Abstract

Our memories play a crucial role in many decisions. Recent work has begun to study how individuals recombine elements of past episodes stored in memory to evaluate the outcome of some decisions (Biderman et al., 2020; Shohamy & Daw, 2015). However, memory is not infallible and can get distorted. Understanding the impact of a fallible memory system on decision-making is essential. To explore how rewards influence memory and subsequent choices, we employed a modified version of the classic Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), where we assigned different levels of reward to different DRM lists at the encoding stage . Words were either novel, studied, or conceptually related critical lures. In Experiment 1, we tested the effect of reward level at encoding on subsequent memory performance. In Experiment 2, we tested the effect of reward level on subsequent memory-guided value-based decision making. We found that high-value critical lures were brought to mind more often than low-value critical lures overall. Interestingly, participants properly identified high-value critical lures as new, despite bringing those words to mind (i.e., participants successfully monitored their memory for high-value critical lures), but failed to so for low-value critical lures. Moreover, participants chose high-value critical lures more often than novel items that were not related to the studied lists when compared to low-value critical lures. These findings suggest that reward can modulate memory representations to be more generalizable and consequently shape decisions that rely on such representations.

Keywords: false memory, reward, value-based decision making

Public significance statements

This research reveals that, while rewards boost memory recall for veridical information, rewards can also increase the incidence that individuals bring to mind related but unstudied information. Bringing to mind such unstudied information more readily influences value-based choices. This insight connects how memory and decision-making work together, offering a deeper understanding of how rewards shape the way we think and make decisions.

Word count: 10189 words

Reward-induced memory distortions bias value-based decisions

Memory is essential for adaptive decision-making in everyday life. For example, imagine someone who remembers receiving excellent service at a particular restaurant; they are likely to choose that restaurant again in the future. This ability to recall past positive experiences is made possible by the hippocampus, which plays a key role in forming and retrieving episodic memories (Burgess et al. 2002; Voss et al. 2017). Recent research further underscores the hippocampus's significance in value-based decision-making (Shohamy & Turk-Browne, 2013), highlighting the critical role of episodic memory in these processes (Biderman et al., 2020; Enkavi et al., 2017; Gershman & Daw, 2017; Murty et al., 2016; Shohamy & Daw, 2015; Li et al., 2022). By encoding individual rewarding experiences into the memory system, individuals can retrieve specific memories of past wins or losses, which directly influence their decisions (Bornstein et al., 2017). While memory serves as an adaptive cognitive process that enhances human cognitive efficiency, this adaptability also makes it susceptible to errors (Schacter et al. 2011; Schacter, 2012). For instance, individuals can develop false memories—recollections of events that never actually occurred—through associations with related events (Gallo, 2010; Loftus & Pickrell, 1995; Roediger & McDermott, 1995). Additionally, the experience of reward associated with a particular stimulus can extend to semantically related but neutral items (Patil et al., 2017). This raises an important question: how do false memories of past rewarding experiences affect decision-making? This study aims to explore the impact of these false memories on value-based decisions.

Reward can spread among semantically related items, transforming once neutral items into valuable ones following a rewarding experience with another member of the same semantic category (Patil et al., 2017). This generalization process is adaptive, integrating episodic memories with semantic knowledge to support more effective decision-making (Tompary & Thompson-Schill, 2021; Wimmer et al., 2012). Research indicates that perceived value can enhance memory by engaging deep semantic encoding strategies (Cohen et al., 2014, 2016; Mason et al. 2017; Murayama and Kitagami, 2014), thereby strengthening memories of related events (Dunsmoor et al., 2015). For example, when individuals receive feedback during the encoding phase, they often employ stronger semantic processing strategies, which in turn bolster memory for high-value information (Mather and Schoeke, 2011; Mason et al, 2017). Knowlton and Castel (2022) highlight both strategic and automatic mechanisms for encoding valuable information, emphasizing that deeper, value-based encoding supports memory retention.

One possibility is that activation of the mesolimbic dopamine (DA) system supports value-based encoding (Clewett & Murty, 2019; Phelps et al., 2014; Shohamy & Adcock, 2010). Studies have shown that reward anticipation (a period known to engage the mesolimbic DA system) during encoding enhances later recollection and source memory during retrieval (Bowen et al. 2020). This enhanced memory is thought to be made possible through the retrieval of enriched sensory detail of the encoding period (Wittmann et al., 2005; Adcock et al., 2006). Functional MRI research has identified increased post-encoding reactivation of sensory information encoded during reward anticipation, along with greater engagement of higher-order sensory and prefrontal cortices during retrieval of rewarding memoranda (Elward et al., 2015; Miendlarzewska et al. 2016; Murty et al., 2017). This sensory recapitulation may involve more integrative representations of sensory information (i.e., broader, less detailed representations) processed in higher-order sensory and multisensory cortex (Murty & Adcock, 2017; Schlichting & Preston, 2016). Encoding high-reward contexts in a broad and less detailed manner aids generalization to new situations, while encoding low-reward contexts with more specificity and detail prevents over-generalization. This specificity is crucial because while it helps an organism avoid the particular low-reward context they've encountered, it prevents unnecessary avoidance of new contexts, thereby minimizing the risk of missing out on significant rewards.

While there are benefits to forming broader, more integrated, memory representations, as laid out above, there are consequences of such representations to the fidelity of memory. Indeed, broader memory representations can lead to memory errors such as false memories (Gallo, 2010). Memories of events or details that never occurred can be generated through the activation of semantic associations (Loftus & Pickrell, 1995; Loftus, 2005; Roediger & McDermott, 1995). This common phenomenon in daily life (e.g., mistaking a stranger for a friend) has been demonstrated in numerous studies showing that people can spontaneously identify items they’ve never seen before as old (Loftus, 2005; Roediger & McDermott, 1995). Previous research has explored false memories related to food experiences (e.g., being ill after eating egg-salad) and the consequences on one’s later eating behavior (Bernstein & Loftus, 2009). It has also been shown that people tend to choose items they believe they have preferred in the past, even when this belief was misremembered (Henkel & Mather, 2007). However, research has been limited in explaining the mechanisms underlying the influence of false memory on decision processes. Despite evidence of the role of reward in memory generalization and the generation of false memories through semantic associations, little research has examined how integrated semantic associations that induce false memories affect value-based decision-making. Therefore, the goals of our study were to 1) test whether the reward value associated with learned items motivates participants to falsely remember semantically related neutral items and 2) test whether reward value spreads to falsely recalled items and bias later choices. Previous literature has treated the first goal and showed that encoding in a high-value environment led to more false memories due to enhanced relational processing associated with a high reward-motivation or positive affective state (Bui et al., 2013; Storbeck & Clore et al., 2005). The novelty of the current study lies primarily in the second goal, which tests the consequences of reward-modulated memory distortions on value-based decision making. We hypothesized that reward enhances reactivation of the semantic networks of learned items, leading to false memory signals for semantically associated neutral items and biasing later choice in favor of falsely recalled information.

One approach to reliably measure false memory generated from semantic associations is through the Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). In this task, participants are given lists of semantically associated words (e.g., "bed," "rest," "tired," "dream"), but the key word that represents the central theme (e.g., "sleep") is intentionally left out. The key word is referred to as a critical lure. When participants are later asked to recall or recognize studied words, they frequently and inaccurately remember the key word critical lure as part of the list (Deese, 1959; Gallo, 2010; Roediger & McDermott, 1995).

In the current study, we used the DRM illusion paradigm to investigate the effect of reward on value-based decisions for unstudied neutral items that are semantically related to studied words. We attempted to replicate prior findings that reward value associated with DRM word lists motivates participants to falsely remember semantically related critical lures. We extended prior findings by testing whether reward value spreads to unstudied critical lures and biases later choices. By bridging prior research on false memory and value-based decisions, our work clarifies the cognitive mechanisms underlying value-based decisions when the choices are semantically related to a rewarding experience. We hypothesized that participants would have better true memory and a higher incidence of false memory for word lists associated with higher reward values. We further hypothesized that these effects on memory would lead to different choice behavior for high-value critical lures over new semantically unrelated words never encountered at encoding when compared to choices involving low-value critical lures.

