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# When performance and risk taking are related: Working for rewards is related to risk taking when the value of rewards is presented briefly

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ABSTRACT

Valuable monetary rewards can boost human performance on various effortful tasks even when the value of the rewards is presented too briefly to allow for strategic decision making. However, the mechanism by which briefly-presented reward information influences performance has remained unclear. One possibility is that performance after briefly-presented reward information is primarily boosted via activation of the dopamine reward system, whereas performance after very visible reward information is driven more by strategic processes. To examine this hypothesis, we first presented participants with a task in which they could earn rewards of relatively low (1 cent) or high (10 cents) value, and the value information was presented either briefly (17 ms) or for an extended duration (300 ms). Furthermore, responsiveness of the dopamine system was indirectly estimated with a measure of risk taking, the Balloon Analogue Risk Task (BART). Results showed that performance after high- compared to low-value rewards was indeed related to the BART scores only when reward information was presented briefly. These results are suggestive of the possibility that brief presentation of reward information boosts performance directly via activating the dopamine system, whereas extended presentation of reward information leads to more strategic reward-driven behavior.



## 1. Introduction

Valuable monetary rewards are an effective tool to boost people's performance on a variety of effortful tasks (Camerer & Hogarth, 1999). Traditional models of decision making suggest that this effect can be explained by the fact that people carefully weigh effort investment against the value of the anticipated reward (e.g., Brehm & Self, 1989; Eccles & Wigfield, 2002; Wright, 2008). That is, people may decide after some deliberation that a valuable reward is worth the effort, and then recruit sufficient resources to get it. Recent work, however, suggests that such increases in effortful performance can also be found when the value of rewards is presented very briefly, i.e., below people's threshold of conscious awareness (e.g., Pessiglione et al., 2007). This work suggests that rewards may boost performance more directly, i.e., without the need for an effort-related, strategic decision (Gendolla, Wright, & Richter, 2011; Hassin, 2013). However, the process via which briefly-presented reward cues enhance performance is still rather unclear. The present work was conducted to gain new insight into this question.

A paradigm to study the effects of briefly-presented reward information on performance was developed by Pessiglione et al. (2007). In this paradigm, participants are presented with a coin of relatively low or high value for a short (e.g., 17 ms) or an extended duration (300 ms) on a trial-by-trial basis. Coins are preceded and followed by masks, so that the value of the briefly-presented coins cannot be consciously perceived. Importantly, participants can earn the value of the presented coin by meeting a performance criterion on a subsequent task. Using this paradigm, research has revealed that high-value coins improve performance on various effortful tasks such as squeezing into a handgrip (Pessiglione et al., 2007), updating information in working memory (Capa, Bustin, Cleeremans, & Hansenne, 2011), and mentally rotating letter stimuli (Bijleveld et al., 2014). Notably, these effects have been found irrespective of the duration of the coin presentation (e.g., Capa et al., 2011; Pessiglione et al., 2007; Zedelius, Veling, & Aarts, 2011, 2012). So, it seems that conscious, strategic decisions to employ effort once a high-value coin is at stake do not drive these effects.

To account for these findings, a framework has been proposed that distinguishes between initial and full reward processing (Bijleveld, Custers, & Aarts, 2012b). According to this framework, reward cues receive *initial processing* in a network of subcortical brain structures that includes the ventral striatum (Delgado,

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2007). This mesolimbic dopamine reward system (for the purpose of brevity hereafter referred to as dopamine system) is known to be involved in the recruitment of effort (Phillips, Walton, & Jhou, 2007; Salamone, Correa, Mingote, & Weber, 2005). Also, it has widespread projections to cortical areas that are involved in various aspects of goal-directed behavior (Haber & Knutson, 2009). So, the idea is that these networks involved in processing reward cues soon after they are perceived (i.e., also when they are presented only briefly) can account for the finding that briefly-presented reward cues boost performance on various tasks.

After this initial stage, reward cues are thought to receive *full processing*. This stage is thought to involve brain structures that are involved in making strategic, conscious decisions that require awareness of the value of the reward that is at stake (Cleeremans, 2008; Dehaene & Naccache, 2001), such as the prefrontal cortex. Indeed, such strategic reward-related decisions are only observed when reward cues are presented for an extended period of time (e.g., 300 rather than 17 ms; for examples, see Bijleveld, Custers, & Aarts, 2010, 2012a; Zedelius et al., 2012; for reviews, see Bijleveld et al., 2012b; Capa & Custers, 2014; Zedelius et al., 2014).

