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# How performance (non-)contingent reward modulates cognitive control

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ABSTRACT

Reward has repeatedly been shown to influence cognitive control. More precisely, performance contingent reward is known to increase preparatory, proactive control. In comparison, performance *non*-contingent reward, that is, reward that is not dependent on a pre-specified performance criterion but is given unconditional for any response, even errors, is a rather understudied topic. Recently, Fröber and Dreisbach (2014) compared performance contingent and non-contingent reward in a single experiment. They found that non-contingent reward seems to modulate cognitive control in an oppositional way than contingent reward, namely by *reducing* proactive control. In the present paper, the authors further investigate this dissociation in two experiments with a reward manipulation that facilitated adaptations to changes in reward availability: reward – with performance contingency varying between subjects – was manipulated not trial-by-trial but in mini-blocks of 20 consecutive trials in an AX-Continuous Performance Task. Performance *contingent* reward significantly increased proactive control. The repeated experience of *non-contingent* reward even for errors did not result in increased error rates, but instead was indicative of stable compliance with task rules over time and with less reliance on proactive control.



## 1. Introduction

Rewards as a motivator for optimized performance are omnipresent in our everyday life. They are used, for example, in education (grades), sports (medals or prize money), and work life (salary and bonuses). Therefore, the long research tradition on reward effects in psychological science is not surprising at all. In recent years, there is particularly growing interest in modulatory influences of reward on cognitive control. So far, however, the existing literature is characterized by heterogeneous results. For example, rewards have been shown to *increase* conflict adaptation in some studies (Braem, Verguts, Roggeman, Notebaert, & Roggeman, 2012; Stürmer, Nigbur, Schacht, & Sommer, 2011), but to *decrease* conflict adaptation in others (van Steenbergen, Band, & Hommel, 2009; van Steenbergen, Band, & Hommel, 2012). Consequently, several reviews over the past few years (Braver et al., 2014; Chiew & Braver, 2011; Dreisbach & Fischer, 2012; Goschke & Bolte, 2014) stressed the need to further differentiate reward effects, while emphasizing one aspect in particular, namely to disentangle motivational from emotional/affective influences (both inherent to reward manipulations, see e.g. Berridge & Robinson, 2003). An important factor in this respect seems to be performance contingency of reward: for example, only performance contingent rewards increase conflict adaptation (Braem et al., 2012; Stürmer et al., 2011), whereas non-contingent rewards decrease conflict adaptation (van Steenbergen et al., 2009, 2012; but see Stürmer et al., 2011), similar to a positive mood induction without any reward manipulation (van Steenbergen, Band, & Hommel, 2010). Likewise, a recent study from our own lab (Fröber & Dreisbach, 2014) found a typical motivational effect for performance contingent reward in terms of increased proactive (preparatory) control, but an emotional effect similar to a positive affect manipulation via affective pictures for non-contingent rewards in terms of reduced proactive control. While literature on performance contingent reward effects is rapidly growing, only few studies can be found on performance non-contingent reward effects, and there are hardly any studies directly comparing contingent and non-contingent reward effects (for exceptions see Braem et al., 2013; Fröber & Dreisbach, 2014; Stürmer et al., 2011[1]). Therefore, the present study is aimed at further investigating the differential effects of contingent vs. non-contingent reward on cognitive control.

In research on cognitive control the dual mechanisms of cognitive control account (Braver, 2012; Braver, Gray, & Burgess, 2007) has been proven very useful. The DMC differentiates two control modes, namely proactive and reactive control. Proactive control is characterized by preparatory activation and maintenance of goals to optimize goal-directed performance and to prevent interference, whereas reactive control is characterized by a transient, "late correction" activation of goal information only when needed to overcome interference. In theory both modes are not mutually exclusive, but there is typically a preference for one mode over the other. Motivational as well as emotional influences are thought to modulate which control mode is favored in a

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[1] Note that only Fröber and Dreisbach (2014) compared contingent and non-contingent rewards in a single experiment, while Braem et al. (2013) and Stürmer et al. (2011) manipulated reward contingency across different experiments.

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given situation. A common tool to investigate such modulatory influences on proactive and reactive control is the AX Continuous Performance Task (AX-CPT, Servan-Schreiber, Cohen, & Steingard, 1996). The AX-CPT is a context processing task, in which participants have to respond to sequences of cue- and probe-letters. A pre-specified target response is required following the probe-letter X but only if it was preceded by the cue-letter A (AX trial). All other cue–probe sequences – A followed by another letter than X (AY trials), X following another letter than A (BX trials), or two completely different cue- and probe-letters (BY trials) – require a different, non-target response. Importantly AX target trials are presented with a higher frequency (70%) than non-target trials (AY, BX, BY; 10% each), which results in a dominant tendency toward the target response. As a consequence of these task characteristics, specifically AY and BX trials are indicative of proactive and reactive control strategies[2]: a predominantly proactive control strategy is associated with strong maintenance of the cue-letter for advance preparation of the expected response. This strategy is beneficial in all cue–probe sequences except AY trials. Because the A cue – due to the high frequency of target trials – will trigger the expectation for an X and the corresponding target response, which then has to be overcome in case of the unexpected Y probe. With a predominantly reactive control strategy cue information is less actively maintained but transiently reactivated only when needed. This strategy results in benefits in AY trials, because no misleading response tendency will be formed based on cue information. Costs should, however, be found in BX trials due to the strong association of an X probe with a target response, which in this case will be less counteracted by cue-based preparation for a non-target response. Recently, we used a modified version of the AX-CPT to directly compare performance contingent and non-contingent reward (Fröber & Dreisbach, 2014). Since the present experiments are based on the results of this study, it will be presented in more detail.

