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Neural correlates of impulsive responding in borderline personality disorder: ERP evidence for reduced action monitoring

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Abstract

Patients with borderline personality disorder (BPD) are characterized by marked impulsive behaviour. The impulsive response style of patients with BPD may be associated with diminished action monitoring, which can be investigated by measuring the error-related negativity (ERN). The ERN is an ERP component generated in the anterior cingulate cortex (ACC) following erroneous responses. Behavioural and ERP measurements were obtained during performance on a speeded two-choice reaction task in a group of patients with BPD ($N = 12$) and in a group of age-matched controls ($N = 12$). The ERP results showed that ERN amplitudes were reduced for patients with BPD, as were the P300 amplitudes after late feedback. The behavioural results confirmed a more impulsive response style for the BPD group, reflected in larger RT differences between correct and incorrect responses and in an increase in erroneous responses to the easy congruent stimuli. Additionally, analyses on post-error congruency effects demonstrated that controls adjusted their behaviour following errors, but patients with BPD did not. The attenuated ERNs indicate reduced action monitoring in patients with BPD. This suggests that the ACC, or the action-monitoring network it is part of, is not functioning optimally. Due to this reduced action monitoring, patients with BPD do not learn from their errors as well as controls. Consequently, they do not adjust their behaviour when necessary and thus maintain their impulsive response style.

Keywords: Borderline personality disorder; Impulsivity; Action monitoring; Error-related negativity; Anterior cingulate cortex

1. Introduction

Marked impulsivity is seen as one of the main characteristics of borderline personality disorder (BPD), together with rapidly changing mood states, aggressive behaviour, instability of interpersonal relationships, self-image, and affects. Impulsive behaviour may express itself in promiscuity, substance abuse, adverse financial behaviour, reckless driving, and binge eating. Suicidal behaviour and self-mutilation are also frequently related to impulsivity (American Psychiatric Association, 2000).

Although impulsiveness is an important clinical feature, the number of studies investigating its neural correlates is still relatively small. This may be explained by the lack of a unified definition, which is due to the wide range of behaviours in which the trait is present (see e.g. Evenden, 1999). Moeller et al. (2001), in their review of the psychiatric aspects of impulsivity, concluded that a reliable definition should at least include the elements of the various behavioural models that have been developed based on findings from targeted laboratory tasks. These

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elements are: (1) rapid, unplanned reactions to stimuli before complete processing of information, (2) decreased sensitivity to negative consequences of behaviour, and (3) lack of regard for long-term consequences. With the current study we aimed at investigating the neural correlates of the first two elements in patients with BPD.

Rapid, unplanned reactions and diminished sensitivity to resulting erroneous responses can be studied by means of electrophysiological measurements during a speeded forced-choice task. Especially the discovery of an event-related potential (ERP) component associated with error or conflict detection has given this type of action monitoring research an important impetus. This so-called error negativity (Falkenstein et al., 1991) or error-related negativity (ERN; Gehring et al., 1993) is characterized by a sharp negative deflection over frontocentrally located electrodes appearing within 100 ms after an error has been made.

Source localization and fMRI studies have found the anterior cingulate cortex (ACC) as the most likely generator of the ERN (see e.g., Dehaene et al., 1994; Kiehl et al., 2000; Ullsperger and von Cramon, 2001), a finding that is in line with earlier studies demonstrating error-related activity in unit recordings from the ACC in monkeys (see e.g., Niki and Watanabe, 1979). The ACC is a mediofrontal brain structure known for its rich innervation from and to other regions of the brain and its rich concentration of different types of neurotransmitters like dopamine. The area is highly interconnected to the motor system, the limbic system, and to prefrontal regions. Because of these characteristics, the ACC has been described as the interface between cognition, motor control, and the drive of the organism (Paus, 2001).

Originally, the ERN was taken to be elicited by a mismatch, i.e., after the error detection system has failed to match a representation of the actual behaviour with a representation of the desired behaviour (see e.g. Falkenstein et al., 1991; Gehring et al., 1993). More recently, Holroyd and Coles (2002) extended this original interpretation in their so-called reinforcement-learning theory of the ERN. According to the theory, predictive error signals indicating whether events turn out to be worse than expected are carried to various brain areas by the dopamine system. These error signals are used to improve performance in order to prevent future errors. When a predictive error signal arrives at the ACC, the ERN is elicited. Alternative accounts refer to the ERN as the reflection of conflict that arises when two incompatible response tendencies are simultaneously activated (Botvinick et al., 2001; Cohen et al., 2000; Yeung et al., 2004). For the current study it is relevant that all three accounts agree that the ERN is generated in the ACC, that it reflects the outcome of an action-monitoring process, and that it is used to optimize performance in the future.

Differences in ERN amplitude have been observed in a variety of personality traits. Individuals low on socialization tend to exhibit smaller ERN amplitudes (Dikman and Allen, 2000), whereas individuals with greater negative affect (Luu et al., 2000) or those with obsessive-compulsive personality traits (Hajcak and Simons, 2002) show larger ERN amplitudes. Pailing et al. (2002) specifically investigated the relation between the ERN and impulsivity. In their study, subjects with large reaction-time differences between correct and incorrect responses had smaller ERN amplitudes. Because (overly) fast reaction times generally lead to more erroneous responses, these larger reaction-time differences were taken to reflect a more impulsive response style. This motivated us to investigate whether this line of reasoning could also be applied to patients with BPD.

PET and fMRI studies investigating neuropsychiatric disorders have demonstrated increased ACC activity in individuals with obsessive-compulsive disorder (OCD; see e.g., Adler et al., 2000; Ursu et al., 2003) and decreased ACC activity in patients with schizophrenia (Carter et al., 2001; Laurens et al., 2003). These differences in ACC activity were also reflected in action monitoring: enhanced ERN amplitudes were found in individuals with OCD (Gehring et al., 2000), whereas decreased ERN amplitudes were observed in patients with schizophrenia (Alain et al., 2002; Bates et al., 2002; Kopp and Rist, 1999; Mathalon et al., 2002).

With regard to BPD, a number of brain imaging studies examining patients have shown hypometabolism in prefrontal cortical areas (see e.g., De la Fuente et al., 1997; Goyer et al., 1994; Soloff et al., 2003). Recently, Tebartz van Elst et al. (2003) demonstrated volume loss of the right ACC in their BPD sample. The authors suggested that specifically this volume loss might differentiate BPD from other neuropsychiatric disorders.

In the present and to our knowledge the first such study in patients with BPD, we employed a speeded two-choice task while measuring ERN amplitudes. We predicted that patients with BPD would show increased impulsivity in different behavioural measures and reduced action monitoring as evidenced by smaller ERN amplitudes.

In order to examine the entire process of action monitoring from stimulus onset to feedback processing, we also examined two other ERP components known to be involved in action monitoring, namely the stimulus-locked N2 and the feedback-locked P300. The amplitude of the N2 is thought to reflect the monitoring of response conflict that arises from simultaneously active response tendencies as it is enlarged after incongruent stimuli compared to congruent ones (see e.g. Yeung et al., 2004). Consequently, the N2 is a reflection of a relatively early process. As we specifically anticipated group differences for the later processes directly related to erroneous responses, we did not expect to find any