dysphoria in BPD (Cheavens & Heiy, 2011; Kuo & Linehan, 2009; Links et al., 2008; Meyer et al., 2005; Reisch et al., 2008; Russell et al., 2007; Selby et al., 2009; Stanley & Wilson, 2006).

More recently research extended the IAPS by pairing slides with acoustic startles (Vitale & Newman, 2012). Participants included prisoners reporting low and high BPD features on the Diagnostic Interview for Borderlines (DIB). Results showed no significant differences between groups, with the group classified as high in BPD symptoms failing to show greater reactivity to negative stimuli, contrary to previous results (Dziobek et al., 2011; Hazlett et al., 2007; Herpertz et al., 1999, 2000). However, those with high-BPD features showed significant slowing of blink sensitivity when viewing pleasant slides. It was concluded that this slowing may be related to the focussed attention required to interpret positive, and thus less familiar stimuli (Vitale & Newman, 2012). These findings contrast with previous studies using the IAPS (Dziobek et al., 2011; Hazlett et al., 2007; Herpertz et al., 1999, 2000), although may be related to the decreased levels of self-reported pleasure (Herpertz et al., 1999, 2000), and psychophysiological deceleration (Herpertz et al., 2000) in response to pleasant stimuli. However, these results need to be taken with caution, as Vitale and Newman's (2012) participants were derived from incarcerated and non-clinical populations, and thus may not be representative of the wider clinical BPD population.

Although research using the IAPS has shown a general trend towards hyperreactivity to unpleasant stimuli (Dziobek et al., 2011; Hazlett et al., 2007; Herpertz et al., 1999), with some evidence for impaired reactivity to pleasant stimuli (Herpertz et al., 1999, 2000), some critics have argued that the IAPS contains generalised images which are unlikely to be emotionally provocative of the diagnosed BPD individuals' psychology, and thus it is postulated that scripts featuring schemas believed pertinent to BPD, namely rejection and abandonment may be more salient and thus provoke the theorised hyperreactivity of BPD.

Research by Limberg, Barnow, Freyberger, and Hamm (2011) used scripts containing either general emotional content or schema-specific content, particularly tailored to evoke the abandonment or rejection schemas. Within-

groups analysis showed that BPD individuals showed significantly greater reactivity, as measured by HR and SCR, during the disorder-specific scripts compared to the general emotion-inducing scripts. Further, between-groups analysis indicated that the BPD group showed significantly greater reactivity to both disorder-specific and general emotion-inducing scripts, when compared to controls (Limberg et al., 2011). It was concluded that those with BPD appear to be more hyperreactive to scripts which are considered salient to BPD symptomatology than general emotion-inducing scripts, and this difference is significantly greater to that of controls (Limberg et al., 2011).

Following the hyperreactivity associated with schema-specific stimuli, researchers have queried whether there may also be differences in psychophysiological reactivity to imagery featuring self-injury, suicide attempts and accidental deaths (Welch, Linehan, Sylvers, Chittams, & Rizvi, 2008). This follows the postulate that self-injury may elicit different levels of reactivity to that of suicide attempts and accidental deaths, with self-injury one of the diagnostic criteria of BPD (APA, 2000). Results showed increased SCR following scripts featuring self-injury, although found no difference in psychophysiological reactivity to scripts featuring suicidal imagery. It was concluded that self-injury appears to be more emotionally provocative for those with BPD, than stimuli featuring suicide attempts (Welch et al., 2008). Given the frequent self-injurious behaviour in BPD, this finding suggests that self-injury elicits greater reactivity to that of suicide attempts, which could have multiple theoretical and clinical implications for this client group.

Given the implications of potential hyperreactivity to self-injurious stimuli, researchers have queried whether the significantly high rates of trauma history among BPD samples may be a confounding variable in psychophysiological research (Paris, 2005). Research by Schmahl et al. (2004) attempted to reduce the potential impact of a trauma history on physiological reactivity using a sample which consisted of all participants reporting a history of childhood physical and/or sexual abuse; with the group delineated depending on diagnosis, either into the BPD group, Post Traumatic Stress Disorder (PTSD) group, and those with no psychiatric diagnosis serving as a control group. Stimuli consisted of scripts developed by incorporating the individual's prior disclosure of their childhood experiences, featuring trauma and abandonment, into personally-salient narratives. These narratives were then read to participants' several days later. In contrast to hypotheses, findings showed no difference between groups, with a non-significant although slight increase of SCR of the BPD group to the scripts featuring abandonment (Schmahl et al., 2004). This non-significant result was unexpected given previous research findings using schema-based scripts which elicited the proposed BPD hyperreactivity (Limberg et al., 2011). However, Schmahl and colleagues' (2004) research had a number of limitations, such as a small sample size (10 in the BPD group), and unequal sample sizes (10 BPD, 14 PTSD, 16 controls), which may have contributed to this non-significant result.