We tested our hypotheses in two experiments. Experiment 1 investigated the effect of reward on false memory; participants studied DRM word lists and their associated values, freely recalled the learned words, and recalled the values associated with the words. Experiment 2 measured choice behavior after learning the same rewarded DRM word lists. We tested memory and decision-making in separate experiments to better control for the intertwining influences of memory and decision making on one another. To preview our results below, we found that participants brought high-value critical lures to mind more readily than low-value critical lures, but were able to more effectively monitor their memory for high-value lists (i.e., identify lures as unstudied). Furthermore, participants were more biased to choose high-value lures when compared to low-value lures, demonstrating that a higher incidence of false memory for high-value lists is accompanied with biased choice in favor of potentially falsely recalled high-value information. We propose that reward distorts memory representations that are later relied upon during value-based decisions. The establishment of a link between memory distortions and biases in value-based decision making furthers the theory that relational memory provides, in many cases, the input to a decision process during preference-based choice.

Method

The task procedure modified the classic Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & Mcdermott, 1995). The word lists used in the experiment were from the DRM lists published in Roediger et al. (2001). Every list contains 10 semantically related words. Prior studies have shown that, after studying the list, individuals frequently recalled a word that represents the main theme of the list despite the fact that it was not previously studied. The theme word is referred to as a critical lure. In Experiment 1, participants studied DRM lists and the reward values associated with them, then completed a recognition task that served as an attention check, and then completed a recall task. In Experiment 2, another sample of participants studied the same lists of words, completed the same recognition task, and finally took part in a decision-making task.

Experiment 1

Experiment 1 represents a deviation from the pre-registered experiment on the Open Science Framework (OSF) platform (see details at https://doi.org/10.17605/OSF.IO/8XNPT). We conducted the pre-registered experiment, but it failed to replicate well-validated results from previous studies (additional details can be found in the supplementary material, section "Experiment 3" and Figure S1). Deviations from pre-registration have been explicitly noted and justified in the following sections.

Participants

Participants were recruited from the online platform CloudReseach. They were compensated at a rate of $7.50/hour and received a $5 bonus for completing the recognition task (see details in procedure). Participants were screened to be between the ages of 18 and 35, proficient in English, and had to pass the comprehension questions at the beginning of the task to participate in the study. Informed consent was obtained from participants prior to participation and all study procedures were approved by the Institutional Review Board at the University of Chicago.

To make sure our study had adequate statistical power, we conducted a power analysis based on previous findings using G*Power software (Faul et al, 2007). We based this analysis on previous findings, anticipating an effect size of w = 0.263. This effect size was derived from a study investigating the impact of high and low reward conditions on false memory rates using the DRM illusion paradigm (E. Horwath, personal communication, July 20, 2023). Setting an alpha level of 0.05, and aiming for power of 0.80, the power analysis revealed that a sample size of 114 participants for each experiment was necessary to obtain the same effect size for a chi-squared model comparison between logistic regression models for the effect of false recall modulated by reward (see pre-registration for details). Based on the power analysis, we recruited 140 participants. Eighteen participants were excluded based on their performance on the memory recognition task (see details in procedure). This left 122 participants for later data analysis (M_{age} = 28.87, SD = 3.87; 47 male, 71 female, 4 other). Following data collection and based on feedback from colleagues, we applied a different exclusion criterion than that pre-registered, which resulted in the exclusion of an additional 43 participants (N = 97, M_{age} = 29.11, SD = 3.48; 38 male, 56 female, 3 other). Despite this change in exclusion criteria, the results remained consistent. The rationale for adjusting the exclusion criteria is detailed in the procedure section.

Procedure

Study phase. At the beginning of the study phase, participants were informed that they would be presented with lists of words and that each word within the lists would be associated with a point-value reward. Participants learned 10 lists, and each list contained 10 semantically related words from the DRM paradigm (Figure 1A). Note that 10 lists is lower than the pre-registered number of 20. The deviation is justified as memory performance on a pure recall test (rather than the pre-registered cued recall task) was predicted to be too low. Participants were instructed that there are two kinds of lists. The high-value lists were cued with a green star prior to the start of the list, and words within the lists were paired with rewards between 50 and 70 points. The low-value lists were cued with a gray star prior to the start of the list, and words within the lists were paired with rewards between 10 and 30 points. Participants were told that correctly remembering words from the high-value list would work towards a bonus of $5 at the end of the study, whereas correctly remembering words from the low-value list would work towards a bonus of $0.1. Half of the lists were high-value lists and the other half were low-value lists. The order of the words within each list, the order of lists, and their value category (high or low) were randomized for each participant.

Prior to the start of each list, a gray or green cue was presented for 2 seconds. Then each of the 10 words was presented for 1 second individually, followed by the reward value associated with it. There was a 1-second inter-trial-interval (ITI) between each word and outcome within the list, and a 3-second ITI between each list. To avoid primacy and recency effects on the later recall task, a low-reward list was presented before and after the 10 lists. The two lists were not included in the main analysis.

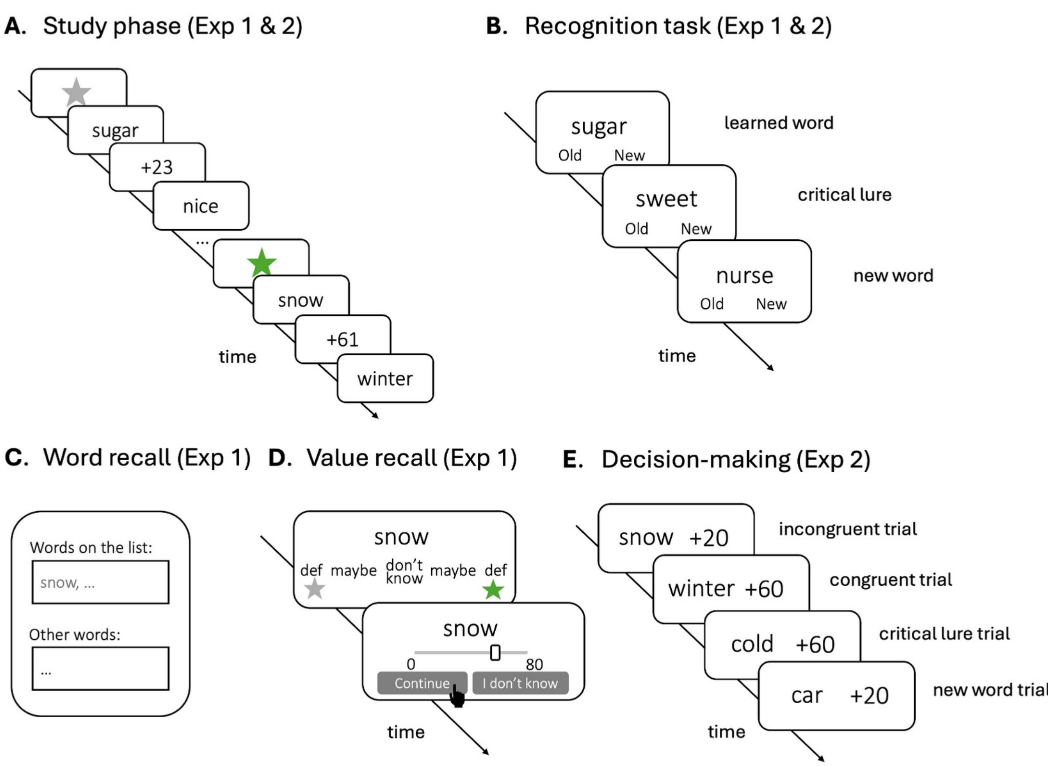

Figure 1. Task design. (A) Study phase in both experiments. Participants learned 10 DRM lists with 10 words each in Experiment 1 and 20 lists in Experiment 2, with words paired with either high-value or low-value points. (B) Recognition task in both experiments. Participants indicated whether a word was old or new. Words from the first and last list (both low-reward lists) were presented. New DRM list words and all critical lures were also presented. (C) Word recall in Experiment 1. Participants freely recalled words from the study phase, and wrote them in either a memory recall box for words they believed were presented or a monitoring box for words that came to mind but they knew were not on the list. (D) Value recall in Experiment 1. Participants viewed the words they wrote in the memory box and identified the associated reward cue then indicated the point value associated with the word. (E) Decision-making task in Experiment 2. Participants made binary choices between a word and a point-value. Participants were instructed to choose the option they believed would maximize their reward. Four trial types were included: 1) incongruent trials pitted a learned word against an average point value from a different value category (i.e., high-value word vs. 20 points or low-value word vs. 60 points); 2) congruent trials pitted a learned word against an average point

value from the same value category (i.e., high-value word vs 60 points or low-value word vs 20 points); 3) lure trials pitted critical lures against the average point value of the list it is related to (i.e., high-value lure vs. 60 points or low-value lure vs. 20 points); and 4) new trials pitted new words against an average point value from either the high or low value lists (i.e. ,new word vs. 20 points or new word vs 60 points).

