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Recognizing what matters: Value improves recognition by selectively enhancing recollection

Joseph P. Hennessee *, Alan D. Castel, Barbara J. Knowlton

University of California Los Angeles, Department of Psychology, 90095, USA

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ABSTRACT

We examined the effects of value on recognition by assessing its contribution to recollection and familiarity. In three experiments, participants studied English words, each associated with a point-value they would earn for correct recognition, with the goal of maximizing their score. In Experiment 1, participants provided Remember/Know judgments. In Experiment 2 participants indicated whether items were recollected or if not, their degree of familiarity along a 6-point scale. In Experiment 3, recognition of words was accompanied by a test of memory for incidental details. Across all experiments, participants were more likely to recognize items with higher point-value. Furthermore, value appeared to primarily enhance recollection, as effects on familiarity were small and not consistent across experiments. Recollection of high-value items appears to be accompanied by fewer incidental details, suggesting that value increases focus on items at the expense of irrelevant information.

Introduction

In everyday life, we are bombarded with a wealth of information, and selectivity is necessary for efficient learning. For example, when studying for a test, a student typically has more course material available to them than they can possibly remember. To optimize test performance, they need to selectively learn the information that is the most important and most likely to be on the test, often at the expense of less important information. Time constraints, item difficulty, and the value of the material, often determine what is selected for learning (Ariel, Dunlosky, & Bailey, 2009). Much research has illustrated that value enhances the learning and recall of short free-recall and cued-recall word lists (Ariel et al., 2009; Castel, Benjamin, Craik, & Watkins, 2002; Castel, Murayama, Friedman, McGillivray, & Link, 2013). To examine value-selective learning, Castel et al. (2002) established the Value-Directed Remembering (VDR) design, wherein participants learn words associated with point-values, and earn those points for correct recall. These point-values were used to simulate some information being more important than other information. They found that although young adults can recall more words than older adults, both older and younger adults are equally able to selectively recall higher-value words (Castel et al., 2002; Castel et al., 2013). In these studies, participants experience the limitations of their ability to freely recall items through feedback on successive tests. Participants thus learn to differentially encode high-value items to maximize their performance.

When recognition memory is tested the need to differentially focus on high-value items would appear less critical due to the larger number of items one can typically recognize compared to recall after a single study of a presented list. For example, it has been shown that recognition memory for individual pictures after a single study

* Corresponding author.
E-mail addresses: jhennessee@ucla.edu (J.P. Hennessee), castel@ucla.edu (A.D. Castel), knowlton@psych.ucla.edu (B.J. Knowlton).

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is nearly limitless (Standing, 1973), while the ability to freely recall items after a single study opportunity is constrained by working memory capacity (Linderholm & van den Broek, 2002; Unsworth, 2007). In addition, recall also leads to substantial output interference (Roediger & Schmidt, 1980). As such, recalling unimportant information has a negative impact on the ability to recall high-value information, while recognizing unimportant information would likely have less impact on the ability to recognize a valuable item. Although there may be little pressure to differentially encode high- and low-value items for a recognition test, there is nevertheless evidence that high-value items are recognized better. For example, Adcock, Thangavel, Whitfield-Gabrieli, Knutson, and Gabrieli (2006) examined the role of value in a recognition task. In their study, participants were presented with 120 scenic pictures while in an fMRI scanner, each worth a high-value ($5), low-value ($0.10), or no value. Participants were told they would earn the corresponding amount of money for correct recognition at testing, and would lose some money for incorrect responses. The following day, higher-value scenes were recognized with both higher accuracy and higher confidence. The ventral tegmental area and nucleus accumbens pars compacta specifically exhibited memory-related activation during high-value reward cues, which is in line with a wide range of research supporting their involvement in reward processing and motivation (Carter, MacInnes, Huettel, & Adcock, 2009; Hyman, Malenka, & Nestler, 2006; Kalivas & Volkow, 2005; Weiland et al., 2014). The hippocampus also displayed memory-related activation both during the reward cue—perhaps in anticipation of important learning—and during scene encoding. This finding suggests that value may enhance later retrieval by supporting encoding that is associated with episodic binding, which has been associated with the hippocampus (Kragel & Polyn, 2015; Mitchell & Johnson, 2009; Simons & Spiers, 2003). The behavioral findings of Adcock et al. (2006) have been replicated in an older adult sample and an additional young adult sample (Spaniol, Schain, & Bowen, 2013). Overall, these studies suggest that value enhances recognition, and raise the question of how value affects the encoding process to support enhanced recognition.

Although much research has investigated the effect of value on later free recall, and some research has investigated its role in recognition, little research to date has investigated the role of value in shaping the quality of memory on a recognition task. A common distinction is made between *remembering* and *knowing* in the experience of recognition. Remembering entails being able to consciously recollect a previous experience or event, typically including the memory of various details related with this episode. Remembering includes awareness of one's existence in a previous experience or event, and is often like reliving the experience (Tulving, 1985). In contrast, knowing involves recognizing information without consciously recollecting the phenomenon or previous event. Knowing can most often be described as feelings of familiarity, without a conscious memory of the learning experience. Based on previous work suggesting greater hippocampal activation during encoding of high-value items (Adcock et al., 2006) it seems plausible that value would differentially enhance recollection, leading to more "Remember" responses, while feelings of familiarity may not be increased.

The subjective experiences of "Remembering" and "Knowing" are often described in the context of the dual-process theory, wherein memory is separated into recollection and familiarity processes. "Remembering" results when a recollection process is active, while a "Know" response results if only a familiarity process is active. By this view value could increase encoding leading to greater recollection and selectively greater "Remember" responses, or it could result in generally greater memory strength, leading to enhanced levels of both "Remember" and "Know" responses. By another view, "Remember" and "Know" responses reflect the application of different thresholds for recognition. According to Unequal Variance Signal Detection (UVSD) models (Dunn, 2004; Wixted & Mickes, 2010), recollection is not a separate process, but rather a higher level of memory strength. By this view, value might shift the strength of items in memory, leading to increases in old items that are recollected and judged familiar. Value could also change the shape of the distribution of old items, leading to a selective increase in those meeting threshold for a "Remember" response.