In addition to these limitations, it could be argued that any such disclosure which features details of an individual's trauma history is likely to elicit a degree of physiological reactivity (Paris, 2005), and hence reactivity of participants was not influenced by diagnosis, rather by the commonality of a trauma history as previously theorised (Schmahl et al., 2004). However, as Schmahl and colleagues (2004) research did not include a control group, with no reported trauma history, this is merely a possibility. Thus, rather than the diagnosis of BPD being characterised by hyperreactivity, it is possible that a history of trauma is a confounding variable which could induce hyperreactivity, and skew psychophysiological results of the BPD population.

In summary, from the current research of reactivity, it appears that those with BPD are no more physiologically reactive to general stimuli than controls. However, they show greater reactivity and increased focus to negatively

valenced stimuli, with some evidence for SNS deceleration and lowered self-reported enjoyment of pleasant stimuli (Gunderson, 1996; Stanley & Wilson, 2006). Further, when the stimuli contained more salient information, such as BPD-relevant schemas of rejection and abandonment, there appears to be a general, although non-significant increase in physiological reactivity. Research investigating the influence of past trauma provides some indication that trauma history, rather than a BPD diagnosis, may explain the theorised hyperreactivity, and potentially behavioural impulsivity in BPD. However, overall, it appears that BPD are no more physiologically reactive to general stimuli than controls, in opposition to the Biosocial theory of BPD (Linehan, 1993).

The Role of Habituation in BPD Arousal and Reactivity

From the current research of baseline arousal and reactivity, there appears to be little psychophysiological evidence supporting the Biosocial theory. However, the third component of the Biosocial theory argues that individuals with BPD are not only hyperaroused and hyperreactive, but remain hyperaroused for longer, having a slower return to baseline arousal levels. Hence, it is theorised that habituation, which is a reduction in arousal over time in response to the continued presence of a stimulus, will be impaired in those with BPD (Linehan, 1993).

This proposed impaired habituation was evident in research by Austin, Riniolo, and Porges (2007), who used a performance task where participants watched three 10 minute emotion-inducing films followed by a series of questions regarding each film. In contrast to the habituation trajectory as seen in controls, the BPD group showed a lack of habituation, with increased arousal, as measured by RSA, in response to prolonged exposure to emotion-inducing films. This increase in SNS activity across the task suggests that the BPD group began to physiologically engage in fight-or-flight responses, rather than the expected habituation with signs of SNS deactivation as seen in controls (Austin et al., 2007). Further research using emotion-induction tasks with individuals diagnosed with BPD have also shown impaired habituation, with those with BPD showing a slower habituation than controls (Dziobek et al., 2011). Similar results were found in other research using learning tasks which used auditory tones paired with inkblots, which showed impaired habituation, as indicated by SCR (Ebner-Priemer et al., 2009).

Further research investigating habituation in BPD using social stressor tasks have shown that those with BPD had significantly increased HR across the task, suggestive of increased SNS activity (Weinberg et al., 2009), which was in contrast to controls, who showed reduced SNS activity across the task. Although findings of impaired habituation are consistent across research using performance tasks and the Biosocial theory, these results of increased SNS activity are contradictory to previous studies of general reactivity in BPD (Dziobek et al., 2011; Hazlett et al., 2007; Herpertz et al., 1999, 2000). It has been suggested that this divergence is due to the nature of stimuli used. Thus when the experiment requires task performance, the BPD individual may become hypervigilant to avoid making errors, and therefore will show the theorised hyperreactivity and impaired habituation during these tasks, which is not present in experiments without such stressors or performance elements.

Weinberg and colleagues (2009) concluded that increased SNS activity during performance tasks indicates that individuals with BPD are more likely to revert to the evolutionary fight-or-flight response during stressors. Hence, individuals with BPD remain physiologically aroused for much longer than controls during performance tasks. However, it appears that this hyperreactivity is limited to occurring during performance tasks. Given these findings, it is possible that the hyperreactivity in the Biosocial theory is applicable to BPD, and the divergence with current psychophysiological research may be because the stimuli chosen in previous research does not adequately elicit the theorised BPD hyperreactivity.