Recognition task. For each trial in the recognition task, participants were presented with a single word on the screen, and were asked to indicate whether they thought the word was old or new (Figure 1B). The words were from the 2 low-reward buffer (first and last) lists in the study phase, from 2 new DRM lists that were not studied, and the critical lures associated with each of the lists. The order of word presentation was randomized. Data from participants whose hit rate (i.e., the rate at which they identified old words as old) was at least 5% higher than their false alarm rate (i.e., the rate at which participants incorrectly identified new words as old) was included in later data analysis. This recognition memory exclusion criterion deviated from pre-registration. The pre-registration states that any participant who responded correctly on all trials or whose hit rate was lower than 50% would be excluded. The latter pre-registered exclusion criterion allowed the inclusion of participants with low memory precision (e.g., ones with a high false alarm rate, even if they have a high hit rate). Given that part of the goal of the current study was to investigate the role of reward on the precision of memory, we opted to revise our exclusion criteria as stated. This revised exclusion criterion was applied to the subsequent analysis, and the results were consistent with those obtained using the pre-registered exclusion criteria. Once the task was completed, participants were presented with the text “Congratulations on completing the task. You earn a bonus of $5!” to remove the retrieval demands on the later recall task.

Word recall. Participants were instructed to freely recall words from all of the lists that they learned in the study phase (Figure 1C). We ignored any recalled words from the first and last list as they had just encountered those words in the recognition task. In this way, we focused on participants' recall of 10 lists and 100 words of interest. This procedure constituted a deviation from the pre-registered plan, which called for a cued-recall procedure. The cued-recall procedure was used in Experiment 3 (see supplemental material) but did not replicate well-established findings, and thus, we opted to change the procedure to a free-recall procedure.

Participants were presented with two input boxes to write down different words. In the first input box, which we coin the memory recall box, participants were instructed to write down words that they believed were presented during the study phase. In the second input box, which we term the monitoring box, participants were instructed to write down words that came to mind but they knew were not on the list. This procedure allows us to assess whether participants successfully monitor the accuracy of recalled information when the content is highly semantically related (Gallo, 2010; Grant et al., 2023). Participants were required to spend at least 10 minutes on this phase and were required to write down at least 1 word before proceeding to the next phase.

In the first input box (memory recall), each recalled word that matched a word on one of the 10 studied lists was counted as a correctly recalled word. The correct recall rate was calculated as the total number of words correctly recalled divided by the total number of words of interest learned during the study phase (100). Each recall of the critical lures from the 10 word lists of interest was counted as a lure recall. The false memory rate was calculated as the total number of lures recalled divided by the total number of critical lures (10). For the second input box (i.e., monitoring), each critical lure that was written down was counted as correct monitoring. The monitoring rate was calculated as the total number of critical lures that were monitored divided by the total number of critical lures (10).

Value recall. In the value recall phase, participants viewed the words that they wrote down in the first input box (i.e., memory box) during the word recall phase (Figure 1D). Participants were instructed to recall the reward cue (i.e., gray or green cue) and point value associated with that word during the study phase. For each trial, they were presented with one of the words that they wrote down, and they were asked to identify the reward cue the word was associated with (i.e., which reward value category it belonged to) by responding on a 5-point scale with labels: "Definitely Gray", "Maybe Gray", "I Don't Know", "Maybe Green", "Definitely Green". After they made a response, they were asked to type the exact value that was associated with the word. Participants had the option to click “I Don't Know” if they could not recall the point value associated with a word. The order of word presentation was randomized. At the end of all procedures, we collected basic demographic information from participants including age, gender, race, and ethnicity.

Transparency and openness

The study follows the JARS guidelines (Appelbaum, et al., 2018). We report the power analysis used to determine our sample size, along with all data exclusions and their justifications, as well as a detailed account of all manipulations and measures employed in the study. All data, analysis code and materials used for the study are available at https://osf.io/mcqyn/?view_only=a1a7f2c8b28e41eba089e8b5fde9eae6. All analyses were conducted in R (version 4.2.3) using the lme4 package (Bates et al., 2015) for mixed effects regression models, and ez package for repeated measures ANOVAs (Lawrence, 2011).

Analysis

The goal of Experiment 1 was to replicate results from prior studies and extend the findings to better characterize the specificity of memory for value. Previous literature suggested that word lists with higher values are better remembered and more likely to induce false memory (Bui et al., 2013; Wang et al., 2024). Our first analysis looked at the influence of value category on correct recall. We ran a paired-sample t-test to determine whether there was a difference between the correct recall rate of words in high-value lists and words in low-value lists for most participants. We then analyzed the probability that participants wrote down critical lures in each input box. If participants wrote down a critical lure in the memory box, they presumably believed that the critical lure was studied, and thus, we consider such occurrences a false recall. However, if participants wrote down a critical lure in the monitoring box, they presumably thought about the word but successfully monitored their memory to determine that they had not studied the word. Therefore, we ran a repeated-measures ANOVA to test if value type (high or low), the input box they wrote the word in (memory or monitoring), and the interaction between the two affected the probability of writing down the critical lure.

To evaluate participants' memories for the list value cue associated with recalled words, we calculated value category accuracy by binarizing participants' responses and assigning 1 if they correctly identified the value cue with "Definitely" or "Maybe" and 0 otherwise. In addition, we conducted a permutation test to examine participants' memories for the value category of the recalled words. First, we calculated the probability of correctly recalling the value category for recalled words for each participant. Then, we randomly shuffled the value category labels with 10,000 iterations to calculate the null distribution for the difference in accuracy between value categories. Finally, we compared the observed difference in accuracy between the value categories to the permuted distributions to determine the likelihood of observing this difference by chance. For critical lures that were recalled in the memory box, we also calculated the congruency of reporting their value category by calculating the probability that participants reported a critical lure as belonging to the same category as the word list that it was associated with. Similarly, we ran a permutation test with 10,000 iterations to investigate the difference in congruently reporting the value of critical lures between the two value categories.

To investigate the specificity of memory for point values associated with recalled words, we selected words that participants correctly classified as having been in a high or low value list, and calculated the distance from the true value of the word to the value estimated by the participant (i.e., recall value distance). We ran a mixed-effects linear regression for recall value distance by value category, including a random intercept per participant. Similarly, for the critical lures, we selected those that participants indicated were in the same value category as the lists they were associated with. We then calculated the distance between the estimated value for those lures and the mean of the list they were semantically related to. We tested the effect of value category on value distance for critical lures by fitting a mixed-effects linear regression model. For words that were not associated with any presented DRM word lists, we analyzed their semantic connections to both studied words (sorted by value categories) and unstudied words. This analysis employed word2vec to determine if those words were semantically more similar to the studied words (additional details can be found in the supplementary material, section "Semantic associations of written words" and Figure S2).

Results

Higher Value Enhances Memory for Learned Words. In Experiment 1, our primary aim was to replicate the findings of prior studies that found enhanced recall for words associated with higher-value categories (Bui et al., 2013; Wang et al., 2024). Words from high-value lists were recalled at a higher rate ($M = 0.09$, $SD = 0.08$) than those from low-value lists ($M = 0.05$, $SD = 0.07$; $t(96) = 5.80$, $p < .001$, see Figure 2A). These results suggest that higher value can motivate participants to better remember associated words. Participants rarely wrote down learned words in the monitoring box ($M = 0.01$, $SD = 0.02$), suggesting that participants could distinguish between the memory box and monitoring box, and were confident that the learned words were old.