If valuable items are recognized better than low-value items, it suggests that encoding differs as a function of value. High-value cues may prompt further elaborative encoding of the target, which has been shown to result in later recollection (Fawcett, Lawrence, & Taylor, 2016; Gardiner, Gawlik, & Richardson-Klavehn, 1994). The involvement of the hippocampus during learning valuable items also suggests that encoding includes episodic binding (Adcock et al., 2006). However, because participants must study a large number of items for recognition tests, it was also plausible that they would instead primarily use less effortful maintenance rehearsal strategies, and that this rehearsal would increase for high-value items. Given this type of rehearsal supports increased familiarity (Fawcett et al., 2016; Gardiner et al., 1994), valuable items may show increases in familiarity as well as recollection.

In addition to differences in the subjective quality of the recognition of items, value could also affect the degree to which recognition is accompanied by memory for incidental details. It may be that if value enhances episodic binding of information during encoding, recognition of high-value items would be accompanied by incidental source memory. Another factor is the influence of value on attention during encoding. Items associated with high value have been shown to be subject to attentional capture (Anderson, Laurent, & Yantis, 2011), and this greater attentional focus could preclude the encoding of irrelevant details.

Experiment 1

In Experiment 1, the effect of value on recognition, recollection, and familiarity was measured using the Remember-Know task. This task relies on participants' introspection about the characteristics of their recognition judgments. For each test item that is judged "old", participants decide if their recognition is based on remembering the study episode for the item, or if they simply knew the item had been presented due to a strong sense of familiarity. This method for assessing recollection and familiarity have been used widely and it has been shown that participants are able to use Remember and Know responses to accurately differentiate between episodic and non-episodic memory (Dudukovic & Knowlton, 2006; Gardiner, Ramponi, & Richardson-Klavehn, 1998; McCabe, Geraci, Boman, Sensenig, & Rhodes, 2011). After studying a long list of words that are assigned either a high or low point-value, we hypothesized the following effects on the Remember-Know test. First, high-value words will be correctly recognized overall more often than low-value words, Second, we hypothesized that high-value words will receive a greater proportion of trials with remember responses due to deeper semantic processing of these items and/or binding of these items to the study context. Conversely, there may also be an increase in Know responses for high-value items if value increased overall memory strength.

Method

Participants

Data for Experiment 1 were collected from 48 University of California, Los Angeles (UCLA) undergraduate students. Data from two students were excluded from analysis because one failed to understand the recognition task procedures, and another scored over two standard deviations above the mean on their remembering false-alarm rate, leaving a final sample size of 46. Recollection was one of the key measures in this study, and unusually inaccurate remember responses may have indicated either a failure to understand the meaning of remembering in this study or a misuse of this rating. The sample was composed of 30 women and 16 men with a mean age of 21.3 years ($SD = 4.5$, range: 18–46). Their fluency in English was not assessed. These participants, and those from the following two experiments, were volunteers from the UCLA psychology subject pool. The participants completed the study for course credit. Informed consent was obtained and the study was completed in accordance with UCLA's Institutional Review Board.

Materials

Stimuli consisted of 180 six-letter English words, including nouns, adjectives, and verbs. Ninety of these words were presented during the study phase, and were paired with point-values of 1, 2, 3, 10, 11, or 12. These values were chosen to maximize the difference between words with low (1–3pt.) and high (10–12pt.) values. During the final recognition test, all 180 words—half that were presented at study and half that were new—were presented randomly intermixed, without their point-value. Words were presented in random order and had a mean frequency of 5974 ($SD = 570$) occurrences per million in the Hyperspace Analogue to Language corpus (Lund & Burgess, 1996). Because the frequency of a word's use in English influences Remember/Know ratings (Reder et al., 2000), HAL frequencies were kept nearly equivalent for high-value words ($M = 5917.40$, $SD = 518.23$), low-value words ($M = 6065.36$, $SD = 576.94$), and distractors ($M = 5954.28$, $SD = 598.27$), $F(2, 178) = 0.84$, $p = .433$, $\eta^2 < 0.01$. Additionally, the number of phonemes, morphemes, and part of speech did not differ significantly between these three item types ($p > .190$).

All materials were presented on an Apple iMac computer and participants completed the study individually. The monitor was placed approximately 15 inches from the edge of the desk. The study was programmed onto the computer and data were recorded using e-prime (ver. 2.0) software. All responses were given using a keyboard.

Procedure

At the start of the experiment, participants were informed that they would be learning a series of English words paired with point-values, and that they would later be tested on which words they could recognize. Instructions stated that the point-values of correctly recognized words would be added to their score, and that their primary goal was to maximize their score. Participants were also told that they would lose points for incorrectly reporting that they recognized a word from before when it was actually a new word. Without the prospect of losing points for incorrect guesses, the optimal strategy for earning points would be to rate all items as being previously presented. Next, participants were presented with the 90 study words, each presented randomly and with its own point-value. Words were presented for 2 s, with a fixation cross presented between word-presentations for 0.5 s.

After viewing all study words, participants had to solve a set of 24 basic multiplication and division problems (e.g., $12 \times 12 =$ ______). This was a distractor task to reduce mental rehearsal, and performance was not examined in later analysis. This task was designed to take participants roughly 5 min to complete, and there was an ample 30 s time-limit for responding to prevent participants from spending too much time on any one problem.

Before completing the recognition task, participants were instructed regarding the difference between remembering and knowing using an adapted form of Gardiner and Java's (1990) instructions (see Appendix A). The experimenter asked each participant to explain what it means to remember and the meanings of remembering and knowing were discussed until the distinction was clear.

Finally, participants completed the recognition task, wherein they viewed a randomized mixture of the 90 previously presented words and 90 new words. During the recognition task, participants were asked if each word was previously presented ("old") or not presented before ("new"). After an old response, participants were asked to report the basis for their recognition, giving either a remember or know response. All responses were self-paced. Participants had the option of contacting the experimenter later if they wanted to know what score they achieved.