Discussion

In conclusion, BPD has long been considered a disorder where individuals are biologically predisposed to emotion dysregulation through baseline hyperarousal, hyperreactivity and impaired habituation. From self-report measures, findings have supported the Biosocial theory, however psychophysiological measures show evidence of hypo-arousal rather than hyperarousal, and significant differences in reactivity between those with BPD and controls. However, there appears to be some evidence of impaired habituation of psychophysiological markers in those with BPD. In summary, these results do not show support for proposed hyperarousal and hyperreactivity in those with BPD, however, do support the theorised impaired habituation described in the Biosocial theory.

Given the mixed results of physiological arousal, reactivity and habituation in BPD, researchers have begun to query whether those diagnosed with BPD are part of a homogenous group, or alternatively the diagnosis of BPD may include multiple symptom trajectories. It is possible that psychophysiological arousal and reactivity re not only dependent on the emotional-valence of the stimulus, but may also be influenced by confounding variables such as trauma and dissociation. Trauma is highly prevalent in those diagnosed with BPD (Yen et al., 2002), and is known to influence psychophysiological measures (Schmahl et al., 2004). Dissociation may be another confounding variable (Ludäscher et al., 2010; Schauer & Elbert, 2010; Stiglmayr et al., 2001; Watson et al., 2006), as the severity of dissociation significantly varies across BPD samples (Ebner-Priemer et al., 2005), and has shown to influence physiological reactivity and habituation (Ebner-Priemer et al., 2005, 2009). Thus, the current Biosocial theory appears relevant, however may not adequately describe all diagnosed with BPD, rather only a subtype of those with BPD, of which dissociation may be a core feature.

Although the potential of a heterogeneous BPD group requires consideration, the current psychophysiological research of BPD can also be considered via the Emotional Coherence theory. This theory argues that inconsistent results of psychophysiological measures across research of both reactivity and arousal suggests that evolutionary models of reactivity/survival are too simplified to adequately address the complexity of emotions (Mauss et al., 2005). It is argued that these theories incorrectly assume that the three components of emotional responsivity, namely experience, physiology and behaviour are coherent and will respond to external stimuli in a functional manner in response to environmental demands. Rather, it is argued that these components are rarely coherent, and respond in multiple ways (Mauss et al., 2005).

Researchers investigated the possible emotional coherence between experiential, behavioural and physiological response systems, with results indicating significant coherence between experiential (self-reported amusement or sadness) and behavioural response systems (facial expressions), although found no significant coherence with psychophysiological measures (Mauss et al., 2005). Thus, although coherence was found between the experiential and behavioural response system, it appears that psychophysiological indicators may not be a comprehensive measure of emotional intensity (Mauss et al., 2005). Further investigation into the potential relationships between the physiological, experiential and behavioural response systems is needed to better understand how the emotion dysregulation in BPD is developed and maintained.

The current psychophysiological research body has multiple implications for the assessment and treatment of BPD. Firstly, the possibility of subtypes (Whewell et al., 2000) which show different arousal and reactivity levels suggest the potential benefits of altering the diagnostic criteria of BPD to encourage more accurate assessment and tailored treatments. Further, research showing hypoarousal, hyporeactivity and impaired habituation suggest

that treatments for BPD need to incorporate gradual exposure to specific emotionally provocative stimuli to encourage habituation, and enhance the emotional coherence between the experiential, behavioural and physiological systems to environmental stimuli in those with BPD.

However as discussed previously, much of the research of physiological arousal and reactivity has a number of limitations including small and/or uneven sample sizes; the use of different diagnostic tests which have different clinical cut-offs (SCID-II; PAI; IPDE; DIB), which can alter who is included into BPD, as discussed by Paris (2007). Further, some samples were derived from non-clinical populations (e.g., university students, incarcerated populations), which may have influenced results, particularly those studies which used the level of BPD features reported to determine inclusion into the BPD groups, rather than obtaining a formal diagnosis of BPD (Dixon-Gordon et al., 2011; Vitale & Newman, 2012). Further, some studies excluded all individuals with comorbid Axis I or II disorders (Austin et al., 2007; Ebner-Priemer et al., 2005, 2009; Limberg et al., 2011), although others incorporated those with comorbid diagnoses into the BPD group (Grootens et al., 2008; Hazlett et al., 2007; Kuo & Linehan, 2009; Limberg et al., 2011; Schmahl et al., 2004; Taylor & James, 2009; Weber et al., 2009; Welch et al., 2008), which may have skewed results. In addition, some studies excluded all individuals who were prescribed psychoactive medications (Hazlett et al., 2007; Herpertz et al., 1999, 2000; Limberg et al., 2011; Mauchnik et al., 2010), although others included these (Kuo & Linehan, 2009; Schmahl et al., 2004; Taylor & James, 2009; Vitale & Newman, 2012), and given the potential dampening of arousal and reactivity associated with these medications, comparisons are limited. As studies were all conducted in laboratory settings, emotion induction may not be provocative of the emotional dysregulation in BPD. In addition, many of the studies only included female participants (Austin et al., 2007; Dixon-Gordon et al., 2011; Dziobek et al., 2011; Ebner-Priemer et al., 2005, 2009; Herpertz et al., 2000; Kuo & Linehan, 2009; Mauchnik et al., 2010; Schmahl et al., 2004; Vitale & Newman, 2012), and thus these findings may not be representative of the psychophysiological markers of males with BPD. Given these limitations, there remains an evident lack of empirically valid and reliable large-scale studies of the physiological arousal and reactivity of individuals with BPD.

