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Motivational orientation modulates the neural response to reward

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ABSTRACT

Motivational orientation defines the source of motivation for an individual to perform a particular action and can either originate from internal desires (e.g., interest) or external compensation (e.g., money). To this end, motivational orientation should influence the way positive or negative feedback is processed during learning situations and this might in turn have an impact on the learning process. In the present study, we thus investigated whether motivational orientation, i.e., extrinsic and intrinsic motivation modulates the neural response to reward and punishment as well as learning from reward and punishment in 33 healthy individuals. To assess neural responses to reward, punishment and learning of reward contingencies we employed a probabilistic reversal learning task during functional magnetic resonance imaging. Extrinsic and intrinsic motivation were assessed with a self-report questionnaire. Rewarding trials fostered activation in the medial orbitofrontal cortex and anterior cingulate gyrus (ACC) as well as the amygdala and nucleus accumbens, whereas for punishment an increased neural response was observed in the medial and inferior prefrontal cortex, the superior parietal cortex and the insula. High extrinsic motivation was positively correlated to increased neural responses to reward in the ACC, amygdala and putamen, whereas a negative relationship between intrinsic motivation and brain activation in these brain regions was observed. These findings show that motivational orientation indeed modulates the responsiveness to reward delivery in major components of the human reward system and therefore extends previous results showing a significant influence of individual differences in reward-related personality traits on the neural processing of reward.

Introduction

Animal and human behaviour is guided by the motivation to achieve pleasant states as well as to maximize rewarding outcomes and avoid unpleasant states or punishment (Daw et al., 2006). This is achieved by approaching stimuli with the highest incentive salience (Berridge and Kringelbach, 2008). The incentive properties of a stimulus and thus its motivational impact do not solely depend on its ability to meet the needs of the organism but also on the individual learning history modulating the motivational orientation. Motivational orientation defines the source of motivation for an individual to perform a particular action, like acquiring knowledge. It can originate from internal desires (intrinsic motivation; e.g., gain of knowledge or insight) or external compensation (extrinsic motivation; e.g., money, social reputation) (Ryan and Deci, 2000a). Therefore, motivational orientation should influence the way feedback (reward and punishment) is processed during learning situations, and this in turn might have an impact on the learning process. Motivational orientation does not only depend on the situational context but is also a personality trait and people differ in terms of the individual amount of intrinsic and extrinsic motivation towards a certain type of action or behaviour.

A large body of neuroimaging studies in humans has identified structures of the mesocortico-limbic dopamine system as being sensitive to the anticipation and delivery of primary (e.g., food) and secondary (e.g., money) reward stimuli (e.g., Thut et al., 1997; O'Doherty et al., 2002; Kirsch et al., 2003; McClure et al., 2003, 2004). These brain regions include the orbitofrontal (OFC) and prefrontal cortex (PFC), the anterior cingulate (ACC), the amygdala, the insula, the striatum (putamen, N. caudatus, and N. accumbens), the thalamus, the mesencephalon and the cerebellum. More specifically, it has been shown that the medial OFC as well as the amygdala and the striatum rather code the relative than the absolute value of a rewarding stimulus (e.g., food, money), supporting the notion of the individually acquired incentive salience of positive outcomes (Elliott et al., 2008).

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Although the neurobiological underpinnings of reward delivery have been extensively investigated, little is known about how individual differences in motivation-related personality traits (e.g., reward sensitivity, reward dependence, motivational orientation) influence the neural processing of reward. Only recently, two studies observed a positive association between reward sensitivity and neural activity in structures of the reward-network (e.g., OFC, striatum) in response to both the anticipation (Hahn et al., 2009) and delivery of reward (Locke and Braver, 2008). In addition, Cohen et al., (2009) have reported that white matter tracts between prefrontal cortex and striatum predict individual differences in reward dependence (i.e., tendency to rely on social approval and to continue previously rewarded behaviour) in that individuals higher in reward dependence show relatively stronger white matter tracts from the striatum to medial and lateral OFC, dorsolateral PFC and supplementary motor area (SMA). These findings underline the impact of individual differences in motivation-related personality traits on neural responses to reward.

Although particularly the motivational orientation, i.e., intrinsic or extrinsic, influences the acquisition of incentive salience of a stimulus as well as feedback processing during learning situations and thus the learning process itself, the modulation of neural responses to reward and punishment through motivational orientation and its impact on learning has not been investigated so far.

The present study scrutinized the relationship between extrinsic and intrinsic motivation and the neural response to reward and punishment in a probabilistic reversal learning task with monetary reward. We hypothesized that extrinsically motivated individuals exhibit an increased neural response in the reward network, particularly the medial OFC, the amygdala and the striatum as these structures have been shown to code the relative salience of a stimulus, here an external compensation, i.e. money. In addition, we assumed that individuals with high extrinsic motivation learn better from monetary reward than individuals with high intrinsic motivation as it has been shown previously that material outcomes might even undermine intrinsic motivation (Deci et al., 1999).