Data analysis

To examine the effects of value, recollection and familiarity, we conducted dependent samples t-tests. Words with values of 1 through 3 were considered low-value, whereas words with values of 10 through 12 were considered high-value. Prior to all analysis, only trials with response times (RTs) between 500 ms and 8000 ms were included. In line with advice by Ratcliff (1993) these criteria were chosen to eliminate the small proportion of responses that may have had abnormally high or low RTs due to factors such as a participant needing procedural clarification or a participant blindly making a quick response to progress through the study more quickly. This RT cutoff eliminated 2.13% of trials from the tails of the RT distribution (M = 2150 ms, SD = 1734 ms). Effect sizes were computed using Cohen's d and partial eta squared.

To compare recognition performance by word-value, signal detection theory (SDT) measures A' and B''_D were used. Sensitivity measure A' is a relatively non-parametric measure of one's ability to distinguish old items from new items and ranges from 0.5 (chance guessing) to 1.0. This measure is favorable to proportion correct, because unlike proportion correct it is unconfounded with response bias (Stanislaw & Todorov, 1999). B''_D is a measure of response bias, with positive values here indicating a bias towards labeling an item as new. Both A' and B''_D were used in place of the traditional measures d' and c, because they do not require the assumption that old and new distributions have equal variance, which is often substantially violated in recognition memory (Glanzer, Kim, Hilford, & Adams, 1999). For a review of SDT measures and their calculation, see Stanislaw and Todorov (1999).

Results and discussion

Recognition performance

Table 1 displays recognition performance from each experiment. In Experiment 1, recognition sensitivity was significantly higher for high-value words (A' = .77, SD = .09) than low-value words (A' = .72, SD = .08), $t(45)$ = 5.28, p < .001, d = 0.79. Likewise, response bias measure B''_D was significantly lower for high-value items (M = −0.23, SD = 0.56) than for low-value items (M = 0.02, SD = 0.58), indicating that participants were more likely to rate high-value items as old, $t(45)$ = −4.53, p < .001, d = −0.67. Additionally, RTs for high-value words (M = 1866 ms, SD = 507 ms) were slightly faster than for low-value words (M = 2007 ms, SD = 530 ms), $t(45)$ = −2.71, p = .009, d = 0.40. Participants were better able to recognize high-value words, suggesting that these words were encoded more effectively. These results are consistent with the findings of Adcock et al. (2006) who demonstrated an advantage of high-value images on a delayed recognition task similar value effect with images as stimuli.

Recollection and familiarity

Fig. 1 displays the proportion of high- and low-value items receiving either a remember or know response. The proportion of items receiving a remember response was significantly greater for high-value words (M = .49, SD = .19) than for low-value words (M = .40, SD = .17), $t(45)$ = 3.65, p = .001, d = 0.54. In contrast, the proportion of items receiving a know response was not significantly different for high-value words (M = .27, SD = .14) than for low-value words (M = .27, SD = .12), $t(45)$ = −0.02, p = .985, d = −0.003.

Performance by response

Next, we examined the accuracy of recognition based on remembering and knowing. As expected, remember responses (M = .79, SD = .13) were more likely than know responses (M = .54, SD = .14) to be correctly made for old items, $t(45)$ = 10.29, p < .001, d = 1.52. Additionally, RTs on correct recognition trials were much faster for remember responses (M = 1694 ms, SD = 436 ms) than for know responses (M = 2415 ms, SD = 700 ms), $t(45)$ = −7.51, p < .001, d = −1.18. Overall, recognition based on remembering was much more accurate and faster than recognition based on familiarity as has been demonstrated in previous studies (Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000; Reder et al., 2000).

This study demonstrated that words that had been associated with high value were recognized more accurately than low-value words, and that this effect was primarily driven by increased recollection. In contrast, familiarity was not significantly affected by value. One limitation of Experiment 1 was that accuracy for Know responses was relatively low, perhaps because some subjects were operationalizing guesses as Know responses.

Table 1
Sensitivity and recognition bias by word-value for Experiments 1–3.

Experiment	Measure	Word-value	
		High	Low
Experiment 1	A'	.77 (.09)	.72 (.08)
	B''_D	-0.23 (0.56)	0.02 (0.58)
Experiment 2	A_z	.75 (.10)	.72 (.10)
	B''_D	-0.03 (0.48)	0.05 (0.48)
Experiment 3	A_z	.76 (.09)	.70 (.08)
	B''_D	0.29 (0.55)	0.41 (0.52)

Standard deviations are presented in parentheses.

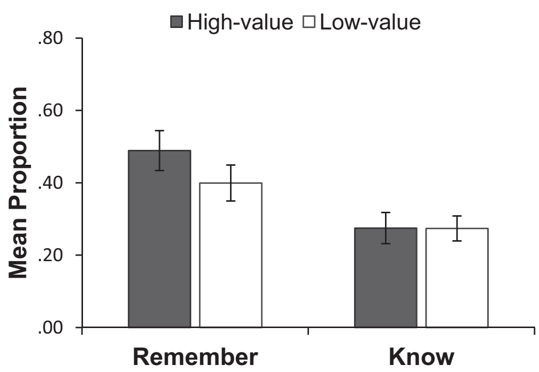

Fig. 1. The proportion of high-value and low-value items that were given either a remember or know response at testing. Error bars represent two standard errors from the mean.

In Experiment 2 we used a more structured method of assessing familiarity using a 6-point scale, allowing us to examine the effect of value on high confidence familiarity responses.

Experiment 2

Experiment 2 was designed to be a conceptual replication of Experiment 1 using a different method of assessing participants' experience of recollection and familiarity. On the recognition test, participants were asked to give either a remember response to indicate conscious recollection of seeing the word earlier in the study or a rating between 1 "Definitely NEW" and 6 "Definitely OLD" to indicate how familiar the word was to them. These response choices are in line with evidence that recollection is more of a threshold process, whereas familiarity has a continuously graded strength (Yonelinas, Aly, Wang, & Koen, 2010).

