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Money enhances memory consolidation – But only for boring material

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ABSTRACT

Money's ability to enhance memory has received increased attention in recent research. However, previous studies have not directly addressed the time-dependent nature of monetary effects on memory, which are suggested to exist by research in cognitive neuroscience, and the possible detrimental effects of monetary rewards on learning interesting material, as indicated by studies in motivational psychology. By utilizing a trivia question paradigm, the current study incorporated these perspectives and examined the effect of monetary rewards on immediate and delayed memory performance for answers to uninteresting and interesting questions. Results showed that monetary rewards promote memory performance only after a delay. In addition, the memory enhancement effect of monetary rewards was only observed for uninteresting questions. These results are consistent with both the hippocampus-dependent memory consolidation model of reward learning and previous findings documenting the ineffectiveness of monetary rewards on tasks that have intrinsic value.

1. Introduction

An old but still central question of both experimental research and educational practice is how learning and retention can be promoted. One factor that has recently attracted increased amounts of attention is monetary reward. Imagine that you reached the one million dollar question on the TV show *Who Wants to be a Millionaire*; it is unlikely that you will ever forget the answer to that question. If you read the same question in a textbook, however, you might forget the answer after a few days. Indeed, recent research has shown that monetary incentives can enhance memory (e.g., Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006; Shigemune et al., 2010; Thornton et al., 2007; see also Knutson & Adcock, 2005), even in incidental learning situations (e.g., Wittmann et al., 2005; see also Wittmann, Schiltz, Boehler, & Duzel, 2008). Money's ability to improve memory has received considerable attention due to new neurological findings indicating that the hippocampal memory system and the mesolimbic reward system form a functional loop (Lisman & Grace, 2005; Rossato, Bevilaqua, Izquierdo, Medina, & Cammarota, 2009). Specifically, these studies suggest that monetary reward promotes memory consolidation by activating the mesolimbic reward system, which increases dopamine release in the hippocampal memory system (Duzel, Bunzeck, Guitart-Masip, & Duzel, 2010). Although growing evidence for this effect has been proffered, two critical issues remain unresolved.

First, hippocampus-dependent memory consolidation is presumed to require an extended period of time to complete (Hamann, 2001; McGaugh, 2000), suggesting that the effects of money on memory should manifest only after some time has elapsed. Indeed, such time-dependent effects of memory enhancement are well known in studies of emotional effects on memory, which also assumes hippocampus-dependent memory consolidation (see Kleinsmith & Kaplan, 1963; Sharot & Phelps, 2004; Sharot & Yonelinas, 2008). Nevertheless, little research has been

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conducted to systematically investigate the consequences of monetary rewards on memory at different time points; immediately after encoding as well as after a delay.

Second and more intriguingly, research in motivational psychology has repeatedly revealed that monetary rewards can undermine task engagement, especially for interesting tasks (for reviews, Deci, Koestner, & Ryan, 1999; Ryan, Mims, & Koestner, 1983), because these rewards may crowd out the intrinsic value inherent in interesting tasks (Deci & Ryan, 1985). This "undermining effect" raises the interesting possibility that the proposed consolidation effects of money on memory performance may be observed only for uninteresting materials, because monetary rewards may interfere with learning process for interesting materials. Previous studies on reward and memory, however, utilized materials that were not meaningful to participants (for an exception in a prospective memory task, see Brandimonte, Ferrante, Bianco, & Villani, 2010), making it difficult to test this possibility.

Given these considerations proffered by research in both neuroscience and motivational psychology, the current study was designed to examine the hypotheses that (1) monetary rewards promote delayed, but not immediate, memory performance, and (2) monetary rewards only enhance memory for uninteresting materials. Participants completed a quiz in which they attempted to answer trivia questions with or without monetary incentives, and their memory was tested in surprise immediate and delayed memory tests. The trivia question paradigm used herein was composed of both interesting and uninteresting materials (Kang et al., 2009), which enabled the comparison of memory performance for interesting and uninteresting items.

2. Method

2.1. Participants and design

Forty-five undergraduate students (mean age = 23.1 years) were randomly assigned to a money or no-money condition.

2.2. Materials and procedure

The stimuli were 44 trivia questions, taken from Kang et al. (2009), Nelson and Narens (1980), and other resources, to which answers are typically not known (e.g., "What is the only planet in the solar system that rotates clockwise?", "What is the national flower of Spain?"). Half of the questions were used in an immediate memory test, and the other half were used in a delayed memory test. Note that we used different questions for the immediate and delayed memory tests in order to prevent possible confounding effects of test repetition (Roediger & Karpicke, 2006). The questions used in the immediate and delayed tests were counterbalanced across participants.

