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Beware the reward – How conscious processing of rewards impairs active maintenance performance ☆

Claire M. Zedelius *, Harm Veling, Henk Aarts

Utrecht University, Department of Psychology, PO Box 80140, 3508 TC Utrecht, The Netherlands

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ABSTRACT

Recently, we showed that conscious and unconscious rewards affect the active maintenance of goal-relevant information differently. Here, we elaborate on the mechanisms enabling the boosting or disrupting effects of consciously processed high rewards, and discuss a few methodological and theoretical implications that may be worth considering in future research on the role of reward processing in working memory performance.

We have shown that relatively high monetary rewards affect active maintenance performance, even when the rewards are processed unconsciously (Zedelius, Veling, & Aarts, 2011). Specifically, we found that both supraliminally and subliminally presented coins of 50 cents compared to 1 cent had the capacity to boost performance when presented at the beginning of a maintenance task (Experiment 1). Importantly, when rewards were presented when participants were already involved in the maintenance process, subliminal high rewards again boosted performance, but supraliminal high rewards led to a decrease in performance (Experiment 2). In a commentary on this article, Vidal and Mossio (2011) question the reported performance decrease and our interpretation of it as an instance of choking. In the following, we will explain why our data show that a relatively high reward of 50 cents can choke active maintenance, and elaborate further on methodological and theoretical implications.

According to Vidal and Mossio (2011), the relative decrease for supraliminal 50 compared to 1 cent trials is questionable as it was marginally significant ($p = .08$). They argue that *conscious* processing of any reward during maintenance, independent of the value, is sufficient to disrupt active maintenance. This disruption may have obscured the performance boost that is usually found for high rewards. However, this alternative explanation cannot account for the present results. Most importantly, comparing the two 1 cent reward conditions, we find no difference in performance, $F(1, 33) = 1.48$, $p = .23$. This is inconsistent with the argument that perception of any consciously processed reward disrupts active maintenance. Comparing the two 50 cents reward conditions, we find that performance is significantly worse when it is presented supraliminally compared to subliminally, $F(1, 33) = 15.60$, $p < .001$. Thus, our data show that it is the value of the coin that modulates the performance: Unconscious processing of high rewards enhances performance, and conscious processing of high rewards impairs performance by distracting attention and disrupting the ongoing maintenance process.

In light of this finding, we agree with Vidal and Mossio (2011) that it is interesting to further elaborate on the mechanisms underlying the boosting and disrupting effects of rewards. By presenting the rewards after the encoding phase (Experiment 2), we showed that rewards have the capacity to affect the active maintenance of information, and not only encoding of the

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* Corresponding author. Address: Utrecht University, Department of Psychology, PO Box 80140, 3508 TC Utrecht, The Netherlands. Fax: +31 30 253 4718.
E-mail address: c.m.zedelius@uu.nl (C.M. Zedelius).

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information. This does not imply, however, that the rewards could not have any influence during the encoding phase. As Vidal and Mossio (2011) point out, the maintenance process for each word is already started during the presentation of the following words. It is therefore indeed reasonable to expect a performance boost already during the encoding phase—which we observed for conscious as well as unconscious rewards.

With regard to the mechanisms enabling the disrupting effects of conscious rewards, several issues were discussed. A first issue concerned the timing of the interference by conscious rewards. In our studies, we demonstrate that the effects of conscious rewards depend crucially on whether or not one is already actively engaged in the maintenance process. When presented at the beginning of the task, high rewards, though potentially distracting as a result of reflecting on it, did not interfere with the subsequent maintenance. We proposed that, at this stage, attention could be re-focused on the task before the target words appeared. In contrast, when rewards were presented during the maintenance phase, conscious perception of a high reward was detrimental. Although attention could again be re-focused on the task, at this stage the target words were no longer externally accessible and a word that was removed from active working memory could not easily be regained. It is in this sense that our data simulate a dual task interference phenomenon—an issue that has been examined on perceptual cognitive and behavioral level (e.g., Johnson & Proctor, 2004; Pashler & Johnston, 1998).

Based on the obtained data, we believe it is the conscious (reflective) processing of the reward itself which *immediately* caused the interference. As Vidal and Mossio (2011) propose, this argument can be further supported by comparing the trials with a longer delay with short delay trials (Experiment 2). If the choking effect were due to influences disturbing performance later in the delay period, we should find a reward $\times$ delay interaction in the supraliminal condition. This interaction was absent ($F < 1$), indicating that performance was indeed affected instantly by conscious processing of high rewards.

Furthermore, Vidal and Mossio (2011) questioned the proposed neural mechanism of the choking effect of high conscious rewards. Since our data do not include neuroanatomical measures, we can only speculate based on previous studies (Gilbert & Fiez, 2004; Pochon et al., 2002). These studies provide evidence that activation in the ventral frontal cortex (VFC) evoked by the affective motivational processing of rewards possibly interferes with cognitive performance. We reasoned that VFC activation resulting from the presentation of a reward should be detrimental for performance when it takes place during the task. Vidal and Mossio (2011) question this explanation. Referring to the above mentioned studies, they argue that the activation and deactivation of the VFC appear to act in a relatively long time-scale and thus cannot be responsible for our findings. Although studies show that the magnitude of a reward can be (cortically) processed within milliseconds (e.g., Yeung & Sanfey, 2004), neuroimaging techniques which are employed to locate different aspects of reward processing are of course not suited to provide accurate information about the actual time-scale of these processes in the brain. Given the methodological challenges of fMRI research on this topic, we agree that the existing studies are not yet conclusive.

As a final note, to assess the effects on performance we analyzed the proportion of trials in which all words were recalled correctly. Vidal and Mossio (2011) criticized this all-or-nothing analysis by stating that it probably resulted in the amplification of the effects. Whether or not such amplification may have occurred, it is important to realize that the rewards could only be obtained by complete correct recall of the given information (a common situation in daily life). Consequently, after forgetting one word, there was no benefit for participants in maintaining the others. Hence, the proportion of all words recalled correctly is the most informative indication of the participants' efforts to gain the rewards. Note that this procedure is different from that of Gilbert and Fiez (2004) where participants received rewards for any word that was correctly recalled.

In sum, in our recent studies, we showed that conscious and unconscious rewards affect the active maintenance of goal-relevant information differently. In this critical examination of the underlying mechanisms, we clarify that the conscious processing of a reward of relatively high value has a unique effect on performance in that it causes interference with an ongoing active maintenance process.

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