One interpretation of Experiment 1 is that value was not associated with increased Knowing because, on average, these responses were not highly accurate and may have reflected guessing to some extent rather than familiarity. By allowing participants to report the strength of their familiarity, we could better separate out the highest-familiarity responses (Definitely Old). An additional benefit of this response set is that it allows both for an examination of self-reported conscious remembering and a detailed examination of the ROC curve. According to the dual process signal detection (DPSD) model, recollection can be measured as the point where the ROC crosses the *y*-axis and familiarity as *d*′ (Yonelinas, 1994). Following the results of Experiment 1, we predicted that high-value words would be recognized more often and have more reported conscious recollection. We did not expect familiarity to be strongly affected by value, whether looking at the mean familiarity or the proportion of Definitely Old responses.

Method

Participants

Data from 64 undergraduate UCLA students were collected for this experiment. Data from three of these participants were excluded because they scored over two standard deviations above the mean on Remember false-alarm rate, leaving a final sample size of 61. This sample size was larger than Experiments 1 and 3, because of the need to increase statistical power to construct ROC curves. All participants received course credit for their participation. We did not assess their English fluency or whether they participated in Experiment 1. However, the experiments were conducted in different academic quarters with a different composition of the subject pool, and thus it is highly unlikely that a subject participated in both experiments. Treatment of subjects was in accordance with the ethical standards of the UCLA Institutional Review Board.

Design, materials, and procedure

The study procedure of Experiment 2 was identical to the first experiment, with a different set of words used. On the recognition test, participants were given the option of responding that they consciously "remember" the word from before, or if they did not consciously remember it, they gave a rating indicating how sure they were that they did or did not see the word before. Participants were informed about the definition of "remembering" using the instructions given in Experiment 1. For non-remembered items, the response options were: 1 "Definitely NEW," 2 "Probably NEW," 3 "Maybe NEW," 4 "Maybe OLD," 5 "Probably OLD," and 6 "Definitely OLD." Because of the possibility that participants from Experiment 1 could be included in this study, a new word list was developed. The word list used in Experiment 2 list had very similar psychometric properties to the list used in Experiment 1: word-length was restricted to six letters and the HAL frequencies did not significantly differ between high-value words ($M = 4746.67$, $SD = 442.92$), low-value words ($M = 4698.31$, $SD = 440.30$), and distractors ($M = 4730.99$, $SD = 440.97$), $F(2, 179) = 0.14$, $p = .866$, $\eta^2 < 0.01$. Likewise, the number of phonemes, morphemes, and part of speech did not differ significantly between these three item types ($p > .372$).

Data analysis

As before, dependent sample *t*-tests were computed to assess effects of value. We compared rates of remembering for high- and low-value items, and mean familiarity rating for non-recollected high- and low-value items. To compare recognition performance by word-value, an ROC analysis was performed. An ROC curve was plotted for high-value and low-value words, plotting the cumulative hit and false-alarm rates by value. The area under the ROC curves (A_z) for high- vs. low-value items was compared. A_z, like A', falls along the scale of 0.5–1.0 (see Stanislaw and Todorov (1999) for a review).

Results and discussion

Recognition performance

Fig. 2 presents a ROC for each word-value, and illustrates that high-value items ($A_z = .75$, $SD = .10$) had a modest advantage in recognition over low-value items ($A_z = .72$,

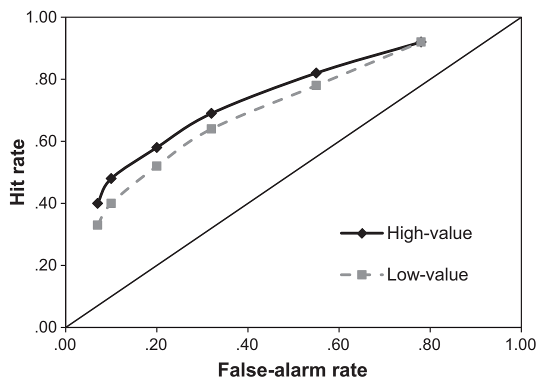

Fig. 2. Plotting of receiver operating characteristic points for high-value and low-value items, using performance for remember responses as the leftmost point.

SD = .10), $t(60) = 3.18$, $p = .002$, $d = 0.41$. Furthermore, response bias measure B''_D was lower for high-value items ($M = -0.03$, $SD = 0.48$) than low-value items ($M = 0.05$, $SD = 0.48$), indicating that participants were more biased to rate high-value items as old, $t(60) = -2.26$, $p = .027$, $d = -0.29$. Lastly, there was no significant difference in RTs between high-value words ($M = 2018$ ms, $SD = 597$ ms) and low-value words ($M = 2102$ ms, $SD = 691$ ms; $t(60) = -1.73$, $p = .088$, $d = -0.23$. Like in Experiment 1, recognition sensitivity was higher for valuable items, thus providing additional support that value enhances recognition.

Recollection and familiarity

Fig. 3 illustrates what proportion of high-value, low-value, and new items were given each of the seven recognition responses. A significantly larger proportion of high-value words ($M = .40$, $SD = .19$) received a remember response at recognition than that of low-value words ($M = .33$, $SD = 0.20$), $t(60) = 3.89$, $p < .001$, $d = 0.50$. In line with Yonelinas and Jacoby (1995), the six responses from Definitely New to Definitely Old were considered an increasing continuum of familiarity strength. Familiarity was not significantly stronger for high-value words ($M = 3.46$, $SD = 0.76$) than low-value words ($M = 3.40$, $SD = 0.69$), $t(60) = 0.81$, $p = .424$, $d = 0.10$. Additionally, just looking at the items with the strongest familiarity (not Remembered, but Definitely Old), there was no difference in the proportion of high-value ($M = .10$, $SD = .11$) and low-value ($M = 11$, $SD = .11$) items receiving this response, $t(41) = -0.47$, $p = .640$, $d = -0.07$. Thus, Experiment 2 did not appear to reveal an effect of value on familiarity.

Experiment 3

Episodic memories are often characterized by the presence of incidental details from the study episode. In Experiment 3, study words were presented in different colors, and on the recognition test participants were asked if they could remember the color and point-value originally associated with each word that was recognized. Based on Dudukovic and Knowlton (2006), we predicted that remember responses would be associated with memory for these two contextual details better than chance. We further predicted that familiarity responses would be associated with chance levels of memory for incidental details. The effects of value on contextual detail retrieval have received considerably less research, thus two competing hypotheses were considered. We hypothesized that recognized high-value items would also be associated with better memory for details than recognized low-value items, which would suggest that value enhances binding of contextual elements to items in memory. Alternatively, it may be that value leads learners to selectively focus on the item, thus impairing memory of extraneous contextual details.