In the (incidental) learning session, participants were randomly presented with each trivia question on a computer screen at the rate of 10 s per question, and were asked to provide an answer. The correct answer was subsequently displayed for 4 s, regardless of whether participants answered correctly or not. Before the learning session, participants in the money condition were instructed that they would receive 0.25 Euros for each question answered correctly. No mention was made in either condition that there would be a later memory test. To keep participants committed to the task, we included 34 filler questions that were easy to answer.

After the learning phase, participants worked on a filler task for 10 min and then completed the surprise immediate memory test. Participants were presented with trivia questions at the rate of 10 s per question in random order, and asked to recall the correct answers. The delayed memory test took place 1 week after the experiment; the procedure was the same as that used for the immediate memory test. No mention of the delayed memory test was made in advance; participants were simply scheduled to return a week later for an unrelated purpose. No monetary reward was promised or provided for either test.

3. Results

One participant expected to be tested later; this individual was omitted from the following analyses. Recall rates were calculated for each participant after excluding the questions answered correctly in the learning session (overall correct answer rate = .07). Effect sizes were calculated based on generalized eta squared statistics (η^2_G; Olejnik & Algina, 2003).

3.1. Time-dependent effects of money on memory

Average correct recall rates as a function of monetary reward and time interval are presented in Fig. 1. As expected, participants in the money condition showed only a small advantage in recall performance in the immediate memory test (M = .78 for no-money, and M = .82 for money conditions), whereas the effect of monetary reward was larger in the delayed memory test (M = .42 for no-money, and M = .53 for money conditions). A 2 (Money: money vs. no-money) × 2 (Time Interval: immediate test vs. delayed test) analysis of variance (ANOVA) revealed significant main effects of Money, $F(1, 42) = 4.89$, $p < .05$,

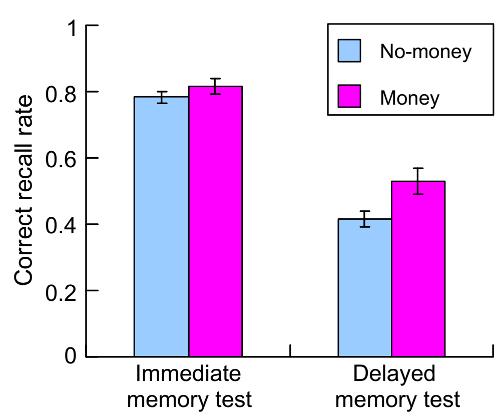

Fig. 1. Correct recall rates as a function of monetary reward and time interval. Error bars represent standard errors of the means.

$\eta_G^2 = .08$ and Time Interval, $F(1, 42) = 284.98$, $p < .01$, $\eta_G^2 = .63$; on average, participants recalled more answers in the money condition, and the immediate test produced higher recall rates. However, these main effects were qualified by a significant Money × Time Interval interaction, $F(1, 42) = 4.33$, $p < .05$, $\eta_G^2 = .03$. Simple main effect analyses showed that participants in the money condition recalled more answers than those in the no-money condition on the delayed test, $F(1, 42) = 6.04$, $p < .05$, $\eta_G^2 = .13$, but not on the immediate test ($p = .25$).

3.2. Comparing interesting and uninteresting questions

To examine whether the observed memory enhancement on the delayed test for participants that received a monetary reward was different for uninteresting and interesting questions, 20 independent judges (mean age = 23.7 years) rated their interest in each question on a 1 (not at all interesting) to 7 (extremely interesting) scale, and the mean interest score was calculated for each item (M = 4.36). The reliability for the mean scores across the judges was sufficient (generalizability coefficient $E\rho^2 = .80$; see Brennan, 2001).