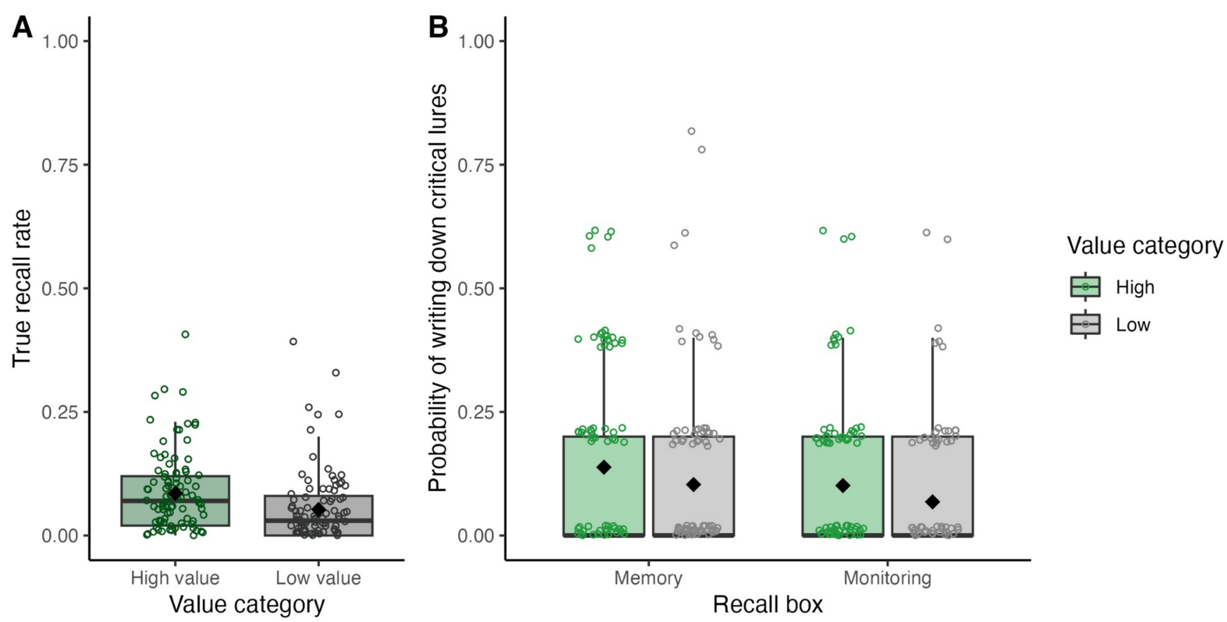

Figure 2. Reward enhances recall and increases the chance unstudied semantically-related words are brought to mind. (A) Probability of correctly recalling learned words. High-value words were recalled more often than low-value words. (B) Probability of writing down high- and low-value critical lures in the memory recall or monitoring boxes. High-value critical lures come to mind more often than low-value critical lures. Black diamonds are means. Thick horizontal lines are medians. The bottom and top edges of each box represent the first quartile (Q1, 25th percentile) and third quartile (Q3, 75th percentile) of the data, respectively, thus defining the interquartile range (IQR). The whiskers extend

to the smallest and largest values within 1.5 times the IQR from Q1 and Q3, respectively. Open circles are individual participant means.

High-value Critical Lures Come to Mind More Frequently. Participants were more likely to write down high-value critical lures compared to low-value ones (main effect of value type $F(1, 96) = 6.20$, $p = .01$, Figure 2B). Participants were slightly more likely to write down lures in the memory box than in the monitoring box (main effect of input box $F(1, 96) = 3.83$, $p = .053$). The interaction between value type and input box was not significant ($F(1, 96) = 0.005$, $p = .94$), indicating that the effect of value type on the likelihood of writing down a critical lure was consistent across input boxes. Overall, the significant main effect of value type suggests that high-value information is more likely to come to mind, irrespective of whether participants believed it was previously presented (false memory) or simply considered but determined to not have been studied (successful monitoring).

Enhanced Memory for Value Category but Not for Specific Value. Participants had better memory of the value category of high-value recalled words ($M = 0.68$, $SD = 0.37$) when compared to low-value recalled words ($M = 0.45$, $SD = 0.43$, see Figure 3A). The difference in accuracy for value categorization between high- and low-value words was significant according to a permutation test ($p < 0.001$, see Table 1 for details). However, high-value lures were classified as being high value ($M = 0.79$, $SD = 0.41$) at roughly the same rate at which low-value lures were classified as low-value ($M = 0.75$, $SD = 0.43$, see Figure 3B). Accuracy in value categorization for the two types of lures did not differ according to a permutation test ($p = 0.67$).

Table 1

Response Frequencies by Value Category for Learned Words

Response	Def low		Maybe low		I don't know		Maybe high		Def high	
	n	%	n	%	n	%	n	%	n	%
High-value words	32	3.8	82	9.8	103	12.3	176	21.1	443	53.0
Low-value words	184	36.0	130	25.3	89	17.3	80	15.6	31	6.0

Note. Def = Definitely. n = number of words across all participants.

We next assessed the specificity of memory for the value associated with recalled words. We calculated recall value distance, defined as the absolute difference between the reported value of a word during the value recall phase and the value of that word learned during the study phase. Recall value distance was higher for high-value words (M = 6.10, SD = 9.54) than for low-value words (M = 3.21, SD = 5.46), but the difference in value distance between high- and low-value words was not significant (β = -2.89, 95% CI = -6.17 - 0.40, p = 0.09; Figure 3C). This indicates that the precision of value recall did not vary significantly by value type. However, recall value distance for high-value critical lures from the mean of the list (M = 11.3, SD = 14.3) was higher than that for low-value lures (M = 5.05, SD = 6.12, β = -7.46, 95% CI = -13.36 – -1.16, p = 0.018; see Figure 3D). This result suggests that the recalled value of high-value critical lures deviated further from the mean value of the list, perhaps because participants recalled high-value lures with a specific (i.e., not the list average) albeit false value attached.

Participants wrote down some words that were not included in any of the studied DRM word lists nor were they lures. For these words, we calculated their semantic associations with both studied and unstudied words using word2vec (Mikolov et al., 2013), which is a machine learning model that transforms words into numerical vectors based on their context in large text data. The analysis revealed that those words were, on average, semantically closer to studied words than to unstudied words (see details in the supplementary Figure S2). These results bolster the claim that participants were bringing to mind information that was semantically related to the studied lists.