Method

Participants

Data from 46 UCLA undergraduate students were collected for this experiment. Data from two participants were excluded from analysis because they scored over two standard deviations above the mean on their remembering false-alarm rate, leaving a final sample size of 44. Participants included 34 women and 10 men, with a mean age of 20.8 years ($SD = 2.21$, range = 18–31). All participants reported that they did not have any type of color-blindness. We did not assess their English fluency or whether they participated in Experiments 1 and 2. However, because this experiment was run in a different academic quarter, it is highly unlikely that there was any overlap of participants. The participants completed the study for course credit, and the study was completed in accordance with UCLA's Institutional Review Board.

Design, materials, and procedure

The methodology of Experiment 3 was identical to the second experiment, except that during the study phase words were each shown in one of five different colors: red, green, blue, yellow, or magenta, the word list from

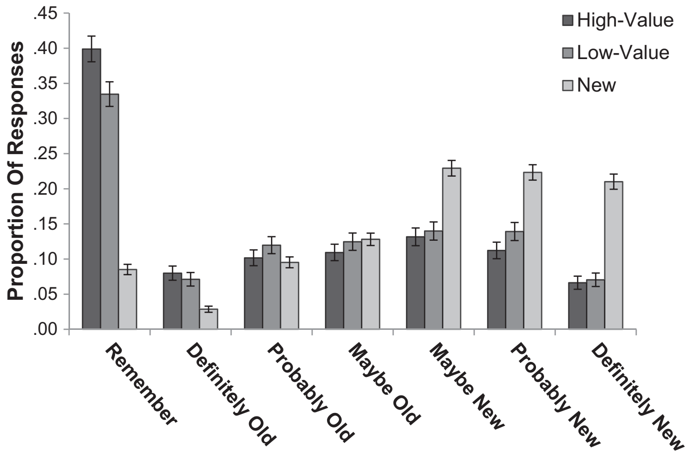

Fig. 3. Proportion of high-value, low-value, and new items given each of the seven recognition responses. Error bars represent two standard errors from the mean.

Experiment 1 was used, and additional questions were asked during the recognition test. Five colors were used, as these were the most distinct colors in the e-prime presentation software. During the study phase, subjects were not explicitly told to memorize the colors of the words, only that they would be asked to recognize the presented words and that they would receive the points presented alongside the words if they were to recognize them correctly. On recognition test trials on which the participant gave a Remember response or one of the three old responses (Definitely Old, Probably Old, Maybe Old), they were further asked if they could remember what color the word was originally presented in. Additionally, they were asked if they could remember the point-value it was associated with. All valid color and point-value options for each of these questions were listed on the screen.

Because we were chiefly interested in participants' ability to consciously recall contextual details, participants were allowed to respond "Completely Unsure" as to what the correct point-value or color was. They were encouraged to make an attempt to choose one of the alternatives if they had as much of a hunch about the correct answer, but to respond Completely Unsure when they felt they would be completely guessing.

Results and discussion

Recollection, familiarity, and recognition by value

A significantly larger proportion of high-value words ($M = .37$, $SD = .21$) were later given a remember response than low-value words ($M = .26$, $SD = .18$), $t(43) = 5.06$, $p < .001$, $d = 0.77$. The proportion of items given a Definitely Old response was also significantly higher for high-value words ($M = .14$, $SD = .13$) than low-value words ($M = .10$, $SD = .09$), $t(25) = 2.62$, $p = .015$, $d = 0.63$. Interestingly, familiarity was also found to be slightly higher for high-value words ($M = 3.26$, $SD = 0.79$) than low-value words ($M = 3.07$, $SD = 0.75$), $t(43) = 2.98$, $p = .005$, $d = 0.45$. As before, recognition sensitivity was higher for high-value words ($A_z = .76$, $SD = .09$) than low-value words ($M = .70$, $SD = .08$), $t(43) = 5.09$, $p < .001$, $d = 0.73$. Furthermore, B''_D was lower for high-value words ($M = 0.29$, $SD = 0.55$) than low-value words ($M = 0.41$, $SD = 0.52$), indicating that participants were more biased to label high-value items as old, $t(43) = -3.78$, $p < .001$, $d = -0.57$. Lastly, the difference in RTs between high-value words ($M = 2911$ ms, $SD = 744$ ms) and low-value words ($M = 3047$ ms, $SD = 727$ ms) was not significant, $t(43) = -2.02$, $p = .050$, $d = -.31$. These results again replicate the value effects observed in the first two experiments, in that value enhanced recognition sensitivity and recollection. Unlike in Experiments 1 and 2, value modestly increased familiarity.

Contextual detail retrieval by value

The primary analyses of Experiment 3 determined how the value of an item and the recognition response given by the participant (e.g., Definitely Old, Remember, etc.) affected memory for contextual details. This measure of contextual detail retrieval included Completely Unsure responses in the proportion, thus it reflects the proportion of items where the participant successfully retrieved the color or point-value. When examining word-value, high-value ($M = .16$, $SD = .10$) and low-value ($M = .14$, $SD = .11$) items had similar probabilities of correct point-value retrieval, $t(43) = 0.88$, $p = .384$, $d = 0.13$. Likewise, high-value ($M = .13$, $SD = .11$) and low-value ($M = .14$, $SD = .11$) items had similar probabilities of correct color retrieval, $t(43) = -0.48$, $p = .637$, $d = -0.07$. Thus, value was not found to affect memory for contextual details.