Fig. 2 presents delayed memory test performance for uninteresting and interesting questions (the bottom one-third and the top one-third; mean interest ratings = 3.68, and 5.11, respectively) in the money and no-money conditions. As expected, monetary reward strongly enhanced memory performance for uninteresting questions ($M = .25$ for no-money, and $M = .45$ for money conditions), whereas memory performance for interesting questions was similar in the no-money and money conditions ($M = .55$, and $M = .59$, respectively). A 2 (Money: money vs. no-money) × 2 (Interest Score: uninteresting vs. interesting) ANOVA revealed significant main effects of Money, $F(1, 42) = 5.72$, $p < .05$, $\eta_G^2 = .08$, and Interest Score, $F(1, 42) = 40.65$, $p < .01$, $\eta_G^2 = .24$: On average, participants recalled more answers in the money condition, and demonstrated better recall for interesting items.[1] Importantly, these main effects were qualified by a significant Money × Interest Score interaction, $F(1, 42) = 4.97$, $p < .05$, $\eta_G^2 = .04$. Simple main effect analyses showed that participants in the money condition recalled more answers than those in the no-money condition for uninteresting questions, $F(1, 42) = 9.80$, $p < .01$, $\eta_G^2 = .09$, but not for interesting questions ($p = .49$).

Transforming interest scores into categories results in a loss of some of the information normally present in continuous variables. Accordingly, we conducted a supplementary analysis that examined the linear relationship between the memory enhancement conferred by monetary rewards and the interest scores. For this purpose, we first determined the benefit of monetary rewards for each question by subtracting the mean recall rate of the delayed memory test in the no-money condition from that in the money condition, and then regressed this value onto the mean interest rating (for similar procedure, see Arnell, Killman, & Fijavz, 2007; Mathewson, Arnell, & Mansfield, 2008). The regression coefficient was marginally significant, $\beta = -.30$, $t(42) = 2.02$, $p = .050$, indicating that the recall benefit associated with monetary rewards decreased with increased interest.

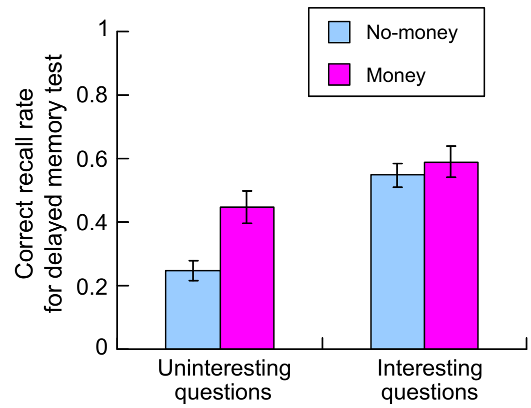

Fig. 2. Delayed memory test performance for uninteresting and interesting questions in money and no-money conditions. Error bars represent standard errors of the means.

3.3. Additional analyses on scaling problems

To this point, we have found that monetary rewards enhanced memory performance only after a delay, and only for uninteresting materials. Although these findings are consistent with our expectations, one could raise concerns about scaling. Performance was relatively high both on the immediate memory test (see Fig. 1) and for interesting questions (see Fig. 2). Therefore, it is possible that diminished performance is responsible for the observed effects of monetary rewards, rather than the delay of the memory test or lower interest levels. To address this possibility, we conducted additional analyses that focused on questions of poorer performance.

Specifically, in the no-money condition, we selected items from the immediate test that were recalled at a rate similar to the mean recall rate on the delayed memory test (i.e., answers that were recalled on average at +/−.2 centered around the average recall rate of the delayed memory test in the no-money condition). By this selection procedure, in the no-money condition, the recall rate for the immediate memory test became almost equivalent to that for the delayed memory test (Ms. = .41, and .42, respectively). Importantly, the impact of monetary rewards on the immediate memory test remained small and unchanged even for these selected items ($M = .41$ for no-money, and $M = .45$ for money conditions), and the difference was indeed statistically nonsignificant ($p = .67$).

In a similar fashion, in the no-money condition, we selected interesting items that were recalled at a rate similar to the mean recall rate for the uninteresting items (i.e., answers that were recalled on average at +/−.2 centered around the average recall rate of the uninteresting

[1] To ensure that the words representing the answers to interesting and uninteresting questions were equally difficult to remember, we asked another sample of 22 participants to memorize the answers without presenting questions. Recall rates for answers to uninteresting and interesting questions did not significantly differ (Ms. = .44 and .46, respectively; $p = .44$).

questions in the no-money condition). By this selection procedure, in the no-money condition, the recall rate for the selected interesting answers became almost equivalent to that for the uninteresting answers ($M = .24$, and .25, respectively). Importantly, the impact of a monetary reward on interesting questions remained small and unchanged even for these selected items ($M = .24$ for no-money, and $M = .27$ for money conditions), and the effect was indeed statistically nonsignificant ($p = .80$).