This literature review aimed to provide an overview of the current psychophysiological research of hyperarousal and hyperreactivity in BPD, however as with all research there are some limitations. Firstly, the research collected was limited to academic peer-reviewed journals, and thus results which may have been non-significant are unlikely to be published, and therefore any analysis of published articles may be skewed. In addition, the research was limited to psychophysiological data, which excludes neurological research of arousal and reactivity in BPD, and thus conclusions are limited to psychophysiological response systems. Hence, this review needs to be considered within the wider research body of emotion dysregulation and BPD.

In summary, although current psychophysiological research findings are mixed, it appears that individuals with BPD tend to be generally hypoaroused, and are no more reactive to stimuli than controls, except when the stimuli are salient to the individual, at which point they show significantly greater reactivity than controls. However, dissociation further complicates the scene, and indicates a possibility of BPD subtypes. Thus further investigation of the potential biological basis of BPD is required, to inform a reconceptualisation of the Biosocial theory and in turn refine both the assessment and treatment of BPD to improve psychosocial outcomes for those diagnosed with BPD.

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Appendix

Table A1

Details of Psychophysiological research of BPD

Study	Sample	Stimuli	Assessment of BPD	Psychophysiological measure	Results
Austin, Riniolo, & Porges (2007)	20 Females: • 9 BPD • 11 control	Emotion-inducing films, followed by questions	DIB-R	RSA	No significant differences between groups during baseline, but BPD group showed opposite trajectory across task to controls.
Dixon-Gordon, Chapman, Lovasz, & Walters (2011)	87 Female students rated on level of BPD features: • 26 High • 32 moderate • 29 low	Problem solving task	PAI	HR, RSA, SCR	Those with high BPD features showed greater SCR during task.
Dziobek et al. (2011)	42 Females: • 21 BPD • 21 control	IAPS; Multifaceted empathy test	MINI; SCID-II; BSL	SCR	No effect of SCR on either condition for BPD or control group.
Ebner-Priemer et al. (2005)	42 Females: • 21 BPD • 21 control	Startling auditory tones	SCID-II	Eye blink, HR, SCR	BPD reported highest dissociation. Higher dissociation was associated with lower eye blink response. BPD group required more trials for habituation.
Ebner-Priemer et al. (2009)	68 Females: • 33 BPD's ranked on dissociation (10 high; 12 moderate; 11 none) • 35 control	Aversive auditory stimuli paired with inkblots	IPDE	SCR	BPD group showed increased SCR to conditioned stimulus. BPD group with high dissociation levels had reduced acquisition of conditioning to controls and those with no dissociation.
Grootens et al. (2008)	• 10 BPD • 13 control (Exp1) • 38 BPD • 28 control (Exp2)	Auditory stimuli (clicks)	SCID-II	Eye blink	BPD group showed greater responsivity to stimuli than controls.
Hazlett et al. (2007)	• 27 BPD (18 M; 9 F) • 21 Control (11 M; 10 F)	Emotion-induction, Auditory and Word stimuli	SIDP-IV	Eye blink	BPD group showed greater startle during unpleasant slides. Overall, BPD group showed slow responsiveness, indicating hypoarousal.
Herpertz & Koetting (2005)	• 28 BPD (4 M; 24 F) • 28 Control (4 M; 24 F)	Auditory Stimuli	IPDE	Eye blink, SCR	No significant differences between groups.

