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Event-related components of the punishment and reward sensitivity

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ABSTRACT

Objective: The present study investigated the properties of feedback-related negativity (FRN) and P3 component of the event-related potentials (ERPs) and their neural sources localization as neurocognitive correlates of the behavioural inhibition and behavioural activation systems (BIS/BAS). The association between BIS/BAS function and anterior cortical asymmetry was tested.
Methods: Fifty right-handed women were investigated with 30-channel recordings during an instrumental Go/No-Go learning task. ERPs were elicited to feedback signals indicating monetary losses and monetary gains. Learning performance, FRN, and P3 amplitude and latency measures were calculated and related to BIS and BAS measures by means of ANOVA and correlation analysis. The neural sources of FRN and P3 components of the ERPs were estimated using LORETA software. A resting EEG-alpha-power (8–13 Hz) asymmetry measure was obtained.
Results: High levels of Reward Responsiveness (RR), a first order factor of the BAS, were associated with shorter RTs and enhanced positive feelings. The FRN was larger to signals indicating monetary Loss as compared to monetary Gain and enhanced with higher BIS and individual learning ability. Higher RR scores were related to greater left-sided resting frontal cortical asymmetry associated with approach orientation. High-RR subjects, as compared to Low-RR ones, had a smaller P3 amplitude for Go/Loss signals. The P3 latency to No-Go/Gain signals was the best positive predictor of RR. LORETA source localization for the FRN component displayed significantly higher brain electrical activity in left-fusiform gyrus and right superior temporal gyrus to monetary Loss in comparison to monetary Gain after incorrect No-Go responses. For the P3 wave, the monetary Loss produced significantly higher activations in the left superior parietal lobule, right postcentral gyrus, and in the ACC.
Conclusion: The FRN was sensitive to cues of punishment and higher BIS was uniquely related to a larger FRN amplitude on No-Go/Loss trials, linking BIS with conflict monitoring and sensitivity to No-Go cues. Furthermore, the significant interaction found between BIS and RR on FRN amplitude together with the findings linking High-RR levels with shorter RTs, smaller P3 amplitudes and enhanced positive feelings are in line with the hypothesis that both BIS and BAS have the potential to influence punishment-mediated and reward-mediated behaviour.
Significance: Results open up new perspectives for future investigations on the relationship between BIS/BAS measures and ERP components to monetary reward during learning.

1. Introduction

A main question in personality and psychophysiology research concerns how individual differences in neurobiological processes relate to personality, motivation and behavioural regulation mechanisms. One popular theory has been derived from behavioural neuroscience research conducted primarily on animals. This personality theory is currently referred to as the Reinforcement Sensitivity Theory (RST; Gray, 1972; Gray and McNaughton, 2000) that has defined the existence of three conceptual brain systems as responsible of adaptive behaviour. The first system mediates fear and is activated by threatening stimuli that need not be faced, but can simply be avoided and has been referred to as the Fight–Flight–Freeze System (FFFS). A second system is activated by appetitive stimuli and mediates the emotion of anticipatory pleasure and is referred to as the Behavioural Approach System (BAS). A third system mediates anxiety and is activated by goal conflicts of all kinds, paradigmatically between approach and avoidance, and is referred to as the behavioural inhibition system (BIS). The BIS is conceptualized as an attentional system that is sensitive to cues of punishment, nonreward, and novelty. It functions to

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interrupt ongoing behaviour in order to facilitate the processing of these cues in preparation for a response. During the last two decades, the interest in the model has grown steadily and the development of reliable self-report measures of BIS and BAS sensitivity has facilitated the validation of RST-derived hypotheses from animal behaviour to the study of human behaviour. However, despite enthusiasm for testings BIS and BAS functions, the different nature of various measurement strategies employed for these constructs makes it difficult to compare results from a number of studies (for a review, see Torrubia et al., 2008). Thus, the general goal of the present study is to differentiate the functions of BIS and BAS in humans in terms of their underlying cognitive and electrocortical mechanisms. Mainly we sought to evaluate how individual differences in BAS and BIS are reflected on electrocortical responses elicited by positive and negative feedback signals during a learning task.

1.1. The BIS and BAS traits

In the revised RST theory (Gray and McNaughton, 2000) the function of BIS and BAS has been proposed within a neuropsychological framework for understanding how behavioural regulation mechanisms relate to personality and psychological dysfunction. This theory outlined that both BIS and BAS have the potential to influence punishment-mediated and reward-mediated behaviour.

The BAS is involved in moving the organism up to the temporospatial gradient through the location of the reward (Corr, 2008; McNaughton and Corr, 2004). Individuals with an overreactive BAS are more susceptible to impulsivity disorders (Gray, 1991; Revelle, 1997; Stanford et al., 1996; Wallace et al., 1991), secondary psychopathy (Flor-Henry, 1976; Hare, 1993; Newman et al., 2005), bipolar disorder (Depue and Iacono, 1989), and attention-deficit/hyperactivity disorder (Mitchell and Nelson-Gray, 2006). The BIS mechanism is thought as a comparator that continuously scans the environment by checking predicted against actual events (checking mode) and being able to stop programmed motor activity by other systems (control mode) if they do not match. This system also modulates the control of exploratory behaviour by diverting attention toward the threatening or novel stimulus. When a mismatch between predicted and actual events occurs, the motor program is stopped and outputs of the BIS seek to take more information by enhancing attention and arousal. High-BIS activation is associated with enhanced attention, arousal, vigilance. The BIS is responsible for negative affect (Corr, 2008). An overreactive BIS maps onto anxiety-related disorders (e.g., Fowles, 1988; Gray, 1982; Quay, 1988), while a very weak BIS has been associated to primary psychopathy (Gray, 1987; Newman et al., 2005).