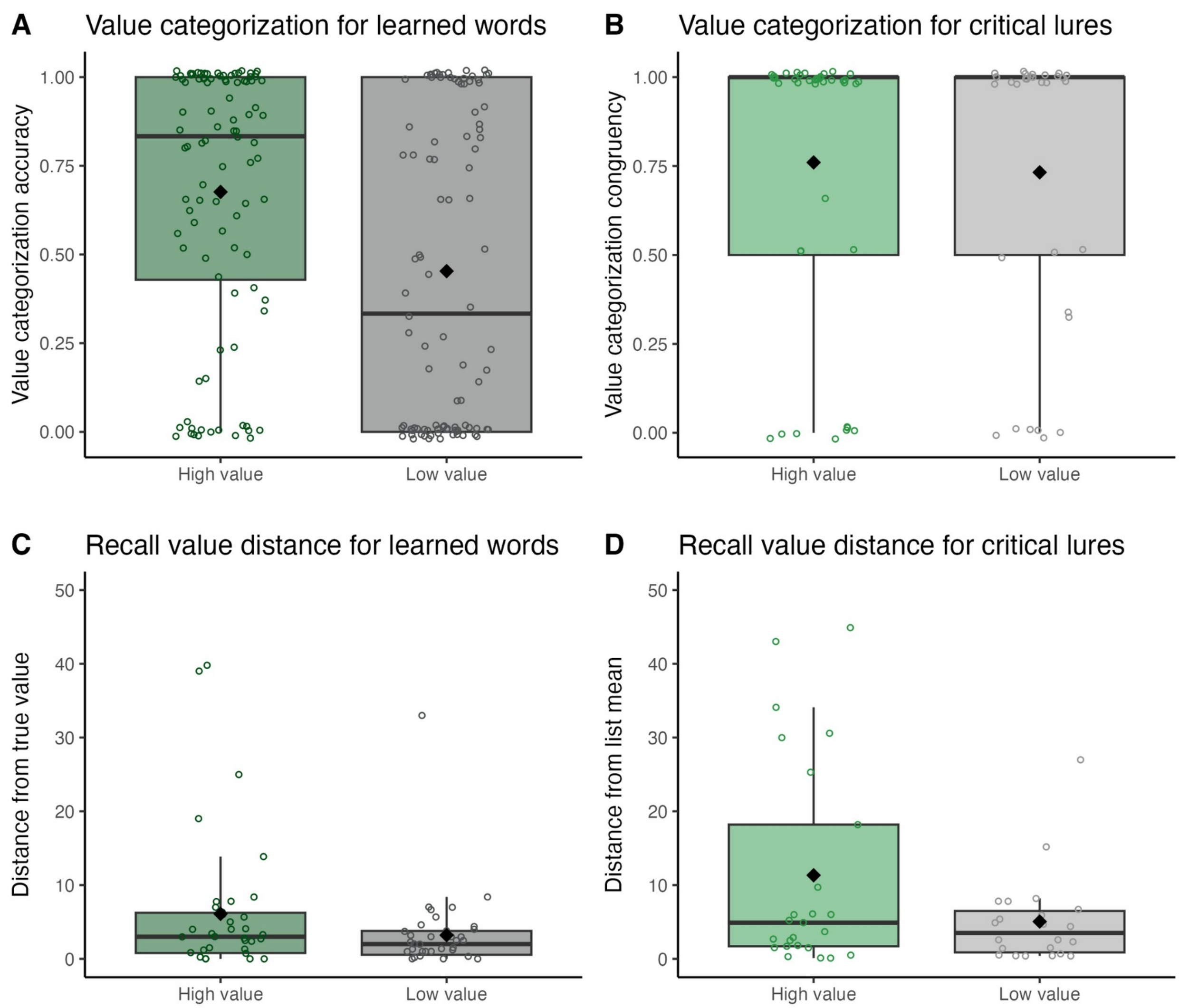

Figure 3. Enhanced memory for value category, but not for specific value. (A) Value categorization accuracy for learned words. High-value words are more likely to be correctly categorized as high-value. (B) Value categorization congruency for critical lures. Participants categorized high-value lures as high-value and low-value lures as low-value at equal rates. (C) The absolute distance from recalled value to the true value of learned words did not differ for words in the two value categories. (D) The

absolute distance from the reported value of a high-value lure to the mean value of the related DRM list was greater than that for low-value lures. Black diamonds are means. Thick horizontal lines are medians. The bottom and top edges of each box represent the first quartile (Q1, 25th percentile) and third quartile (Q3, 75th percentile), respectively, thus defining the interquartile range (IQR). The whiskers extend to the smallest and largest values within 1.5 times the IQR from Q1 and Q3, respectively. Open circles are individual participant means.

Discussion

Reward motivation enhances memory accuracy in many contexts (Wittmann et al., 2005; Adcock et al., 2006). Our findings replicate previous research, indicating that rewards can enhance memory for learned words. Participants recalled words from high-value lists more frequently than those from low-value lists, aligning with prior studies suggesting that rewards improve memory retention (Bui et al., 2013; Wang et al., 2024).

This enhanced recall of words from high-value studied lists was accompanied by a higher incidence of semantically related critical lures being brought to mind. Indeed, more high-value than low-value lures were written down. But it appears that participants were quite good at monitoring source memory for high-value lures and were able to identify these lures as new (i.e., listed them in the “monitoring box”) as often as they failed to do so. This finding extends DRM illusion studies that used classic memory recognition tasks that do not prompt individuals to monitor their memory. Prior reward-motivated recognition memory studies typically showed an increase in false memories for high-reward lists (Bui et al., 2013; Wang et al., 2024). Consistent with these studies, our modified DRM paradigm that incorporates a cue to monitor the source of memory content, revealed that participants were more likely to think about high-value critical lures, regardless of whether they believed these lures were actually presented. These findings suggest that reward enhances the activation of semantic networks, leading to increased retrieval of related but unstudied items.

In addition to memory enhancement for rewarded information, we expected that high-value items would be represented in memory in a less detailed, more gist-like manner. Indeed, according to many theories, it is adaptive to encode high-reward contexts more broadly and with less detail to aid generalization to new contexts (Patil et al., 2017; Clewett & Murty, 2019). Low-reward contexts should be encoded more specifically and with more detail to prevent over-generalization. The latter is important because it is adaptive for an organism to avoid the specific low-reward context they have experienced, but should not extend avoidance to a novel context for they would risk forgoing significant reward too often. However, our findings do not support the idea of more detailed memory for low-value word lists. We found no significant difference in the recall value distance between high-value and low-value words, although the average distance for low-value words was numerically (but non-significantly) smaller. Furthermore, we find that high-value critical lures may be recalled with more false detail for value when compared to low-value lures. However, one major limitation of our study was the low false memory rate. This limitation reduced the number of available trials for analyzing the value memory of critical lures, hindering our ability to draw firm conclusions about the impact of reward on false memory specificity.

In summary, our study replicated previous findings that rewards enhance memory for learned words and increase the likelihood of activating unstudied items that are related to high-value studied items. The enhanced recall for high-value words supports the notion that rewards facilitate deeper semantic encoding (Cohen et al., 2014, 2016). Furthermore, high reward environments do not seem to uniformly lead to the formation of sparser, more gist-like memory representations as we had predicted. Although more research is needed to elucidate the cognitive mechanisms that govern the role of reward in false memory, our findings offer clues. Recall of high-reward information may preferentially activate a wider network of associations when compared to recall of low-reward information, but the source of the associations can be effectively monitored to sort fictive from true associations. Given that memory often offers a source of evidence to make decisions, we next set out to investigate the consequences of reward-modulated memory on value-based decision-making.

Experiment 2

The goal of Experiment 2 was to measure participants' choice behavior after learning the DRM lists with reward values. The study was pre-registered on the Open Science Framework (OSF) platform at https://doi.org/10.17605/OSF.IO/8XNPT, which outlined our research questions, hypotheses, methods, and planned analysis. Deviations from the pre-registration have been explicitly noted and justified in the following sections.

Participants

Similar to Experiment 1, participants were recruited on CloudResearch with an hourly rate of $7.50 and a $5 bonus. The screening criterion was the same as in Experiment 1 and constituted a deviation from that pre-registered. We recruited 142 participants, and 30 of them were excluded based on their performance in the recognition task, leaving 94 participants (M_{age} = 29.37, SD = 3.97; 31 male, 61 female, 2 other) for data analysis. The results using the pre-registered exclusion criterion were consistent with the results reported below.

Procedure

The procedure for Experiment 2 was conducted as pre-registered. Participants went through the same study phase as Experiment 1, but they were presented with 20 DRM lists to study in Experiment 2 (as pre-registered) instead of 10 lists. Participants then went through the same recognition task with 2 filler lists and 2 buffer lists before and after the 20 word lists. After completing the recognition task, they received the same message as in Experiment 1: “Congratulations on completing the task. You earn a bonus of $5!”, followed by the decision-making task below.

Decision-making task. In this task, participants were presented with binary choices. For each of the choice trials, they were asked to choose between a word and a point value (Figure 1E). Participants were instructed to choose whichever option they think will maximize their reward. Therefore, they should choose the word if the reward value associated with it during the study phase is larger than the alternative point value presented on the screen. However, if they think the point value presented on the screen is larger than the value associated with the word, they should choose the reward value instead.

For each trial, participants were presented with a word paired with a number, and they had to press the key “j” to choose the item on the left or press the key “k” to choose the item on the right. Trials did not time out and continued until a response was made. There was a 1-second fixation between trials. Participants were asked to make their choice on each trial as quickly and as accurately as possible. The trial order and the positions (left or right) of the word and number on each trial were randomized for each participant.

There were 4 kinds of choice trials, which sum up to 120 trials in total:

1. Incongruent trials: 20 learned words from the high-value lists paired with a point value of 20 (which is the average value for low-value lists), and 20 learned words from the low-value lists paired with a point value of 60 (which is the

average value for high-value lists). There were 40 incongruent trials, which aimed to test if participants learned the general value category of the words.

2. Congruent trials: 40 learned words from both value categories paired with the average point value of the corresponding list. The average point value for the low-value list was around 20, while the average point value for the high-value lists was around 60. For the following analysis, these average values were referred to as either 20 or 60. There were 40 congruent trials, and the goal of the trials was to test if participants remembered the specific values associated with the words.

3. Lure trials: 20 trials of critical lures from the studied lists paired with the average point value of the corresponding studied DRM list. Similarly, these average values were referred to as either 20 or 60, and the aim of the trials was to test if participants made choices based on the values of the lists that the critical lures were associated

4. New trials: 20 trials of critical lures from other DRM lists that did not appear during the study phase, paired with a point value of either 20 or 60. The goal of the trials was to measure the choice behavior for new words and compare them with lure trials.

