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Differentiating Motivational from Affective Influence of Performance-contingent Reward on Cognitive Control: The Wanting Component Enhances Both Proactive and Reactive Control

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ABSTRACT

Positive affect strongly modulates goal-directed behaviors and cognitive control mechanisms. It often results from the presence of a pleasant stimulus in the environment, whether that stimulus appears unpredictably or as a consequence of a particular behavior. The influence of positive affect linked to a random pleasant stimulus differs from the influence of positive affect resulting from performance-contingent pleasant stimuli. However, the mechanisms by which the performance contingency of pleasant stimuli modulates the influence of positive affect on cognitive control mechanisms have not been elucidated. Here, we tested the hypothesis that these differentiated effects are the consequence of the activation of the motivational "wanting" component specifically under performance contingency conditions. To that end, we directly compared the effects on cognitive control of pleasant stimuli (a monetary reward) attributed in a performance contingent manner, and of random pleasant stimuli (positive picture) not related to performance, during an AX-CPT task. Both proactive and reactive modes of control were increased specifically by performance contingency, as reflected by faster reaction times and larger amplitude of the CNV and P3a components. Our findings advance our understanding of the respective effects of affect and motivation, which is of special interest regarding alterations of emotion–motivation interaction found in several psychopathological disorders.

1. Introduction

Cognitive control covers several cognitive mechanisms that regulate and coordinate our thoughts and behavior according to our internal goals (Miller & Cohen, 2001). According to the DMC framework (Dual Mechanisms of Control: Braver, 2012; Braver, Gray, & Burgess, 2007), cognitive control can be recruited either in an anticipatory mode, to maintain goal-relevant information in a sustained manner, or in a transient mode, to temporarily reactivate task goals after the occurrence of a crucial event. The first mode is referred to as the proactive mode, and the second as the reactive mode. The recruitment of these two modes of control can be modulated by several factors, including positive affect. Positive affect can emerge from the presentation of a pleasant stimulus but also from the attribution of a reward (Chiew & Braver, 2011; Dreisbach & Fischer, 2012). It is still debated whether a pleasant stimulus or a reward has similar or different effects on cognitive control. However, results suggest that it may be less the intrinsic nature of the stimulus itself (pleasant or reward) that determines its influence on cognitive control, than its relationship with task performance. Indeed, it has been shown that the influence of a pleasant stimulus on cognitive control varies depending on whether it is task irrelevant, or it indicates a performance contingent monetary gain (Braem et al., 2013). Similarly, a monetary reward attributed independently of performance elicits the opposite effects to a performance contingent reward (Fröber & Dreisbach, 2014, Fröber & Dreisbach, 2016). Furthermore, the effects of a performance non-contingent pleasant stimulus are similar to those induced by a performance non-contingent reward (Fröber & Dreisbach, 2014). Hence, depending on the degree of performance contingency of the stimulus, different psychological components may be activated (Zedelius, Veling, & Aarts, 2013). Indeed, reward has been described

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as involving three main components: liking, wanting and learning (Berridge & Robinson, 2003), based on distinct neurobiological mechanisms (Berridge & Kringelbach, 2008; Berridge, Robinson, & Aldridge, 2009; Leknes & Tracey, 2008; Schultz, 2006), whose respective activation is thought to have different effects on cognitive control (Notebaert & Braem, 2015). The specific influence of each of these three components on cognitive control is not yet fully understood, and the aim of our study was thus identify the specific influence of the motivational component (wanting) on the proactive and reactive modes of control, in comparison with the affective component (liking).