However, the translation of BIS and BAS sensitivity into different self-report questionnaires, that usually are not directly derived from Gray's model (e.g., Gupta and Shukla, 1989; Patterson et al., 1987), has produced new uncertainty regarding the conceptualization of the core elements of emotion and motivation. Two hypotheses have received some experimental support. The first suggests that BIS is responsible for behavioural inhibition (e.g., Arnett and Newman, 2000; Cools et al., 2005; Fowles, 1980, 1988; Gomez and Gomez, 2002; Harmon-Jones and Allen, 1997; Hewig et al., 2006; Keltner et al., 2003; Monteith et al., 2002; Newman and Kosson, 1986; Newman et al., 2005; Patterson et al., 1987; Patterson and Newman, 1993). The second hypothesis proposes the BIS as responsible for behavioural withdrawal (e.g., Blair et al., 2004; Elliot and Thrash, 2002; Elliot et al., 2006; Gable et al., 2000; Heimpel et al., 2006; Sherman et al., 2006; Sutton and Davidson, 1997; Thrash and Elliot, 2003; Updegraff et al., 2004). This is in contrast with a number of EEG findings relating the BIS with neural mechanisms associated to conflict monitoring, and BAS to approach motivation (Amodio et al., 2008; Bartussek et al., 1996; Boksem et al., 2006; De Pascalis et al., 1996; De Pascalis and Speranza, 2000).

In an attempt to understand the plethora of mixed results reported in the literature (see review by Matthews and Gilliland, 1999), Corr (2001) proposed the "joint subsystems" hypothesis, in which the BIS and the BAS are not independent (as it is assumed in the standard RST; Gray, 1981), but influence each other in an interdependent manner. In line with the revised RST (Gray and McNaughton, 2000), he outlined that both BIS and BAS have the potential to influence punishment-mediated and reward-mediated behaviour. The BIS and BAS exert two effects that are one facilitatory and the other antagonist. More in particular, the BAS facilitates and the BIS antagonize the process of reward stimuli, i.e., High-BAS/Low-BIS individuals should display the highest appetitive responses and positive emotions to these stimuli. Similarly, the BIS facilitate and the BAS antagonize the process of punishment stimuli, i.e., High-BIS/Low-BAS individuals should show the highest aversive responses and negative emotions to these stimuli.

1.2. BIS/BAS and frontal activity

Several recent studies specifically examined the relation of anterior trait asymmetry with behavioural activation and behavioural inhibition (e.g., Coan and Allen, 2003; Hagemann et al., 1999; Harmon-Jones and Allen, 1997; Sutton and Davidson, 1997). For example, Sutton and Davidson (1997) reported that greater left frontal cortical activity was positively associated with the BAS (as measured with the BIS/BAS scales by Carver and White, 1994), and greater right frontal cortical activity was positively associated with the BIS. These findings support the position that behavioural activation and behavioural inhibition are related to anterior asymmetry. The view that cognitive inhibition and activation are linked to specific frontal lateralization is confirmed by recent findings derived from lesion-mapping studies (see review of Aron et al., 2004a,b). Lesion studies have evidenced that the right inferior frontal cortex (IFC), but not other frontal regions, is responsible for inhibitory performance as that occurring during a Go/No-Go task or as measured by stop-signal task (Aron et al., 2003). In another study, Aron et al. (2004a,b) examined inhibitory mechanisms during task-switching performance, in patients with focal right frontal (RF) and left frontal (LF) lesions. The left middle frontal gyrus (MFG) was linked to top-down control of task-sets triggered by stimuli in a switching task and more specifically to the selection and maintenance of task-sets. The inferior frontal gyrus (IFG) accounted for by impaired inhibition of inappropriate responses or task-sets. In line with these findings, Harmon-Jones and Allen (1997) showed a significant relation between greater left frontal cortical activity and the BAS. In a subsequent study, Coan and Allen (2003) also reported that there was a significant positive relation of greater left frontal activity and BAS (Carver and White, 1994). However, there was no significant relation between anterior asymmetry and BIS in these latter two studies. In further work BAS activity has been associated with approach orientation (Harmon-Jones, 2003a,b; Pizzagalli et al., 2005). Frontal asymmetry is believed to reflect asymmetric dopamine signaling from the striatum (Berridge et al., 2003). An alternative view suggests that behavioural activation comprises approach and withdrawal motivation and that the BAS is related to greater bilateral frontal cortical activity (Hewig et al., 2006). Recent findings by Amodio et al. (2008) support the hypothesis that greater BAS activity is uniquely associated with greater left-sided frontal EEG cortical asymmetry. EEG literature does not support the idea that BIS is directly associated with right-sided frontal EEG activation or with approach/withdrawal orientation (for a review, see Coan and Allen, 2003; Hewig et al., 2006; but see Sutton and Davidson, 1997; Wacker et al., 2003). Rather EEG research supports the view that greater