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Brain activity elicited by reward and reward omission in individuals with psychopathic traits: An ERP study

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ABSTRACT

Psychopathy has been associated with behavioral adaptation deficits, which might be associated with problems in feedback and reward processing. In the present study, we examined the relation between psychopathic traits and reward processing in a passive gambling task. A total of 39 male participants who scored high (HP) and 39 male participants who scored low (LP) on the Triarchic Psychopathy Measure (TriPM), total score were tested. Feedback-related Event-Related Potentials (ERPs; i.e., P2, FRN, and P3) on predicted and unpredicted rewards and reward omissions were compared between both groups. It was found that in HP individuals, the P2 was enhanced for predicted rewards and reward omissions, but not for unpredicted stimuli. Moreover, HP individuals as compared to the LP individuals demonstrated a generally reduced P3 amplitude. The FRN amplitude, however, did not differ between the two groups. In addition, HP individuals showed enhanced reward sensitivity on the self-report level. Taken together, these findings suggest that HP individuals show enhanced sensitivity to early and reduced sensitivity to later markers of processing reinforcement learning signals, which points in the direction of compromised behavioral adaptation.

1. Introduction

Psychopathy has been defined as a mental disorder in which amoral and antisocial behavior are the most prominent features, but it can also be measured in non-clinical samples by using various measurement tools. Psychopathy is associated with cognitive and behavioral problems, including lack of guilt, lack of empathy, and fearless and antisocial behavior (Hare & Neumann, 2008). More specifically, it has been found that psychopathic individuals display a greater difficulty in evaluating outcomes of behavior and adapting their behavior accordingly (Brazil et al., 2009, 2013; Budhani & Blair, 2005; Finger et al., 2008; Mitchell, Colledge, Leonard, & Blair, 2002; Varlamov, Khalifa, Liddle, Duggan, & Howard, 2011; Von Borries et al., 2010). These behavioral adaptation deficits appear to be particularly relevant for explaining the antisocial behaviors observed in psychopathic individuals (Blair, 2004; Budhani & Blair, 2005; for a review, see Newman & Wallace, 1993). Previous research has shown that impaired behavioral adaptation in various psychiatric populations is associated with general reward processing deficits (Budhani & Blair, 2005; Finger et al., 2008; Franken, van Strien, Franzek, & van de Wetering, 2007, Franken, van Strien, Nijs, & Muris, 2008; Gatzke-Kopp et al., 2009). For example, a number of studies have shown that psychopathic individuals persevere in responding to the non-rewarding stimulus while performing a reward-related reversal learning task, which requires response shifting as a consequence of changing reinforcement contingencies (Blair, 2007; Budhani & Blair, 2005; Budhani, Richell, & Blair, 2006; Finger et al., 2008; Newman, Patterson, & Kosson, 1987; Roussy & Toupin, 2000). On the basis of these previous findings, it has been suggested that psychopathic individuals are less able to use reward-related information appropriately irrespective of the provision of an adequate feedback signal (e.g., Blair, 2007; Finger et al., 2008), which implies that reward processing is compromised in these individuals. While adequate reward processing is an important aspect of normal adaptive behavior, only a limited number of studies addressed this issue in relation to the concept of psychopathy, and are typically limited to analyzing behavioral performance.

Previous research has identified electrophysiological correlates (e.g., Event-Related Potentials; ERPs) of reward processing including feedback-related negativity (FRN), P2, and P3 (Franken, van