Our previous study (Fröber & Dreisbach, 2014) was aimed at comparing effects from different sources of positive affect – direct affect induction, performance contingent reward, and performance non-contingent reward – on cognitive control processes in the AX-CPT. To this end, affect only (positive vs. neutral) was manipulated via presentation of affective pictures in a first experimental phase (baseline). In a then following second experimental phase (reward phase) two different reward conditions were added: participants received reward cues before a random subset of 50% of the trials, that is, reward availability varied randomly from trial to trial. The actual reward was given after the response. In one group this reward was contingent on performance (i.e., only for fast and accurate responses), in the other group reward was provided non-contingent as a gift (i.e., any response was rewarded, even in case of an error). We found a typical positive affect effect (in the baseline) in terms of reduced proactive control as indicated by reduced AY errors (cf., Dreisbach, 2006; Fröber & Dreisbach, 2012; van Wouwe, Band, & Ridderinkhof, 2011; but see also Chiew & Braver, 2014) and a typical motivational effect of performance contingent reward (in the reward phase) in terms of increased proactive control as indicated by increased AY errors (cf.Chiew & Braver, 2013, 2014; Jimura, Locke, & Braver, 2010; Locke & Braver, 2008; Padmala & Pessoa, 2011). Moreover, the combination of an affect and a reward manipulation in an integrative design revealed some new findings: (1) the influence of performance contingent reward outweighed the comparatively subtle effect of positive affect. That is, the difference between the positive and neutral affect groups vanished, when performance contingent reward was added in the second experimental phase. And (2), the effect of performance non-contingent reward mirrored performance under direct induction of positive affect (i.e., reduced proactive control), which is the most critical finding for the present research. Any response was rewarded under performance non-contingent reward, that is, even errors. A feasible consequence could have been that participants take the opportunity to change their response strategy towards more careless behavior, that is, to disengage from the current task and give just any response irrespective of the current task demand. So, rewarding erroneous responses could have resulted in promoting erroneous responses. Instead we found constantly decreased error rates over the course of the experiment, and especially so on AY trials. Taken together, both performance contingent and non-contingent reward prospect influenced behavior but in opposite ways, the first by promoting proactive control and the latter by reducing proactive control. While the observation of increased proactive control under conditions of reward prospect is well documented in the literature (e.g. Chiew & Braver, 2013, 2014; Jimura et al., 2010; Locke & Braver, 2008; Padmala & Pessoa, 2011), the finding of a reduction of proactive control under performance non-contingent reward was new. Note, however, that in our study the cues announcing a reward or not changed randomly from trial to trial. So, maybe, participants kept their performance on a reasonable level because they had reason to expect a change in reward contingencies on any given trial. The question thus is whether a more continuous experience of receiving performance non-contingent reward would still show reduced AY errors (and thus reduced proactive control). Alternatively, one might also expect that participants adopt a more careless strategy (resulting in increased error rates) on consecutive trials of unconditional reward.

The importance of investigating the behavioral consequences not only of performance contingent but also non-contingent reward becomes even more obvious when one considers its applied significance: for example, German public officers usually have a tenured position with a fixed monthly salary, and are virtually impossible to dismiss. So, compared to a piece worker, who gets paid contingent on the number of units produced and gets easily fired when he does not meet the daily quota (= performance contingent reward), public officers receive performance non-contingent reward for their work. As a consequence, they are often faced with the stereotype of getting paid for doing nothing. Based on our previous results, we can say that performance non-contingent reward has indeed a different effect than contingent reward, but it is not a deterioration of performance. Although any behavior would have been rewarded, participants still complied with task instructions but with less reliance on proactive control compared to performance contingent reward. To expand the current knowledge on effects of performance (non-)contingent reward the present study was planned as a follow-up study to our previous study (Fröber & Dreisbach, 2014) with emphasis on the following issue: to our knowledge, there is little ongoing research investigating how expectation of a performance *non*-contingent reward impacts behavior. Our previous study provided first evidence that this kind of reward manipulation is accompanied by a reduction of proactive control in contrast to an increase in proactive control under performance contingent reward. Therefore, the primary aim of the present study was to test the reliability of this dissociation, but under intensified conditions. In the previous study, we had manipulated reward availability randomly on a trial-by-trial basis. This led to clear *global* reward effects, that is, performance differences between the baseline without reward and the reward phase. But we found only few *local* reward effects, that is, performance differences between rewarded and non-rewarded trials within the reward phase. Maybe local reward effects would be more pronounced, if reward availability is more predictable, that is not only for a single trial but for an extended sequence of trials. So, to test whether the repeated experience of being rewarded even for slow and erroneous responses under continuous non-contingent reward would still result in reduced proactive control, or whether it would promote careless and error prone behavior, we used again an AX-CPT because of its proven sensitivity to manipulations of proactive or reactive control (for a recent

[2] In several studies effects have been found more reliable for AY than BX trials. For a recent discussion see Goschke and Bolte (2014).