We collected basic demographic information from participants including age, gender, race, and ethnicity after the decision-making task.

Analysis

To investigate whether participants learned the value category of word lists, we first tested choice accuracy for incongruent trials in the decision-making task. The choice was correct when participants chose the higher-value option: choosing the word when the word was associated with high value, or choosing the point-value when the word was associated with low value. We predicted that choice accuracy would be above chance for both high-value and low-value word trials if participants learned the value category associated with the words. We tested this prediction using a t-test against .5. In addition, to test whether participants are biased when choosing learned words differently for high- and low-value words, we compared the likelihood of choosing the word over the alternative point value when the word is a high-value word to when it is a low-value word. A mixed-effects logistic regression model was employed to compare the likelihoods of choosing words between value categories in incongruent trials and congruent trials. The model included the main effects of the alternative point-value (20 or 60) and word value category (high- or low-value word) and the interaction between these two factors. Random intercepts were entered for each participant. We also analyzed performance on congruent trials to check if participants can correctly recall the specific value associated with the word (and not merely the value category of the word list) and make correct choices (i.e., choose the word if it was associated with a value higher than the average of the list or choose the number if the value associated with the word is lower than the average for the list). We tested the choice accuracy using a t-test against .5. A logistic regression model was also applied to test for differences between high and low-value categories in accuracy on congruent trials.

In addition, we tested whether participants chose differently between trials with critical lures and trials with new, never before seen, words. According to previous literature, we hypothesized that participants generalize reward values from learned words to semantically related critical lures, and these values acquired through generalization subsequently influence choice behavior. We predicted that value generalization and subsequent choice effects would be stronger for high-value lists than low-value lists. To test this prediction, a mixed effects logistic regression model was employed to assess the effect of value category (high vs. low) and word type (critical lure or new) on the likelihood of selecting the word over the alternative point-value. The binary outcome variable was the selection of an item (0 = select value, 1 = select word). Alternative point-value (0 = 20, 1 = 60) and word type (0 = new word, 1 = critical lure) were treated as fixed effects. The interaction between the alternative point-value and word type was included, and individual participant variability was accounted for as a random intercept.

To better understand the cognitive process involved in making choices, we conducted an exploratory analysis of reaction times (RT) for trials where participants chose words over point values. The RT was log-transformed for fitting the regression models. Firstly, we compared RT for trials with learned words from different value categories. A mixed-effects linear regression model assessed the effect of value category (high vs. low) and alternative point-value (20 vs. 60), with both congruent and incongruent trials fitted within the same model, including the interaction between the value category and the alternative point-value. Random intercepts were included for each participant. Additionally, we explored differences in RT for trials involving new words and critical lures. Using a similar mixed-effects linear regression model, we compared RT for choosing words between word type (new or critical lure) and alternative point-value (20 or 60) on choice trials. This model also included an interaction term between the two variables and accounted for individual participant variability with random intercepts.

Finally, to better understand participants' decision-making processes when selecting critical lures compared to learned words, we investigated RT differences between congruent trials and critical lure trials. This analysis aimed to determine whether participants' deliberation times indicated they treated critical lures similarly to genuine memories, suggesting a false memory effect, or if longer deliberation times implied inference about the value of critical lures during decision-making. To test these hypotheses, we employed a mixed-effects linear regression model. This model assessed the impact of value category (low = 0, high = 1) and word type (learned = 0, lure = 1) on RT in trials where participants selected a word over the alternative point value. The model included an interaction term between value category and word type and accounted for individual participant variability through a random intercept.

Results

Decisions Driven by Value Category, Not Specific Values. Participants' ability to select higher-value stimuli was assessed, where the correct choice involved selecting a word when it was associated with a high value, or the alternative point value number when the word was low-value. The overall choice accuracy for incongruent trials significantly exceeded 50% chance level, with participants achieving an average accuracy of 73% ($SD = 0.18$, $t(93) = 12.42$, $p < 0.001$). To test for differences in choice performance, we applied a mixed-effects logistic regression model with random intercepts for participants. We tested the effect of word value category and the point-value alternative on choice of the word for incongruent and congruent trials. The results showed a significant main effect of alternative point-value ($p < 0.001$, see Table 2 for details), indicating that participants were more likely to choose 60 points than 20 points, regardless of word value. Additionally, there was a significant main effect of value category ($p < 0.001$), with high-value words being selected more often than low-value words. There was no interaction between the alternative point-value and word value category ($p = 0.97$, see Figure 4A). These results suggest that participants tended to choose the higher-value option (either point value or word, whichever is worth more). Additionally, participants were biased to choose the word more often if the word was in the high-value category.

The results above suggest that participants knew the value category of the words and made choices accordingly to maximize their reward. We further tested whether participants chose accurately based on the specific value associated with the word at encoding. To achieve this, we analyzed congruent choice trials. In a congruent trial, participants chose between a word previously associated with a specific value at encoding and an alternative point value equal to the average value of the list that word was on. We tested whether choice accuracy (i.e., the probability of choosing the higher-value option, which could be the word or the alternative point-value) is predicted by the word's value category. The average choice accuracy was 50% ($SD = 0.09$) for all congruent trials. The t-test suggests that the choice accuracy was not significantly different from chance ($t(93) = -0.17$, $p = 0.87$). In addition, logistic regression analysis showed no significant difference in choice accuracy between high- and low-value categories ($OR = 0.98$, 95% $CI = 0.86 — 1.11$, $p = 0.74$). These results suggest that although participants make choices according to the overall value category the word belongs to, they are not sensitive to the specific values of the words when making choices.