Because participants had the option of indicating that they were completely unsure of what the contextual details were for words they recognized, we compared the rates of these responses for different item values. When examining point-value retrieval, the proportion of Completely Unsure responses did not significantly differ between high-value ($M = .36$, $SD = .27$) and low-value ($M = .40$, $SD = .30$) items, $t(43) = -1.73$, $p = .091$, $d = -0.27$. Likewise, for color retrieval, there was no significant difference in the proportion of Completely Unsure responses for high-value ($M = .48$, $SD = .31$) versus low-value ($M = .51$, $SD = .32$) items, $t(43) = -1.41$, $p = .167$, $d = -0.21$. These results further support that memory for contextual details was not substantially influenced by item value alone.

Finally, we examined whether contextual detail retrieval associated with word recollection or familiarity was influenced by value. Fig. 4 displays the results of these 2×2 analyses. A 2 (value) $\times$ 2 (recollected or familiar) repeated measures ANOVA for point-value retrieval indicated that there was no significant interaction between value and type of memory, $F(1,39) = 2.02$, $p = .164$, $\eta^2 = .05$. A significant main effect of response was observed such that point-value retrieval was more likely after recollected ($M = .20$, $SD = .10$) than familiar items ($M = .07$, $SD = .08$), $F(1,39) = 56.65$, $p < .001$, $\eta^2 = .59$. The main effect of value on point-value retrieval was not significant, $F(1,39) < 0.01$, $p = .962$, $\eta^2 < .01$. In contrast, a 2×2 ANOVA for color retrieval detected a significant interaction between value and memory type, $F(1,39) = 10.97$, $p = .002$, $\eta^2 = .22$. This interaction occurred primarily

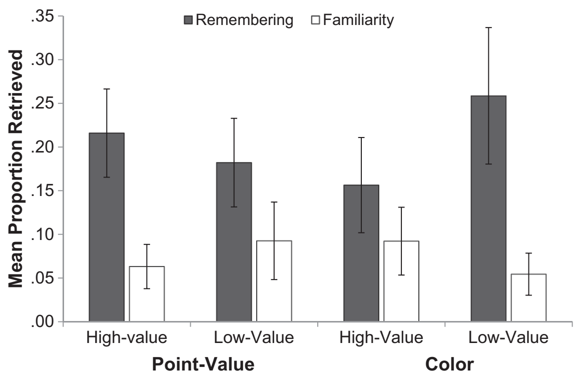

Fig. 4. Proportion of point-values and colors retrieved by word-value and whether the item was recollected or familiar. Only trials on which an item was correctly recognized were included. Completely Unsure responses were included in the proportion, hence the low retrieval rates. Error bars represent two standard errors from the mean.

because color retrieval was more likely for remembered low-value words ($M = .24$, $SD = .23$) than remembered high-value words ($M = .16$, $SD = .18$), $t(41) = -2.72$, $p = .010$, $d = -0.43$. Additionally, high-value words given one of the three familiar responses (Maybe Old, Probably Old, or Definitely Old; $M = .09$, $SD = .13$) were associated with significantly more color retrieval than familiar low-value words ($M = .05$, $SD = .08$), $t(41) = 2.52$, $p = .016$, $d = 0.43$. These results suggest that for familiar items, some aspects of the episode may be encoded better for valuable items, though correct point-value and color retrieval associated with feelings of familiarity was very poor and not reliably above chance ($p > .218$).

Perhaps surprisingly, recollection for low-value items resulted in substantially more retrieval of the associated color than for high-value items. Because high-value items were much more likely to be recollected and recognized than low-value items, it is possible that recollection that is driven by value is based on recollection of internally-generated thoughts associated with the item, and that low-value items are more likely to be recollected when other details of the experience are associated with the item. These results suggest that the effect of value on enhanced recollection does not occur through enhancement of binding of the item to nonessential contextual features. Rather, value enhances memory for the item, perhaps by increasing attention to item semantics.

General discussion

In three experiments, we examined how value influences recognition memory, conscious recollection, and familiarity. Our first two experiments used different self-report measures of recollection and familiarity, while the third experiment added source memory judgments. Results from all three studies suggest that recognition is enhanced by value, such that recognition sensitivity is increased for high-value items. This enhanced learning of high-value material has also been observed in the delayed recognition of pictures and the immediate free recall of words (Adcock et al., 2006; Castel, Lee, Humphreys, & Moore, 2011; Castel et al., 2013). This study adds to this literature by demonstrating that the effect of value on short-term recognition is driven primarily by enhanced recollection. In all three experiments, remember responses were much more prevalent for high-value words than low-value words. In contrast, value's effect on familiarity was considerably smaller and inconsistent; in Experiments 1 and 2, value did not significantly affect familiarity. This likely indicates that value has an effect on encoding that differentially supports subsequent recollection.

There are multiple mechanisms that may explain why value at encoding improves recognition. First, selective-attention is likely used, such that attentional resources are allocated to learning more valuable information. It is well documented that value automatically and involuntarily captures attention (Anderson, 2013; Hickey, Chelazzi, & Theeuwes, 2010; Kiss, Driver, & Eimer, 2009). Conversely, a commonly used and often effective learning strategy is to ignore low-value items (Robison & Unsworth, 2017). However, if value solely captures attention such that participants maintain valuable information longer, but does not affect the depth of their encoding, we would expect to have observed increased familiarity for valuable items. This reasoning follows from research suggesting that maintenance rehearsal predominantly enhances familiarity (Fawcett et al., 2016; Gardiner et al., 1994). Instead, the current findings suggest that value encourages deeper elaborative encoding and semantic processing, as these encoding strategies are linked with later recollection (Fawcett et al., 2016; Gardiner et al., 1994). This selective increase in elaborative encoding for high value items may render them more distinctive than low value items, which may also lead to a relative increase in recollection (Rajaram, 1998).

Because high-value items were more likely to be recollected than low-value items, we tested whether high-value items were encoded in a way which made them more likely to be bound to the study context. Research suggests that cues indicating high value activate neural reward centers in the brain, such as the ventral tegmental area and the nucleus accumbens (Adcock et al., 2006; Carter et al., 2009). High-value items may receive enhanced hippocampal processing during encoding via activation of projections from these mesolimbic dopaminergic regions. However, contrary to our initial hypothesis, we did not find evidence that value enhances binding of items to incidental details in the context. Rather, high value appears to have resulted in enhanced encoding of the valuable item, and the associated increase in recollection may be based on internally-generated thoughts associated with the item being brought back at test. Such a use of the recollection response is common when contextual details are not retrieved (Gardiner et al., 1998). While the retrieval of details about the external context is often considered a sufficient condition for recollection, it is not a necessary one. Retrieval of internally-generated encoding context may be the basis of a recollection judgment. In our study, recollection responses were actually associated with less retrieval of external contextual details (i.e., word color) for valuable items, suggesting that participants often selectively encoded the valuable items at the expense of encoding these extraneous details.

