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How positive affect modulates cognitive control: The costs and benefits of reduced maintenance capability ☆

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Abstract

Adaptive action in a constantly changing environment requires the ability to maintain intentions and goals over time and to flexibly switch between these goals in response to significant changes. Dreisbach and Goschke (2004) argued that positive affect modulates these antagonistic control demands in favor of a more flexible but also more distractible behavior. In the present paper, the author will present further evidence for the affective modulation of cognitive control: mild positive affect reduced maintenance capability in a simple cuing paradigm (the AX Continuous Performance Task) as compared to negative and neutral affect. This reduced maintenance capability results in costs when a to be maintained goal has to be executed and conversely results in benefits when a to be maintained goal unexpectedly changes. The data will be discussed with respect to existing theories on positive affect, cognitive control, and dopamine.

Keywords: Cognitive control; Positive affect; Dopamine

1. Introduction

One of the main challenges intelligent organisms are constantly confronted with is to dynamically adjust actions and thought to changing demands from the environment. On the one side the organism must be able to maintain intentions and goals over time and shield them against distraction. On the other side, the same organism must be flexible enough to switch from one thought or action to another whenever significant changes occur (Dreisbach & Goschke, 2004; Goschke, 2003; O'Reilly, Braver, & Cohen, 1999). Adaptive action thus requires a dynamic, context-dependent balance between maintaining and switching intentions. Goal of the present article is to present further evidence that this balance is modulated by positive affect (see also Dreisbach & Goschke, 2004; Dreisbach et al., 2005).

From behavioral studies there already exists ample evidence that positive affect as compared to negative or neutral affect has an influence on a broad range of cognitive processes (see Ashby, Isen, & Turken, 1999 for a review): positive affect enhances cognitive flexibility (Isen & Daubman, 1984; Isen, Niedenthal, & Cantor, 1992), increases verbal fluency (Philips et al., 2002), helps to overcome functional fixedness and improves problem solving (Greene & Noice, 1988; Isen, Daubman, & Nowicki, 1987), increases variety seeking among safe alternatives (Kahn & Isen, 1993), facilitates implicit judgments of semantic coherence (Bolte, Goschke, & Kuhl, 2003), and can reduce Stroop interference (Kuhl & Kazén, 1999). Taken together, these studies support the assumption that positive affect increases cognitive flexibility. Dreisbach and Goschke (2004), however, could show that the increased cognitive flexibility under positive affect happens at the cost of increased distractibility.

Studies using functional neuroimaging methods provide further evidence for the interaction of affect and higher

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cognition (e.g., Drevets & Raichle, 1998; Yamasaki, LaBar, & McCarthy, 2002; see also Dalgleish, 2004, for a review). For example, Yamasaki et al. (2002) used an oddball paradigm with emotional distracters and found the middle frontal gyrus activated by targets but deactivated by emotional distracters (positive and negative pictures) whereas the opposite activation pattern was found for the inferior frontal gyrus. In the same line, Drevets and Raichle (1998) report increased activation for emotion-related tasks in the amygdale, posteromedial orbital cortex, and the ventral anterior cingulate cortex (ACC) but decreased activation in these very regions for attentionally demanding cognitive tasks. These latter tasks conversely activated dorsolateral PFC and dorsal ACC, regions that were deactivated by induced or pathological emotional states. Taken together the results suggest a reciprocal relationship between dorsal and ventral PFC for cognition and emotion (cf. Yamasaki et al., 2002). Note, however, that in the Drevets and Raichle study only negative emotions (sadness, fear) were examined, whereas in the Yamasaki et al. study distracters of any emotional valence were included. It is therefore problematic to directly derive specific predictions for the effects of positive affect on cognitive control processes.