In the present research, we take a novel approach to examining the dopamine system's involvement in processing briefly-presented rewards. The reason we sought to address this issue is that previous attempts were rather inconclusive. In an early fMRI study, Pessiglione et al. (2007) found involvement of the ventral pallidum, which is indeed a structure that is part of the dopamine system. However, in the condition in which this effect was found, coins were presented for 50 ms, which is still relatively long (compared to 17 ms). In an EEG study, Capa, Bouquet, Dreher, and Dufour (2012) found that briefly-presented, high-value coins led to a greater contingent negative variation (CNV; suggesting the preparatory recruitment of effort) upon perception of the coin, and to smaller alpha band activity during task performance (suggesting the investment of effort). However, it would be a stretch to infer activity in the dopamine system from this finding. Finally, in a recent fMRI study, no brain effects of briefly-presented, high-value coins were detected at all (which was striking, as these same coins did in fact improve behavioral performance, Bijleveld et al., 2014). Taken together, it is currently not very clear *how* briefly-presented reward cues can influence performance.

Based on the ideas that (a) briefly-presented rewards activate the dopamine system, and that (b) increases in performance due to briefly-presented rewards are a direct effect of this activation, we reasoned that the *sensitivity* of people's dopamine system should predict the extent to which briefly-presented, high-value rewards increase performance. It is important to note that there are strong individual differences in the sensitivity of people's dopamine system (e.g., Buckholtz et al., 2010). Therefore, the present study was designed to examine whether individual differences in the sensitivity of people's dopamine system could predict performance after high-value rewards.

Specifically, in the present research, we test the hypothesis that individual differences in sensitivity of the dopamine system predict the magnitude of the impact of briefly-presented rewards on performance. This prediction is based on the distinction between initial and full reward processing: Although extended presentation of reward information (enabling full reward processing) should initially activate the dopamine system, this activation should be less strongly related to performance (compared to briefly-presented rewards), as higher level cognitive processes may subsequently be recruited (e.g., deliberative strategic considerations to maximize gains in the service of current goals; such as obtaining money to buy lunch). Such subsequent processing may well affect performance independently from mesolimbic dopamine processes. Therefore, we expect individual differences in sensitivity of the dopamine system to be more strongly related to the effect of briefly-presented rewards compared to the effect of longer-presented rewards.

To measure people's sensitivity of the dopamine system, the Balloon Analogue Risk Task (BART; Lejuez et al., 2002) was employed. The BART is a measure of risk-taking behavior in which people repeatedly make choices between two options (a risky vs. a safe option). Higher BART-scores reflect more risk-taking behavior. The reason we selected a risk-taking task to measure individual differences in responsiveness of the dopamine system is that risk taking has been linked to the dopamine system in a number of studies. First, several studies have shown that people's risk-taking tendencies are a function of the availability of dopamine receptors in the midbrain (Buckholtz et al., 2010; Driver-Dunckley, Samanta, & Stacy, 2003; Forbes et al., 2009; Zald et al., 2008). For instance, artificially boosting the dopamine system (using dopamine agonists) can induce pathological gambling tendencies (Driver-Dunckley et al., 2003). Second, risk-taking choices in the BART have been shown to be associated to activity in the dopamine system (e.g., the ventral striatum; Rao, Korczykowski, Pluta, Hoang, & Detre, 2008). Third, and more broadly, people scoring high on BART show behaviors that are plausibly related to the responsiveness of the dopamine system (e.g., they smoke more, have more unprotected sex, respond more strongly to performance pressure; Bijleveld & Veling, 2014; Lejuez, Aklin, Zvolensky, & Pedulla, 2003). Taken together, prior research suggests that people who score high on risk-taking measures, and on the BART specifically, have a more sensitive dopamine system.

To test the hypothesis that the intensity of people's responses to briefly-presented rewards correlate with sensitivity of the dopamine system, we first measured people's performance on a demanding task known to be sensitive to high-value (vs. low-value), briefly-presented rewards (Bijleveld et al., 2012a). Next, participants performed the BART (Lejuez et al., 2003). We expected a positive relation between performance on the BART and performance on high versus low rewarded trials when reward value was presented briefly. However, we did not expect a relation between the BART and performance on high-reward versus low-reward trials when rewards were presented for an extended duration, because in this case behavior is also controlled by more strategic processes (e.g., Bijleveld et al., 2012a).

## 2. Methods

### 2.1. Participants and design

Sixty-nine participants were recruited across a period of three weeks in the psychological laboratory at the campus of Utrecht University (a convenience sample). Data of the tapping task was not recorded for one participant and the data for the BART was not recorded for another participant, leaving 67 participants for analyses (35 women; mean age = 22.90, $SD = 5.86$). Participants received a fixed amount of money for their participation (€3), in addition to money obtained during the performance task ($M = €3.05$, $SD = .66$). A 2 (coin duration; extended versus brief) by 2 (coin value: low versus high) within-subjects design was employed with BART score as a continuous predictor.

### 2.2. Tapping task

To measure performance as a function of coin presentation duration and coin value a task from previous work was used (Bijleveld et al., 2012a). Participants were told that they could earn coins in the upcoming task of low (1 cent) and high value (10 cents), by tapping a space bar within a time limit. Moreover,