As described in the introduction section, single-process signal detection models also often offer a valid interpretation of recognition findings. Signal detection models posit that "Remembering" and "Knowing" responses reflect the setting of different decision criteria for subjects based along a single dimension of memory strength (Dunn, 2004; Wixted & Mickes, 2010). Under this interpretation, the result here suggest that value increases memory strength in a non-linear way, with more items at high levels of memory strength without substantially increasing the proportion with more moderate memory strength. The Unequal Variance Signal Detection Model (Mickes, Wixted, & Wais, 2007), for example, may achieve this by assuming value changes the distribution of memory strength of old items and not simply the probability that the item is judged old. The present study was not designed to differentiate between dual- and single-process models of recognition. However, our finding that retrieval of contextual details was only above chance after a remember response suggests that recollection and familiarity may be qualitatively different memory processes. Previous research suggests that under some circumstances, there may be some memory for the source in familiarity-based memories (Hicks, Marsh, & Ritschel, 2002). However, findings from the current study suggest that even strong familiarity judgments were not reliably associated with accurate memory for contextual details.

The effect of value on recognition memory measured here was not as large as what is typically seen using immediate free recall tests (Ariel et al., 2009; Castel et al., 2011). The key difference is that in a free recall test, the number of individually presented items one can freely recall from a list is quite limited, so one must selectively focus on higher value items. In contrast, the number of items one can recognize is generally much less limited, so low-value items do not have the potential to interfere to the same extent. One benefit of using a recognition test with many items is that differential rehearsal or retrieval strategies, particularly those in which high-value items are recalled first and interfere with recall of low-value items could not account for the effects of value on performance. Rather, high-value items appear to be encoded more effectively than low-value items during study. To further investigate this hypothesis, future research could manipulate encoding strategies by manipulating the materials used or study time to further explore the idea that high-value items preferentially benefit from elaborative encoding.

An important difference between the present study and the work of Adcock et al. (2006) and Spaniol et al. (2013) is that these studies used a 24 h delay between the study and test phases. In the present study, there was only a 5 min filled delay between the end of the study phase and the beginning of the recognition test. With longer delays, there may have been a more robust effect on familiarity-based memory. Many items that would be initially recollected may be merely familiar after a long delay, as episodic detail memory fades (Dudukovic & Knowlton, 2006). It has also been hypothesized that dopamine release due to presentation of cues indicating high value will enhance consolidation processes, with effects apparent in retention over a long delay (Murayama & Kitagami, 2014). Specifically, research suggests that this dopaminergic enhancement of memory is not apparent 30 min or even 9 h after study, and often takes approximately 12–24 h to manifest (Bethus, Tse, & Morris, 2010; Rossato, Bevilaqua, Izquierdo, Medina, & Cammarota, 2009). In previous studies, the effect of value on recognition at short delays may not have been as robust if performance in these previous studies was primarily based on familiarity.

The present results demonstrate that the benefits of value on recognition are also apparent after a short delay, and that these are primarily driven by increased recollection. Although recollection is often associated with significant memory for contextual details, recollection of valuable items appears to be less likely to be accompanied by memory for these details. High-value items may have been encoded at a deeper, more elaborative and semantic level than low-value items that were recollected. Thus, value may promote encoding that results in a qualitatively different memory trace than what results from encoding items that are less valuable to the learner.

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Appendix A

Remember-know instructions (Experiment 1)

These instructions were read by the experimenter, and are as follows:

Now you will be shown a series of individual words and asked if you recognize the word from the studying phase or if it is a new word. As you make your decision about recognizing a word, I would like you to bear in mind the following:

Often, when *remembering* a previous event or occurrence, we consciously recollect and become aware of aspects of the previous experience. At other times, we simply *know* that something has occurred before, but without being able consciously to recollect anything about its occurrence or what we experienced at the time. For example, if I see a friend on the bus today and recall having lunch with him earlier, I would say that I *remember* that person from before. If I see someone on the bus that appears familiar, but I can't remember having met him, I would say that I only *know* that person.

On the following task, you will be asked to make two responses for each word. You will press the button "n" on your keyboard if you believe it is a new word or the button "o" if you believe it is a word you have seen before. Then, you will press "r" if you remember the word consciously, "k" if you simply know that you saw the word earlier, or "space bar" if you believe it was a new word. These instructions will be repeated on the computer and button values will be on each slide with the word.

Appendix B

Remember-know instructions (Experiments 2 and 3)

These instructions were read by the experimenter, and are as follows:

Now you will be shown a series of individual words and asked if you recognize the word from the studying phase or if it is a new word. As you make your decision about recognizing a word, I would like you to bear in mind the following:

Often, when *remembering* a previous event or occurrence, we consciously recollect and become aware of aspects of the previous experience. At other times, we simply *know* that something has occurred before, but without being able consciously to recollect anything about its occurrence or what we experienced at the time. For example, if I see a friend on the bus today and recall having lunch with him earlier, I would say that I *remember* that person from before. If I see someone on the bus that appears familiar, but I can't remember having met him, I would say that I only *know* that person.

On the following task, if you recollect the word consciously, please press the button "r" on your keyboard. If you simply know that the word was in the previous study set, please press one number from "1" to "6" to indicate how confident you are that you saw or did not see that word before. So, for each word you see, please press "r" if you recollect its occurrence, or a number between "1" and "6" if you *simply know* that it was shown before."

Appendix C. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jml.2016.12.004.

References

Adcock, R. A., Thangavel, A., Whitfield-Gabrieli, S., Knutson, B., & Gabrieli, J. D. E. (2006). Reward-motivated learning: Mesolimbic activation precedes memory formation. *Neuron, 50*, 507–517. http://dx.doi.org/10.1016/j.neuron.2006.03.036.