Study	Sample	Stimuli	Assessment of BPD	Psychophysiological measure	Results
Herpertz, Kunert, Schwenger, & Sass (1999)	• 24 BPD • 27 control	IAPS	IPDE	HR, SCR,	BPD group showed greater startle during unpleasant slide. Overall, BPD group showed hypoarousal.
Herpertz et al. (2000)	81 Females: • 27 BPD • 27 Avoidant PD • 27 control	IAPS	IPDE	Eye blink, HR, SCR	BPD showed SCR hypoarousal. Startle response showed BPD group experienced pleasant stimuli as less positive than others.
Herpertz et al. (2001)	50 incarcerated males: • 25 BPD • 25 Psychopath • 25 control	IAPS	IPDE	Eye blink, SCR	BPD group less facially responsive than controls; no other differences.
Kuo & Linehan (2009)	60 Females: • 20 BPD • 20 Social Anxiety Disorder • 20 control	2 Emotion induction conditions (Generalised film, tailored script)	SCID-II	RSA, SCR	BPD group showed lower baseline RSA, and higher baseline SCR. No differences in reactivity.
Limberg, Barnow, Freyberger, & Hamm (2011)	• BPD (37 F; 3 M) • Control (27 F; 5 M)	Scripts General; BPD specific (abandonment; trauma)	SCID-II	Eye blink, HR, SCR	BPD group showed greater startle during disorder-specific scripts than controls. No other differences.
Lobbestael, Arntz, Cima, & Chakhssi (2009)	• 45 BPD (12 M; 33 F) • 21 Antisocial PD • 26 Cluster C PD • 25 control	Stress-induction interview	SCID-II	BP, HR, SCR	BPD group showed lower baseline HR. No differences in reactivity.
Mauchnik, Ebner-Priemer, Bohus, & Schmahl (2010)	33 females with BPD: • 15 comorbid PTSD • 18 no comorbidity	Ink blots paired with aversive startles	IPDE	SCR	No differences in baseline arousal, comorbid group showed continued SCR hyperarousal to stimulus after extinction, suggesting impaired habituation.
Schmahl et al. (2004)	40 females: • 10 BPD • 14 PTSD • 16 control	Schema-related scripts (personalized trauma and abandonment)	SCID-II	BP, HR, SCR	BPD had slight, but not significant increased SCR during abandonment scripts.

Study	Sample	Stimuli	Assessment of BPD	Psychophysio-logical measure	Results
Taylor & James (2009)	182 university students: • 52 Substance Dependent • 12 Antisocial PD or BPD • 35 comorbid substance and PD • 83 control	Auditory sounds (predictable and unpredictable white noise blasts)	SCID-II; PDQ	HR, SCR	BPD group showed no significant differences to controls.
Vitale & Newman (2012)	62 Female offenders: • 19 high-BPD features • 43 low-BPD features	IAPS	DIB-R	Eye blink	No significant differences when viewing unpleasant slides; But high-BPD group showed significant blink attenuation when viewing pleasant slides.
Weber et al. (2009)	• 6 BPD (4 F; 2 M) • 19 MDD (10 F; 9 M) • 15 Schizophrenia (3 F; 12 M) • 10 Substance disorder (10 M) • 20 Control (8 F; 12 M)	IAPS	MINI	HR	BPD group showed no significant differences in arousal or reactivity compared to other groups.
Weinberg, Klonsky, & Hajcak (2009)	All university students: • 12 high- BPD features • 28 control	Social stressor task	MSI-BPD	HR, RSA	Those with high-BPD features showed greater SNS activity and impaired habituation compared to controls which showed expected habituation trajectory.
Welch, Linehan, Sylvers, Chittams, & Rizvi (2008)	• 42 BPD (38 F; 4 M)	Imagery scripts	IPDE	RSA, SCR	The group showed increased SCR following scripts featuring self-injury, but not after those featuring suicidal imagery.
Williams, Sidis, Gordon, & Meares (2006)	• 15 BPD (11 F; 4 M) • 15 control (11 F; 4 M)	Stressor Task (Auditory discrimination)	DIB-R	SCR	No significant differences in amplitude of SCR, but BPD group showed significant SCR delays compared to controls.

Note. BPD= Borderline Personality Disorder; M= Male, F= Female; PD= Personality Disorder; DIB-R= Diagnostic Interview for Borderlines; RSA= Respiratory Sinus Arrhythmia; PAI= Personality Assessment Inventory; SCR= Skin Conduct Response; IAPS= International Affective Picture System; HR- Heart Rate; MDD= Major Depression Disorder; MINI= Mini-International Neuropsychiatric Interview; SCID-II= Structured Clinical Interview; BSL= Borderline Symptom List; IPDE= International Personality Disorder Examination; SIDP-IV= Structured Interview for DSM-IV Personality Disorders; PDQ= Personality Diagnostic Questionnaire; MSI-BPD= MacLean Screening Instrument for BPD.

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