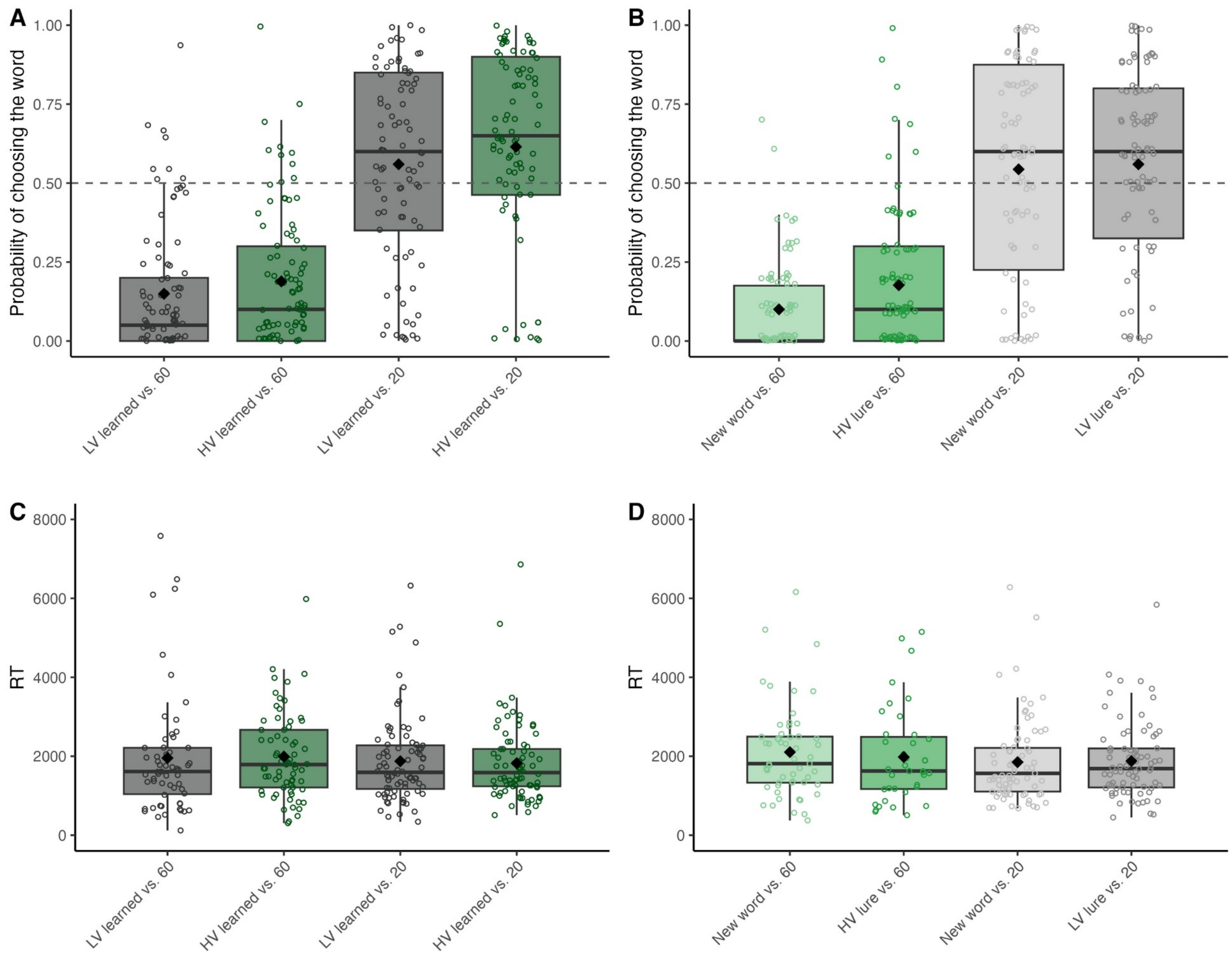

Figure 4. Participants were more likely to choose learned words and critical lures than they were to choose new words. (A) The probability of choosing the word for incongruent (LV vs 60 [best to always choose 60] and HV vs 20 [best to always choose word]) and congruent trials (HV vs 60 and LV vs 20). Participants were more likely to choose the word when it was paired with 20 points, and they were more likely to choose high-value learned words. (B) The probability of choosing lure and new words. Participants were more likely to choose critical lures than new words, in particular when lures are semantically related to high-value lists. (C) RT when choosing the word on incongruent and congruent trials. Participants took equal time to choose the word when the word was in the high- or low- value category. (D) RT when choosing new words and critical lures. Participants took equal time to choose the word over 60 points or 20 points, as well as to choose either new word or critical lure. Black diamonds are means. Thick horizontal lines are medians. The bottom and top edges of each box represent the first quartile (Q1, 25th percentile) and third quartile (Q3, 75th percentile), respectively, thus defining the interquartile range (IQR). The whiskers extend to the smallest and largest values within 1.5 times the IQR from Q1 and Q3, respectively. Open circles are individual participant means.

Greater Choice Disparity Between New Words and High-value Critical Lures. To understand how false memory for rewards influences decision-making, a mixed-effects logistic regression model was conducted with random intercepts for participants. The model tested the effects of value category (high- or low-value lure, new words were randomly placed into the high- or low-value category) and word type (critical lure vs. new) on choice of the word over the point-value alternative. We predicted that participants would be more likely to falsely remember high-value critical lures. Therefore, when choosing between high-value critical lures and 60 points, they would choose the critical lures more often than in trials with new words versus 60 points, reflecting their belief that the word was previously learned. Results indicated a significant main effect of alternative point-value ($p < 0.001$, see Table 2 for details), suggesting a stronger tendency to select words over point values when the point-value is 60. Additionally, results showed no main effect of word type ($p = 0.41$), suggesting that participants are equally likely to choose critical lure words and they were to choose new words over the alternative point-value. Finally, the interaction between alternative point-value and word type was significant ($p < 0.001$, see Figure 4B), indicating that there is a greater difference in choice between new words and critical lures for trials where words were pitted against high point values. As predicted, in trials where words were paired with 60 points, participants were more likely to choose high-value critical lures than new words, suggesting they treated the critical lures similarly to learned words. Taken together, these results suggested that participants chose high-value critical lures more often than novel words that were not related to studied lists.

Table 2

Results of Logistic Regression for Choice Preferences and Linear Regression for Reaction Times

Regression models for learned words

Variable	Probability of choosing the word				Reaction Time			
	OR	*95% CI*	*z*	*p*	*β*	*95% CI*	*t*	*p*
Value category (Low-value = 0)	1.38	[1.18, 1.61]	4.10	< 0.001	-0.03	[-0.08, 0.02]	-1.35	0.18
Alternative point-value (20 points = 0)	0.09	[0.07, 0.10]	-27.06	< 0.001	-0.002	[-0.09, 0.08]	-0.06	0.95
I (Value category * Alternative point-value)	1.00	[0.79, 1.28]	0.04	0.97	0.04	[-0.07, 0.14]	0.71	0.48

Regression models for new words and critical lures

Variable	Probability of choosing the word				Reaction Time			
	OR	*95% CI*	*z*	*p*	*β*	*95% CI*	*t*	*p*
Alternative point-value (20 points = 0)	0.06	[0.04, 0.07]	-20.33	< 0.001	0.09	[-0.03, 0.23]	1.38	0.17
Word type (New word = 0)	1.09	[0.89, 1.35]	0.83	0.41	0.02	[-0.05, 0.09]	0.60	0.54
I (Alternative point-value * Word type)	1.93	[1.35, 2.76]	3.59	< 0.001	0.04	[-0.12, 0.20]	0.47	0.64

Note. OR = Odds ratio, CI = Confidence interval.

More deliberation when choosing high-value critical lures than learned words. To explore the possible differences in RT for congruent and incongruent trials when participants chose the learned word over point-value, a mixed-effects linear regression model was applied with random intercepts for participants. The result showed no significant differences in RT for learned words associated with high-value and low-value ($p = 0.18$, see Table 2 for details). There was no evidence showing difference in RT for learned words by alternative point-value, suggesting that participants spent equal time for trials paired with 20 points or 60 points ($p = 0.95$). Also,no interaction was found between the two factors ($p = 0.48$). These findings suggest no overall differences in RT for learned words.

To investigate potential differences in RT for new words and critical lures, another mixed-effects linear regression model with random intercepts for participants was applied. The model revealed no significant differences in deliberation time on trials where they chose words over 60 points than 20 points ($p = 0.17$, see Table 2 for details). There was no main effect for word type, suggesting that there was no difference in RT for choosing critical lures or new words ($p = 0.54$). No interaction was found between the word type and value categories ($p = 0.64$). These results indicate that neither word type nor alternative point-value impacted the decision-making processes in terms of response time.

Finally, to investigate differences in decision-making processes between critical lures and learned words, a mixed-effects logistic regression model was conducted with random intercepts for participants. The model examined the effects of value category (low vs. high), word type (learned vs. critical lure), and their interaction on reaction times (RT) when participants selected a word over a point value on congruent trials and critical lure trials. Results indicated no differences in

RT on value category (β = -0.002, 95% *CI* = -0.06 – 0.06, p = 0.95), revealing that participants took equal time for high-value words (both learned and critical lures) over 60 points and low-value words over 20 points. There was no main effect of word type (β = 0.001, 95% *CI* = -0.08 – 0.08, p = 0.99), showing equal deliberation times for critical lures than for learned words. Importantly, there was a significant interaction between value category and word type (β = 0.14, *95% CI* = 0.01 – 0.26, p = 0.03), indicating a greater RT difference between learned words and critical lures, particularly for high-value associations. These findings suggest that participants spent more time deciding to choose a critical lure than a learned word over the alternative point-value, with the longest deliberation times observed for high-value critical lures.

Discussion

The role of memory in decision making is well established (Gershman & Daw, 2017; Shohamy & Daw, 2015; Biderman et al., 2020). Memory, by its constructive nature, is prone to error (Schacter, 2012). Experiment 2 sought to investigate the effect of memory errors on decision making. Our findings indicate that both true and false memory of rewarding experiences can bias value-based decisions. In our task design, words were pitted against a point value on each choice trial. This meant that participants chose between an option that presented full and certain information (i.e., the alternative point value) and an uncertain option that required participants to remember the point values associated with the word at encoding. Participants exhibited a general trend to be risk-averse, often choosing the sure-bet point value over the uncertain words.

Comparison across trial types, however, allows us to make inferences. Participants were biased to choose words most often if words were previously associated with high values. This suggests that participants learned the value category associated with words. However, participants chose words or specific alternative point values from the same value level equally often (i.e., their choice accuracy was at chance). Together, these results suggest that, while participants remembered the value category of words (high or low), they did not have specific memories of the exact values of words to base their decision on.