First, when not linked to performance, a pleasant stimulus or a reward will mostly activate an affective component, also called "liking", corresponding to consummatory pleasure (Kring & Barch, 2014), and mainly generated by subcortical regions such as the ventral pallidum and nucleus accumbens, and by the orbitofrontal cortex (Berridge & Kringelbach, 2013; Burgdorf & Panksepp, 2006). The influence of liking on cognitive control seems tenuous. Some studies highlight a decrease in the proactive mode after the presentation of non-performance contingent positive stimuli (Fröber & Dreisbach, 2014, 2016), at times associated with an increase in reactive mode (Dreisbach, 2006; Fröber & Dreisbach, 2012, Fröber & Dreisbach, 2014; van Wouwe, Band, & Ridderinkhof, 2011) but others show an increase in proactive control without modulation of reactive control (Chiew & Braver, 2014). Secondly, when a positive stimulus is related to performance (i.e. when a pleasant stimulus like money or food is attributed depending on performance), a motivational component, also called "wanting", and a "learning" component, which refers to positive reinforcement, will also be activated (Berridge & Robinson, 2003; Berridge et al., 2009). On the one hand, wanting corresponds to the intrinsic motivation to get a reward and the cognitive representation of plans to obtain the reward (Berridge & Robinson, 2003). It is triggered by a cue informing participants that an upcoming trial will be rewarded if performed successfully (Notebaert & Braem, 2015) and is mostly mediated by dopaminergic transmission, relying on a broad mesocorticolimbic network including the nucleus accumbens, the basal forebrain and the cortex (Berridge & Aldridge, 2009; Berridge & Robinson, 2003). On the other hand, learning represents the positive reinforcement induced when a reward is attributed as a consequence of a particular behavior (Pessiglione et al., 2008; Sutton & Barto, 1998). An association is made between an action and gaining a desirable outcome, allowing for reward prediction (Schultz, Dayan, & Montague, 1997), and encouraging participants to reproduce the behavior. Feedback is crucial for reinforcement learning (Sutton & Barto, 1998), so this component is typically manipulated using reinforcement procedures, where participants receive feedback on whether their performance allowed them to obtain the reward or not. Among the different cerebral structures involved, learning relies on striatum and orbitofrontal cortex activity (Balleine, Daw, & O'Doherty, 2008). Effects induced by performance contingent rewards have repeatedly been shown to improve proactive control (Chiew & Braver, 2014; Fröber & Dreisbach, 2014; Jimura, Locke, & Braver, 2010; Locke & Braver, 2008; Padmala & Pessoa, 2011). However, insofar as the task design used in these studies involved a feedback procedure, it probably simultaneously activates liking, wanting and learning, making it difficult to identify the specific influence of each component (Berridge & Robinson, 2003; Berridge et al., 2009). No study has actually aimed at isolating the specific effects of the motivational (wanting) component compared with the affective one (liking), in order to disentangle their respective influence on proactive and reactive modes of control. Yet, the wanting component is crucial for developing goal-directed plans toward getting a reward. Acknowledging that goal-directed behavior impairments are found in many psychiatric diseases, including bipolar disorders, depression or schizophrenia, and that they can be linked to alterations of motivation and emotion (Chaillou, Giersch, Bonnefond, Custers, & Capa, 2015; Kring & Barch, 2014; Salamone, Koychev, Correa, & McGuire, 2015; Tremeau, Antonius, Nolan, Butler, & Javitt, 2014; Wessa, Kanske, & Linke, 2014), the issue of identifying the mechanisms by which wanting modulates cognitive control is of particular interest, especially in the field of psychopathology.

Using the AX Continuous Performance Task (AX CPT) (Servan-Schreiber, Cohen, & Steingard, 1996), our aim was to identifying the specific influences of the liking and wanting components on proactive and reactive modes of control. This paradigm consists in sequentially presented letters, forming cue–probe pairs. The target sequence is the cue letter A followed by the probe letter X (namely AX trials). In addition, there are three types of non-target trials, called AY if the probe letter is not X, BX if the cue letter is not A, or BY if the cue and the probe letter differ from A and X, respectively. The subject is instructed to press a given response key only when the letter X is displayed and has been preceded by the letter A. The cue letter has to be actively maintained until the occurrence of the probe, mobilizing proactive control processes, in order to decide which response has to be given (target AX trials or non-target trial). To create a strong association between the A cue and the X probe letter, target trials are frequent (around 70% of the trials) – which means that the cue letter A is mostly followed by the probe letter X. The cue letter therefore becomes a strong predictor of the upcoming probe – an A cue announcing an X probe and thus a target trial, and a B cue announcing a non-target trial. However, in some cases, the probe does not match the learned response pattern, resulting in conflicting trials (AY trials), which require efficient reactive control processes. Strongly relying on proactive control processes, and thus strongly maintaining the cue letter, will improve performance in trials where the cue is reliable (namely AX, BX and BY), but will be detrimental in conflictual trials (AY), when an unpredicted probe appears. On the contrary, favoring a reactive mode of control would result in improved reactivity to an unexpected probe, and hence improved performance in conflictual AY trials. However, when using a reactive control strategy, if the maintenance of the cue is not strong enough, the occurrence of the probe letter X may lead to inappropriate target response on BX trials. The results can thus be used to distinguish between different strategies. In addition to behavioral measures, we assessed electrophysiological activity during the task, which allowed us to analyze cortical brain activity with high temporal precision. More specifically, and based on previous studies (Morales, Yudes, Gomez-Ariza, & Bajo, 2015; van Wouwe et al., 2011), we used the event-related potentials technique, which provides reliable indicators of proactive and reactive modes of control. The proactive mode is assumed to occur during presentation of the cue. Specifically, the contingent negative variation (CNV) measured during the cue–probe interval and fronto-centrally distributed reflects response preparation and is associated with preparatory effort (Falkenstein, Hoormann, Hohnsbein, & Kleinsorge, 2003). The reactive mode is activated after presentation of the probe and is assumed to be reflected by the N2 and the P3a. The N2 component is an indicator of conflict monitoring (Van Veen & Carter, 2002a,Van Veen and Carter, 2002b) and is therefore mostly expected to occur in conflictual AY trials. The P3a reflects response inhibition (Bekker, Kenemans, & Verbaten, 2004; Smith, Johnstone, & Barry, 2008) and may be associated with conflict resolution. Given that individual differences play an important role in modulating affective and motivational influence on cognitive control, we used an intra-subject design to control for inter-individual differences. Participants took part in two sessions, one with an affective induction (positive pictures not linked to performance), and one with a motivational induction (possibility to gain a performance contingent monetary bonus on specified trials). Our aim was to isolate the wanting component. We used an