In addition to these analyses, we ran the same regression analysis conducted earlier but included average recall rate (on the delayed memory test) for each question as an additional control variable. This regression analysis allowed us to examine the effect of interest level for questions with equal rates of memory performance. The analysis showed that the regression coefficient became slightly stronger and statistically significant, $\beta = -.34$, $t(41) = 2.07$, $p < .05$. In sum, these results indicate that our findings cannot be attributed to poorer memory performance in the delayed test or for uninteresting questions. In other words, scaling does not seem to be a viable explanation for our findings.

4. Discussion

The present findings demonstrated that monetary rewards help memory only after a delay, and only if the learning materials are uninteresting. In other words, monetary rewards are not a panacea to improve learning: Rewarding individuals with money may indeed help learning if the materials are uninteresting. If someone is interested in the learning materials, however, it is just a waste of money.

The observed time-dependent effects of monetary rewards are consistent with the hippocampus-dependent memory consolidation model of reward learning (Adcock et al., 2006; Lisman & Grace, 2005). Interestingly, the time-dependent effects of monetary rewards on memory performance parallels findings on the effects of emotion on memory performance (for a review, see McGaugh, 2004), showing that the experience of emotions during learning enhances retention over time (Kleinsmith & Kaplan, 1963; LaBar & Phelps, 1998; Sharot & Phelps, 2004; Sharot & Yonelinas, 2008). However, although the time-dependent effects of emotions are also typically explained by hippocampal-dependent consolidation processes (e.g., Hamann, 2001), the neural circuits underlying both phenomena seem to be different. Specifically, whereas the amygdala has been shown to be critically implicated in emotional influences on memory (McGaugh, 2004), reward-related learning tasks typically involve the reward network, such as the striatum, but not the amygdala (Haber & Knutson, 2010; Schultz, 2006). Research investigating the behavioral differences of the effects of reward and emotion on memory merits future inquiry (see Wittmann et al., 2008).

Previous research has shown that monetary incentives can promote attention and task engagement (Jimura, Locke, & Braver, 2009). Intriguingly, the time-dependent effects observed in our study suggest that attentional factors might play only a minor role in the memory enhancement effects of monetary rewards. Indeed, enhanced attention to the task should increase memory performance largely independently of the retention interval (see Sharot & Phelps, 2004). One could argue, however, that effects of monetary rewards were not found in immediate memory because the attentional threshold required by immediate memory tests is rather low, so that all the answers could be remembered easily regardless of reward condition. We think this seems implausible given that answers with lower recall rates in the immediate memory test (i.e., the answers that are likely below the attentional threshold required by the immediate memory test) were not affected by reward manipulation. However, using a task that directs more attentional resources to memorization (i.e., intentional learning task) may amplify the effect of attention and reveal the effects of monetary incentives on immediate memory performance (e.g., Weiner & Walker, 1966).

The finding that the benefits of monetary rewards are limited to uninteresting questions is in line with previous studies demonstrating the ineffectiveness of monetary rewards for interesting tasks (Deci and Ryan, 1985). These findings not only provide insight into the current literature on reward and memory, which implicitly assumes that the memory enhancement effects of monetary rewards are universal, but also broadens the scope of the undermining effect literature, which has not documented a link to basic cognitive process like memory (for an exception in a prospective memory task, see Brandimonte et al., 2010). It is worth noting that our experiment did not reveal negative effects of monetary rewards. That is, although monetary rewards did not significantly increase memory performance for interesting questions, monetary rewards did not decrease memory performance either (see Fig. 2). We speculate that two contrasting aspects of monetary rewards produced the observed null findings. On the one hand, monetary rewards crowd out the intrinsic value of interesting tasks. Given that interesting materials are in and of themselves well remembered (Kang et al., 2009; see also Fig. 2), undermining interest should lead to decreased memory performance. On the other hand, monetary rewards could enhance memory performance (even for interesting materials) by facilitating a memory consolidation process. As a result, it is possible that the undermining effect of monetary rewards is counteracted by the facilitated memory consolidation process, producing an overall null effect. Future research would do well to examine detailed psychological and neural mechanisms that produced our findings (see Murayama, Matsumoto, Izuma, & Murayama, 2010).

Though research on reward and memory has made considerable progress by incorporating recent findings from neuroscience, our research illustrated that motivational psychology provides another important perspective that has been largely overlooked in this field. Given that there are many things and events that are inherently interesting in everyday life, we believe that considering motivational factors is critical for future models of reward-related learning that attempt to capture real-life learning.

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