Methods

Participants

Thirty-seven right-handed healthy volunteers were recruited from university faculties and community facilities. Four subjects had to be excluded from the analysis of fMRI data due to excessive head movements (>2 mm or 2° in every dimension) or due to regular use of cannabis. Thus, results from 33 participants (17 male, 16 female) are reported here. The participants' mean age ± SD was 22.64 ± 2.92 (range 19–32). All study participants underwent the Structured Clinical Interview for DSM-IV (First et al., 1997).

To specifically assess extrinsic and intrinsic motivation towards the type of task used in the present study (reversal learning gambling task), we used the Gambling Motivation Scale (GMS; Chantal et al., 1994) to measure extrinsic and intrinsic motivation towards gambling. Study participants completed the subscales intrinsic motivation toward knowledge, accomplishment, and stimulation, as well as external, introjected and identified regulation. The first three were regrouped to one score representing "intrinsic motivation," the last three to one score representing "extrinsic motivation" towards gambling. Items are scored on a 7-point scale ranging from 1 ("does not correspond at all") to 7 ("corresponds exactly"). The GMS has been shown to be a reliable instrument, with respect to both internal consistency (Cronbach's α ranging from 0.86 to 0.93 for the subscales) and test–retest reliability ($r = 0.77$–0.91 for the subscales) (Chantal et al., 1994). The GMS has been developed on the basis of the self-determination theory (SDT) by Deci and Ryan (1985). The scale is based on the concept that intrinsic motivation originates from the satisfaction of innate, organismic necessities (needs as defined by Deci and Ryan, 1985; Ryan and Deci, 2000b), implicating that the action as such represents the reward and not the action's outcome. In contrast, extrinsic motivation relates to acquired motives and an instrumental or material value of the performed action. To this end, an adult individual's action is often not solely intrinsically motivated (as it is for example the case for small children) but can to some extent be driven by both intrinsic and extrinsic motivation. In the GMS, this fact becomes obvious by low to moderate positive correlations ($r = 0.25$–0.40) between the intrinsic and extrinsic motivation subscales. In the present study, intrinsic and extrinsic motivation scores correlated to a similar extent ($r = 0.40$; see Fig. 1). Thus, the questionnaire's dimensions intrinsic and extrinsic motivation do not represent two poles of one dimension that exclude each other. Therefore, it seems reasonable to include both scores into a multiple regression analysis separately and to estimate their differential contributions to the outcome variable (here neural response to reward, punishment and behavioural switching).

None of the participants fulfilled any criterion of a current or past psychiatric diagnosis or had any current or past neurological disease. No subject was on regular medication. The study was approved by the local research ethics committee and adhered to the Declaration of Helsinki. Written informed consent was obtained from all subjects before study participation.

Experimental design

An event-related fMRI paradigm on probabilistic reversal learning, adapted from previously published experimental designs (O'Doherty et al., 2001; Cools et al., 2002; Remijnse et al., 2005; Jocham et al., 2009) was used in the present study.

Subjects were instructed to choose one of two playing cards displayed on the screen and they were told that they could learn a rule concerning which card is correct. While sticking to that rule, they would win in most cases and thus maximise their total gain. Subjects were also informed that the rule might change from time to time (reversal) and if they were sure of that change, they should change their behaviour accordingly. Two playing cards from the French deck (anglo-american) were presented for 3000 ms to the left and right of a fixation cross and subjects were told to make their choice within these 3000 ms. Subsequently, a feedback concerning the amount of money (ranging from 0.10 to 1.00€) won or lost, was presented for 2000 ms

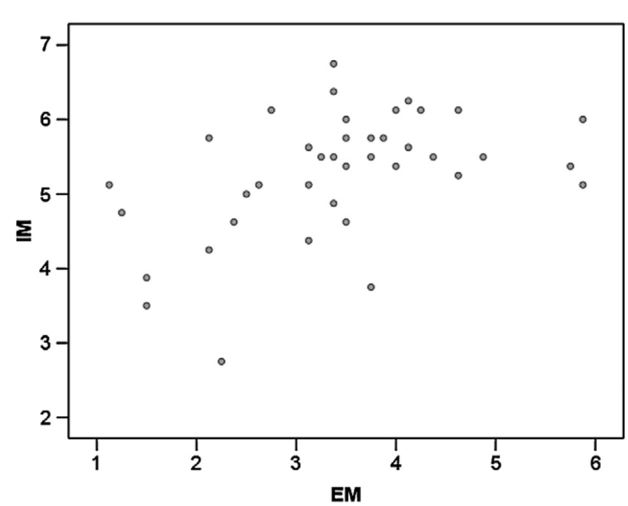

Fig. 1. Scatter plot for the subscale scores 'intrinsic' (IM) and 'extrinsic' (EM) motivation showing a modest correlation ($r = 0.40$) between the two subscales.