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den Berg, & van Strien, 2010; Hajcak, Moser, Holroyd, & Simons, 2007; Holroyd & Coles, 2002; Martin & Potts, 2004, 2011; Pfabigan, Alexopoulos, Bauer, Lamm, & Sailer, 2011a; Potts, Martin, Burton, & Montague, 2006). For example, Potts et al. (2006) have employed a passive gambling task, a task in which reward prediction and outcome delivery are manipulated. They demonstrated that the FRN amplitude is reduced in the presence of an unpredicted reward and enhanced when a predicted reward was not delivered. Several other studies have shown a comparable finding in which the FRN amplitude is enhanced when outcomes are worse than predicted (i.e., reward prediction errors; Bellebaum & Daum, 2008; Bellebaum, Polezzi, & Daum, 2010; Bellebaum, Kobza, Thiele, & Daum, 2011; Holroyd, Nieuwenhuis, Yeung, & Cohen, 2003; Holroyd, Krigolson, Baker, Lee, & Gibson, 2009; Pfabigan, Alexopoulos, Bauer, & Sailer, 2011b; Wu & Zhou, 2009; Yasuda, Sato, Miyawaki, Kumano, & Kuboki, 2004). Furthermore, the FRN is thought to be generated in the anterior cingulate cortex (ACC) and represents the electrophysiological index of feedback monitoring (Gehring & Willoughby, 2002; Holroyd & Coles, 2002; Miltner, Braun, & Coles, 1997; Nieuwenhuis, Slagter, Alting von Geusau, Heslenfeld, & Holroyd, 2005). A second ERP component that has been related to the brain reward system is the P2. This component is thought to reflect attention selection (Ito & Urland, 2003, 2005; Oray, Lu, & Dawson, 2002; Potts et al., 2006) and salience detection (Kenemans, Kok, & Smulders, 1993; Potts, Patel, & Azzam, 2004; Potts, Liotti, Tucker, & Posner, 1996, Potts et al., 2006; Potts & Tucker, 2001; Riis et al., 2009; San Martin, Manes, Hurtado, Isla, & Ibanez, 2010). It has been suggested that the P2 amplitude is sensitive to any task-relevant item that has a motivational value (e.g., reward information), and has therefore also been found to be associated with reward sensitivity (Martin & Potts, 2004; Potts et al., 2006; Rolls, 1999). A third relevant component is the feedback-related P3. The P3 is a stimulus-locked ERP component, peaking around 300–600 ms at posterior/parietal sites. The P3, it thought to reflect reallocation of attention when task demands change or an update of task representations is needed. Consequently, P3 amplitudes are found to be larger when outcomes are unexpected. Several studies have found that this component is sensitive to reward magnitude (e.g., small/large amount of reward; Sato et al., 2005; Yeung & Sanfey, 2004), reward valence (e.g., gain/loss) (De Pascalis, Variale, & D'Antuono, 2010; Ramsey & Finn, 1997; Van den Berg, Franken, & Muris, 2011; Van den Berg, Shaul, van der Veen, & Franken, 2012), or both reward magnitude and reward valence (Martin & Potts, 2009, 2011; Yeung, Holroyd, & Cohen, 2005). For instance, De Pascalis et al. (2010) examined the influence of valence on P3 amplitude using a reward-related Go/No-Go task, and found that monetary loss elicits a larger P3 amplitude as compared to monetary gain. Other research, however, has looked into the effects of feedback expectancy and valence on P3 amplitude using a probabilistic gambling paradigm, and demonstrated that unexpected feedback elicits a larger P3 amplitude as compared to expected feedback, irrespective of valence (Hajcak, Holroyd, Moser, & Simons, 2005; Hajcak et al., 2007; Holroyd et al., 2003; Holroyd, Larsen, & Cohen, 2004; Martin & Potts, 2004; Pfabigan et al., 2011a). To summarize, these studies suggest that the FRN, P2, and P3 amplitudes are all sensitive to feedback valence (e.g., reward/non-reward) and feedback expectancy (e.g., predicted/unpredicted), which may reflect motivational significance of the outcomes.

