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When opportunity meets motivation: Neural engagement during social approach is linked to high approach motivation

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A B S T R A C T

Social rewards are processed by the same dopaminergic-mediated brain networks as non-social rewards, suggesting a common representation of subjective value. Individual differences in personality and motivation influence the reinforcing value of social incentives, but it remains open whether the pursuit of social incentives is analogously supported by the neural reward system when positive social stimuli are connected to approach behavior. To test for a modulation of neural activation by approach motivation, individuals with high and low approach motivation (BAS) completed implicit and explicit social approach–avoidance paradigms during fMRI. High approach motivation was associated with faster implicit approach reactions as well as a trend for higher approach ratings, indicating increased approach tendencies. Implicit and explicit positive social approach was accompanied by stronger recruitment of the nucleus accumbens, middle cingulate cortex, and (pre-)cuneus for individuals with high compared to low approach motivation. These results support and extend prior research on social reward processing, self-other distinctions and affective judgments by linking approach motivation to the engagement of reward-related circuits during motivational reactions to social incentives. This interplay between motivational preferences and motivational contexts might underlie the rewarding experience during social interactions.

1. Introduction

Approaching potential rewards is highly adaptive and relevant across species. Human neuroimaging studies have identified the nucleus accumbens (NAcc) as a key node in reward processing, coding the incentive motivation that potentially triggers approach behavior (Knutson and Cooper, 2005). These "value" representations encompass different reward categories, i.e., primary incentives (e.g., food), secondary enforcers (e.g., money), and social rewards (Bhanji and Delgado, 2014; Izuma et al., 2008; Lin et al., 2012; Spreckelmeyer et al., 2009).

Social rewards can be broadly defined as positive experiences with other people (Bhanji and Delgado, 2014). Despite the large range of potential rewards in social interactions, research has mainly focused on social approval, usually signaled by pictures of smiling faces. In line with animal studies suggesting social interaction to be naturally rewarding itself (Insel, 2003), the recruitment of mesocorticolimbic reward circuits has recently been shown for humans when interacting with one another (Pfeiffer et al., 2014).

Altered neural responses to social incentives have been linked to social motivational deficits. Individuals with an avoidant attachment style (Vrticka et al., 2008), low social proficiency (Gossen et al., 2014), autism, or social anxiety disorder (Kohls et al., 2013; Richey et al., 2014) all showed reduced engagement of the striatum, particularly the NAcc. With severe deficits forming one end of the spectrum, these findings point toward individual differences in the neural sensitivity toward social rewards. As personality dispositions can increase the reinforcing value of social incentives (Buss, 1983), engaging in social interactions might be experienced as intrinsically rewarding for those with a heightened inclination to seek social rewards.

In Gray's (1970, 1990) biopsychological theory of personality, a specific neurobiological emotional system accounts for individual

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differences in the pursuit of reward. The behavioral activation system (BAS; sometimes also referred to as behavioral approach system) is based on approach motivation and guides, for instance, responses to smiling faces and upcoming rewards (Kennis et al., 2013). Although the BAS is often correlated with the personality disposition of extraversion, i.e., the propensity to experience positive affect (Eysenck, 1990), it has been conceptualized as a stimulus-sensitive, motivational system. The promotion of approach and consummatory behavior to rewards is then likely to contribute to positive affective states. Along these lines, individuals with a high BAS activate reward-related circuits in response to positive stimuli more easily (Kennis et al., 2013).

Apart from the consistently reported association between BAS and engagement of the striatum, BAS-related personality traits were found to correlate positively with activation of the ventral/orbital parts of the prefrontal cortex, the dorsal cingulate, and the middle/inferior temporal gyri (Hahn et al., 2009; Hooker et al., 2008; Locke and Braver, 2008; Mobbs et al., 2005; Yucel et al., 2007; for review see Kennis et al., 2013). These neural correlates of BAS converge with the mesocortical dopaminergic system as particularly the orbitofrontal cortex subserves the processing of the reward value of stimuli and the selection of appropriate responses (e.g., Kahnt et al., 2010; Kringelbach and Rolls, 2004). The cingulate has been implicated not only in the conscious representation of motivational states (Becker et al., 2015; see also Denton et al., 1999a, 1999b), but also in social cognitive processing (Schilbach et al., 2012). The meta-analyses by Schilbach et al. (2012) point out that the cortical midline network, including the precuneus, underlies introspection and social interaction. Accordingly, this network might be similarly engaged during the conscious evaluation of social motivational tendencies.

We investigated the pursuit of social reward by combining functional magnetic resonance imaging (fMRI) with well-established implicit and explicit measures of social approach–avoidance tendencies (Derntl et al., 2011; Kobeleva et al., 2014; Radke et al., 2015; Seidel et al., 2010a, 2010b). Action tendencies were evoked by pictures of facial expressions. In an implicit joystick task, participants were required to execute approach and avoidance movements by pulling or pushing a joystick depending on a valence-irrelevant feature. Explicit approach–avoidance was quantified by rating their tendency to move toward or away the face. Exploring differences in task-related activation, we anticipated stronger involvement of motor regions during the implicit joystick task, and stronger involvement of frontal and midline structures during the explicit rating.