Perhaps more interestingly, we show that participants were more likely to choose critical lures than new words that were never studied and not semantically related to any of the studied lists. If participants had thought that the critical lures were new words, then they would exhibit the same, lower bias toward choosing them. This result suggests that participants may have formed false memories of critical lures, and these false memories were reflected in later decisions. Alternatively, participants may have recognized the lures as unstudied but reasoned that they may have similar value to semantically-related studied words. To explore the underlying deliberation processes further, we analyzed the reaction times (RT) for different trial types. The RT data revealed no significant differences in the time taken to choose between critical lures and new words, which contrasts with the behavioral tendency to choose critical lures more frequently. This discrepancy led us to examine whether the deliberation process for choosing critical lures resembled that for choosing studied words. If the RTs were similar, it would support the notion of false memory formation regarding critical lures. Conversely, longer RTs for critical lures might suggest that decisions were influenced by value-based inferences rather than memory, as participants took additional time to evaluate. Our analysis showed that participants spent the longest time deliberating prior to choosing high-value critical lure words, hinting that they were possibly inferring the value of these lures from the values associated with related studied lists. Notably, high-value critical lures were chosen more often than new words, while low-value critical lures were chosen at the same rate as new words. These results support prior findings that reward can enhance memory activation and generalization (Patil et al., 2017). Our results support the predictions that choices of high-reward critical lures differ from choices of low-reward critical lures and that false memory of rewarding experiences, or at least a stronger semantic inductive reasoning about high-value lures, can bias choices.

One limitation of our experiment is the comparison of choice trials that included an anchoring point value. This allowed us to compare choice behavior between critical lures and new words but introduced the confound of participants being risk-averse. Future studies might benefit from comparing choices directly between two words to mitigate this issue.

In Experiment 2, we examined the impact of memory errors on decision making. Our findings show that both true and false memories of rewarding experiences bias value-based decisions even in the case where participants generally prefer sure-bet alternative point values over value-uncertain words. Participants were more likely to choose high-value words and critical lures over new, unrelated words, indicating that false memories may have influenced their choices. High-value critical lures had a greater impact on choice behavior than low-value lures, highlighting the role of reward in enhancing memory activation and generalization.

General Discussion

The purpose of the current study was to explore how false memories of past rewarding experiences affect value-based decision-making. We hypothesized that high-reward experiences would enhance both veridical and false memory, with implications for subsequent preference-based choices. Across two experiments, we investigated the interplay between memory and decision-making processes, focusing on the impact of reward on both accurate and false memories and the downstream consequences of such impact on choice.

Both experiments employed a modified Deese-Roediger-McDermott (DRM) illusion paradigm where lists of words were encoded in either a high- or low-reward environment. Our results demonstrated that high-reward words are better remembered, consistent with previous findings that rewards engage deeper semantic encoding strategies (Cohen et al., 2014, 2016). In Experiment 1, participants were more likely to recall words associated with high values. Similarly, in Experiment 2, participants were more likely to choose learned words over an alternative fixed point value if the words were associated with high values at encoding, suggesting participants had better memory for high-value words and chose them over lower alternative fixed point values with higher confidence.

Both experiments also showed a consistent pattern where participants remembered the value categories but not the specific details. Experiment 1 results indicated that participants recalled the value category of words but not the specific values associated with them at encoding. Likewise, in Experiment 2, participants performed above chance in incongruent trials, which tested memory for the words’ value categories, but their accuracy was close to chance in congruent trials, which tested memory for the words' specific point values. These findings suggest that participants effectively learned the general reward categories of words but did not retain precise memory of specific values. These findings are consistent with prior literature as encoding in high-reward environments can form broader, more generalizable memory representations (Murty & Adcock, 2017; Clewett & Murty, 2019). Such a broad memory representation of high-value lists in our task could explain better memory for value category but not for specific details such as point values.

Our findings also support the theory that rewards can enhance memory activation and generalization (Patil et al., 2017). In Experiment 1, participants were more likely to bring to mind high-value when compared to low-value critical lures—unstudied words semantically related to high- or low-value studied word lists, respectively. The findings suggest that the search for high-reward words enhances activation of related semantic networks and can lead to false memories. Participants were adept at monitoring these false memories when cued to do so, effectively identifying critical lures as items not presented during the study phase. Based on the activation-monitoring framework, these results suggest that higher values are more likely to induce automatic associations and generalizations through the semantic networks, and thus make the words more likely to be brought to mind (Gallo, 2010; Roediger et al., 2001). In addition, high-value critical lures were relatively well-monitored, indicating that false memories induced by reward may be fuzzy-traced (i.e., familiarity-based memory signals) rather than recollection-based episodic memories (Brainerd & Reyna, 2011). However, in Experiment 2, when participants were not prompted to monitor their memories, their choices were biased towards critical lures, especially high-value ones. This suggests that the absence of monitoring cues leads to decisions influenced by false memories of rewarding experiences. Alternatively, participants knew that lures were unstudied, but reasoned that they may have similar value to semantically related studied words. Since more high-value lures likely came to mind preferentially, this inductive reasoning process would have occurred more often for high-value lures. Our reaction time data reinforces this idea; participants took the longest to deliberate prior to choosing high-value critical lure words. This suggests that they were assessing the value of these lures based on their associations with previously studied lists. These observations align with those from Experiment 1, where participants, when prompted, could effectively identify critical lures as new words. Even so, during decision-making, they engaged in value-based reasoning concerning the associated lists, even after correctly recognizing some lures as new. Taken together, these results align with our predictions based on previous literature that high-reward experiences enhance memory and that this effect extends to semantic activations and false memories, thereby influencing subsequent choices (Patil et al., 2017; Wang et al., 2024).

These findings highlight the complex relationship between memory and decision-making, making several key contributions to extant literature. Our research replicates prior work by confirming that rewards improve general recall accuracy (Cohen et al., 2014, 2016). However, it also extends prior findings that rewards enhance the likelihood of generating false memories (Bui et al., 2013) by demonstrating that memory for high-reward information can be effectively monitored for source accuracy. Additionally, our research provides novel insights into how rewards can promote the generalization of reward value to related but unstudied items, influencing subsequent choices. When monitoring cues are absent, potential false memories significantly bias decision-making, especially for high-reward semantic associates. This suggests that while rewards enhance memory activation, they also promote the generalization of reward value to related but unstudied items, subsequently influencing choices. This finding bridges the gap between theories of memory activation and value-based decision-making, contributing to a more nuanced understanding of how rewards shape cognitive processes.

One limitation is that we cannot draw causal inferences due to the task design, which did not allow for the direct measurement of memory for the words and decision-making within a single experiment. We chose to separate the memory task and decision-making task because extensive literature has shown that memory and decision-making are integrated cognitive processes (Gershman & Daw, 2017; Shohamy & Daw, 2015; Biderman et al., 2020). People tend to have better memory for items they previously chose, and their decisions are easily biased by their memories, with individuals tending to choose items they remember better, even if their values are equal to the alternative (Mechera-Ostrovsky & Gluth, 2018). In the current study, false memories likely influenced participants' choices of words over point values since people tend to choose items they have encountered before (Kraemer et al., 2022). Additionally, the reward associated with words can bias memory, making higher-value words better remembered and more likely to generate false memories. While future studies could ideally make causal inferences about the interaction between false memory and decision-making, simply including a memory test alongside the decision-making test would lead to the aforementioned problems. Moreover, future research could explore whether bias towards high-value words can be mitigated by cueing participants to "double-check if the word was learned" for critical lures.

In conclusion, our study demonstrates that rewards enhance memory retention and induce memory distortions, and such memory distortions bias value-based decisions. The findings underscore the complex relationship between memory and decision-making, revealing that false memories of rewarding experiences can bias choices the same way veridical memories do. These insights contribute to our understanding of how rewards shape cognitive processes and have significant implications. For instance, they can inform strategies to avoid poor decisions and develop interventions to help clinical populations, such as those with eating disorders, make better choices. Overall, this research has broad applications across fields including psychology, neuroscience, and behavioral economics.

Constraints on Generality

The findings from this study should be interpreted with consideration of the specific characteristics of the sample. The data were collected from an online sample in the United States, which represents a WEIRD (Western, Educated, Industrialized, Rich, and Democratic) population (Henrich, Heine, & Norenzayan, 2010). As such, the results may not generalize to populations outside of this demographic. Future research should assess whether similar patterns emerge in more diverse, non-WEIRD populations to strengthen the external validity of the findings.

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