According to the revised reinforcement sensitivity theory (rRST; Corr, 2002; Gray & McNaughton, 2000), responsiveness to signals of reward and frustrative non-reward are linked to the so-called behavioral activation system (BAS). Subsequently, an increasing number of studies have examined the association between individual differences in reward responsiveness and ERP responses to reward and non-reward. For instance, individuals with greater responsiveness to reward demonstrate an enhanced P3 (Van den Berg et al., 2011) to stimuli signaling reward, whereas, an enhanced FRN (Lange, Leue, & Beauducel, 2012) and a reduced P3 amplitude (De Pascalis et al., 2010) were observed in these individuals following signals of non-reward. However, no effects were found for reward sensitivity and P2 amplitudes (Van den Berg et al., 2011). Since various aspects of psychopathy have been related to a hypersensitive/hyperreactive response to reward (see for example, Buckholtz et al., 2010; Pujara, Motzkin, Newman, Kiehl, & Koenigs, 2014), it is important to study electrophysiological correlates of reward processing in relation to psychopathic traits.

With respect to the relation between the FRN, P2 and P3 and psychopathy and related externalizing psychopathology, contrasting results have been found. Pfabigan et al. (2011a) compared individuals who scored high or low on antisocial personality traits using a probabilistic gambling task, and found a larger FRN amplitude in the high scoring group following expected and unexpected monetary loss. The authors concluded that individuals with high antisocial traits demonstrate a problem in external feedback processing, and are oversensitive to the motivational salience of concrete reward cues (i.e., money). The increased FRN found in their study was supportive of a model of frustrative non-reward, which can be seen as the reaction to the withdrawal or prevention of reward, predicting an enhancement of general arousal if a predicted reward is not given (Amsel, 1962; Amsel, 1994; Dudley & Papini, 1997). However, Bernat et al. (2011) did not find and FRN effect in externalizing individuals using a simulated gambling task. Interestingly, one other study, using a time-estimation task in healthy females, found reduced FRN amplitudes to be associated with the Fearless-Dominance factor of the Psychopathic Personality Inventory-Revised (PPI-R; Lilienfeld & Andrews, 1996) and not with the Self-Centered Impulsivity factor. This would mean that the FRN is implicated in the interpersonal-affective features of psychopathic personality, and not with the more general antisocial-impulsive (externalizing or disinhibitory) features of psychopathy.

Studies on the reward-related P3 component in psychopathy have been mixed (Venables & Patrick, 2014). Several studies have found a P3 reduction to be associated with different externalizing psychopathologies (Gilmore, Malone, Bernat, & Iacono, 2010; Yoon, Malone, Burwell, Bernat, & Iacono, 2013), but not all studies have reported this association (e.g., Pfabigan et al., 2011a). A recent study by Bernat et al. (2011) found, for instance, P3 reductions but no FRN reductions to feedback cues in a simulated gambling task for individuals scoring high on externalizing proneness. Venables and Patrick (2014) concluded that P3 amplitude reduction in various paradigms is a robust correlate of externalizing proneness (i.e., disinhibitory behavior) and not psychopathic personality per se. It should be noted, however, that some studies using the oddball or the continuous performance task could not find this correlation (e.g., Jutai, Hare, & Connolly, 1987; Raine & Venables, 1988).

To our best knowledge, studies on P2 in reward processing in psychopathy have not been published. However, studies using paradigms of affective modulation, for example using an emotional Stroop task, found that those scoring high on psychopathic traits display reduced P2 amplitudes to negative valenced stimuli compared to controls (i.e., Carolan, Jaspers-Fayer, Asmaro, Douglas, & Liotti, 2014).

The primary objective of this study was to examine whether individuals scoring high on psychopathic traits have different brain responses to predicted and unpredicted reward and non-reward than individuals who score low on psychopathic traits. To study this, we used the Triarchic Psychopathy Measure (Patrick, 2010). This measure assesses different phenotypic constructs of psychopathy. Boldness is defined as a phenotypic manifestation of an underlying genotypic predisposition of fearlessness (Patrick, Fowles, Krueger, & RF, 2009). Individuals high on boldness lack fear, have the ability to remain calm under stressful circumstances, and