A detailed neuropsychological theory of positive affect has been developed by Ashby et al. (1999) and Ashby, Valentin, and Turken (2002). They assume that the cognitive and behavioral effects of positive affect are mediated by the neurotransmitter dopamine (DA). More specifically, the authors suggest that the enhanced cognitive flexibility under positive affect is mediated by DA release in the ACC. The assumed association between positive affect and DA gets support from studies showing that drugs that enhance dopaminergic activity like cocaine and amphetamine elevate mood (Beatty, 1995) whereas drugs that reduce dopaminergic activity (like the neuroleptic haloperidol) produce flattened affect (Hyman & Nestler, 1993).

Taken together, positive affect, presumably via mild increases in brain DA, seems to be well suited to mediate the balance between maintenance and flexibility. Derived from the general assumption that maintenance and flexibility impose antagonistic processing modes, positive affect, while increasing cognitive flexibility, should on the other side weaken the maintenance capability in working memory (WM). On first glance this assumption might seem to be at odds with findings from animal studies, showing that DA improves performance in simple WM tasks (Arnsten, Cai, Murphy, & Goldman-Rakic, 1994; Brozoski, Brown, Rosvold, & Goldman, 1979; Williams & Goldman-Rakic, 1995). However, empirical studies with humans on the effects of DA on WM performance yield ambiguous results and show that the influence of DA on WM performance in humans is highly complicated and only partly understood as its influence depends on several factors like dosage, time characteristics of the task, task information, and individual differences in WM capacity (see Kimberg & D'Esposito, 2003). In the light of these equivocal results, it seems even more necessary to collect behavioral data with paradigms that are sensitive to detect costs and benefits of improved cognitive flexibility.

To this end I used a modified version of the Continuous Performance Test (CPT, Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), the AX-CPT (Servan-Schreiber, Cohen, & Steingard, 1996). This task seems to be well suited to examine processes of task maintenance because it predicts differential costs and benefits under the different task conditions in dependence of the maintenance capability. In the AX-CPT participants have to press a prespecified key (e.g., right key) to the probe "X" but only if it follows a designated cue "A" (see Fig. 1). Hence, the cue has to be maintained in WM until the probe appears. Whenever the X follows another letter (e.g., B) or whenever another letter than X follows the A (e.g., Y) a different key has to be pressed (e.g., left key). To impose a strong intentional set for target trials (AX), they will appear with 70% frequency whereas non-target trials will occur with 10% frequency each (BX, AY, BY where B represents any "non A" cue and "Y" represents any "non X" probe). Maintenance capability predicts different costs and benefits under the different non-target conditions. In the AY condition weak maintenance capability (as assumed under positive affect) predicts a *benefit* in terms of decreased RTs and/or fewer errors relative to strong maintenance. Accordingly, strong maintenance capability (as assumed under neutral or negative affect) would predict costs in terms of increased RTs and/or more errors relative to weak maintenance. The rationale is that the cue A predicts the probe X with 70% frequency. Hence, the stronger the cue A is maintained, the higher the costs if this expectation is hurt. At this point one might argue that improved performance on AY trials under positive affect might rather be due to enhanced cognitive flexibility that helps to rapidly switch the cognitive set when the A is followed by an unexpected Y. Therefore, it is important to take a look at the performance on BX and BY trials: on

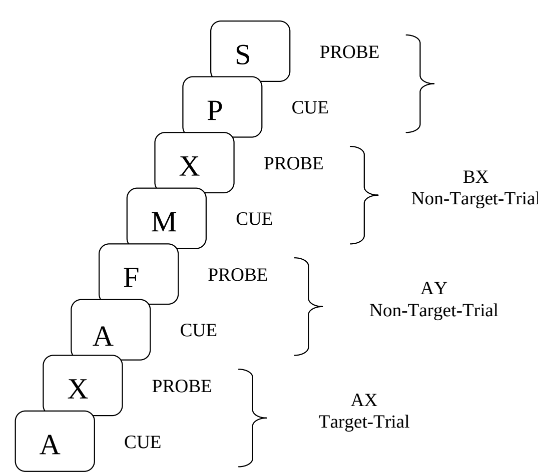

Fig. 1. The AX-CPT task with four different cue–probe-conditions as used in Experiment 1. Target trials appeared with 70% frequency and the non-target trials with 10% frequency each.