The main focus of the current study, however, was to determine how individual differences in approach motivation manifest at the neural level when trait and state, i.e., the motivational context, match. Thus, instead of merely presenting signs of social approval, both implicit and explicit tasks provide a direct link to social motivational behavior. Elucidating how normal trait variation relates to neural responses during positive social approach contributes to our understanding of the neurobiological systems that may underlie the engagement in rewarding social interactions. On the basis that i) positive stimuli activate the BAS and that ii) a more active BAS has been associated with increased recruitment of the mesocortical reward system, we expected stronger activation during implicit and explicit positive social approach in individuals with higher scores in trait measures of BAS, i.e., approach motivation. Within this framework, the pursuit of social incentives should be supported by enhanced NAcc activity when positive stimuli are connected to approach behavior because this appetitive motivational context stimulates the BAS and provides an opportunity to obtain positive affect through consummatory behavior. This opportunity to act according to their motivational preferences of approach is likely to be more self-relevant for individuals with a highly sensitive BAS, which might manifest as increased activation of cortical midline structures (Schilbach et al., 2012; Whitfield-Gabrieli et al., 2011). Behaviorally, we expected individuals with high trait approach motivation to show increased approach tendencies. The current study indexed trait approach motivation by BAS instead of extraversion scores based on the notion that the BAS energizes appetitive behavior directed at obtaining rewards (Smits and Boeck, 2006), while extraversion is more strongly associated with positive emotionality than with motivational behavior.

2. Methods and materials

2.1. Sample

Thirty-six right-handed healthy Caucasian volunteers (M age $=$ 28.4, $SD = 8.4$, range 19–48, 19 females) participated in the study. Exclusion criteria were history of neurological or psychiatric disorder, current medication, and MRI contraindications such as metal parts in the body. The presence of psychiatric disorders (according to DSM-IV) was excluded on the basis of the German version of the Structured Clinical Interview for DSM (SCID; Wittchen et al., 1997) conducted by experienced clinical psychologists. Data from 9 females and 6 males have already been included in a previous publication, functioning as control sample for depressed patients using the same tasks (Derntl et al., 2011).

All participants were recruited via advertisements posted at the RWTH Aachen University, Germany, and paid for their participation. The study was approved by the local institutional review board. Subjects provided written informed consent and were treated according to the Declaration of Helsinki (1964).

2.2. Self-reported motivation and temperament

All participants completed the German version of the BIS-BAS scale (Action Regulating Emotion Systems Scale; ARES; Hartig and Moosbrugger, 2003) as well as the NEO-Five Factor Inventory (Costa and McCrae, 1989). The ARES assesses BIS-sensitivity with the subscales *anxiety* and *frustration* and BAS-sensitivity with the subscales *drive* and *gratification*. The currently used short version contains 20 items and shows satisfying psychometric properties (Cronbach's α of .89 for BIS and .80 for BAS, respectively) and a factorial structure consistent with Gray's model (Hartig and Moosbrugger, 2003).

Based on a median split of the BAS scores, 20 participants were classified as high in approach motivation (BAS $M = 35.9$, $SD = 1.8$, range 34–39) and 16 as low in approach motivation (BAS $M = 31.1$, $SD = 1.7$, range 28–33). Importantly, groups differed only with regard to BAS ($t_{34} = 8.20$, $p < .001$), and not with regard to BIS ($t_{34} = .440$, $p = .66$), neuroticism ($t_{34} = -1.10$, $p = .28$), or extraversion scores ($t_{34} = 1.43$, $p = .16$).

To explore the relationship between trait motivation, behavioral tendencies, and brain activity across the entire range of Approach Motivation, analyses in which BAS is treated as a continuous variable were also performed (see Supplementary Methods and Results). Moreover, all analyses were repeated with extraversion as a predictor instead of BAS (see Supplementary Methods and Results).

2.3. Implicit joystick task (cf. Fig. 1A)

In this fMRI-adapted reaction time task (Derntl et al., 2011), participants responded to visually presented emotional facial expressions by pulling a joystick either toward their body (approach movement) or pushing it away from their body (avoidance movement). Colored pictures were taken from a standardized stimulus set (Gur et al., 2002) and consisted of three expressions (happy, angry, neutral) displayed by sixty different Caucasian actors (balanced for sex). Each face was presented twice, once within a blue and once within a yellow frame.

In the course of four blocks with sixty pictures each, participants had to pull the joystick toward them when the stimulus appeared within a blue frame and to push the joystick away from their body when the stimulus appeared within a yellow frame, irrespective of the facial