Anderson, B. A. (2013). A value-driven mechanism of attentional selection. *Journal of Vision, 13*(3), 7. http://dx.doi.org/10.1167/13.3.7.

Anderson, B. A., Laurent, P. A., & Yantis, S. (2011). Learned value magnifies salience-based attentional capture. *PLoS One, 6*(11), e27926. http://dx.doi.org/10.1371/journal.pone.0027926.

Ariel, R., Dunlosky, J., & Bailey, H. (2009). Agenda-based regulation of study-time allocation when agendas override item-based monitoring. *Journal of Experimental Psychology: General, 138*, 432–447. http://dx.doi.org/10.1037/a0015928.

Bethus, I., Tse, D., & Morris, G. M. (2010). Dopamine and memory: Modulation of the persistence of memory for novel hippocampal NMDA receptor-dependent paired associates. *The Journal of Neuroscience, 30*(5), 1610–1618. http://dx.doi.org/10.1523/JNEUROSCI.2721-09.2010.

Carter, R. M., MacInnes, J. J., Huettel, S. A., & Adcock, R. A. (2009). Activation in the VTA and nucleus accumbens increases in anticipation of both gains and losses. *Frontiers in Behavioral Neuroscience, 3*, 1–15. http://dx.doi.org/10.3389/neuro.08.021.2009.

Castel, A. D., Benjamin, A. S., Craik, F. I. M., & Watkins, M. J. (2002). The effects of aging on selectivity and control in short-term recall. *Memory & Cognition, 30*, 1078–1085. http://dx.doi.org/10.3758/BF03194325.

Castel, A. D., Lee, S. S., Humphreys, K. L., & Moore, A. N. (2011). Memory capacity, selective control, and value-directed remembering in children with and without attention- deficit/hyperactivity disorder (ADHD). *Neuropsychology, 25*, 15–24. http://dx.doi.org/10.1037/a0020298.

Castel, A. D., Murayama, K., Friedman, M. C., McGillivray, S., & Link, I. (2013). Selecting valuable information to remember: Age-related differences and similarities in self- regulated learning. *Psychology and Aging, 28*, 232–242. http://dx.doi.org/10.1037/a0030678.

Dudukovic, N. M., & Knowlton, B. J. (2006). Remember-know judgments and retrieval of contextual details. *Acta Psychologica, 122*, 160–173. http://dx.doi.org/10.1016/j.actpsy.2005.11.002.

Dunn, J. C. (2004). Remember-Know: A matter of confidence. *Psychological Review, 111*, 524–542. http://dx.doi.org/10.1037/0033-295X.111.2.524.

Eldridge, L. L., Knowlton, B. J., Furmanski, C. S., Bookheimer, S. Y., & Engel, S. A. (2000). Remembering episodes: A selective role for the hippocampus during retrieval. *Nature Neuroscience, 3*, 1149–1152. http://dx.doi.org/10.1038/80671.

Fawcett, J. M., Lawrence, M. A., & Taylor, T. L. (2016). The representational consequences of intentional forgetting: Impairments to both the probability and fidelity of long-term memory. *Journal of Experimental Psychology: General, 145*(1), 56–81. http://dx.doi.org/10.1037/xge0000128.

Gardiner, J. M., Gawlik, B., & Richardson-Klavehn, A. (1994). Maintenance rehearsal affects knowing, not remembering; elaborative rehearsal affects remembering, not knowing. *Psychonomic Bulletin & Review, 1*, 107–110. http://dx.doi.org/10.3758/BF03200764.

Gardiner, J. M., & Java, R. I. (1990). Recollective experience in word and nonword recognition. *Memory and Cognition, 18*, 23–30. http://dx.doi.org/10.3758/BF03202642.

Gardiner, J. M., Ramponi, C., & Richardson-Klavehn, A. (1998). Experiences of remembering, knowing, and guessing. *Consciousness and Cognition, 7*, 1–26. http://dx.doi.org/10.1006/ccog.1997.0321.

Glanzer, M., Kim, K., Hilford, A., & Adams, J. K. (1999). Slope of the receiver-operating characteristic in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*, 500–513. http://dx.doi.org/10.1037/0278-7393.25.2.500.

Hickey, C., Chelazzi, L., & Theeuwes, J. (2010). Reward changes salience in human vision via the anterior cingulate. *The Journal of Neuroscience, 30*(30), 11096–11103. http://dx.doi.org/10.1523/JNEUROSCI.1026-10.2010.

Hicks, J. L., Marsh, R. L., & Ritschel, L. (2002). The role of recollection and partial information in source monitoring. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 503–508. http://dx.doi.org/10.1037//0278-7393.28.3.503.

Hyman, S. E., Malenka, R. C., & Nestler, E. J. (2006). Neural mechanisms of addiction: The role of reward-related learning and memory. *Annual Review of Neuroscience, 29*, 565–598. http://dx.doi.org/10.1146/annurev.neuro.29.051605.113009.

Kalivas, P. W., & Volkow, N. D. (2005). The neural basis of addiction: A pathology of motivation and choice. *American Journal of Psychiatry, 162*, 1403–1413. http://dx.doi.org/10.1176/appi.ajp.162.8.1403.

Kiss, M., Driver, J., & Eimer, M. (2009). Reward priority of visual target singletons modulates event-related potential signatures of attentional selection. *Psychological Science, 20*(2), 245–251. http://dx.doi.org/10.1111/j.1467-9280.2009.02281.x.

Kragel, J. E., & Polyn, S. M. (2015). Decoding episodic retrieval processes: Frontoparietal and medial temporal lobe contributions to free recall. *Journal of Cognitive Neuroscience, 28*(1), 125–139. http://dx.doi.org/10.1162/jocn_a_00881.

Linderholm, T., & van den Broek, P. (2002). The effects of reading purpose on working memory capacity on the processing of expository text. *Journal of Educational Psychology, 94*(4), 778–784. http://dx.doi.org/10.1037/0022-0663.94.4.778.

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co- occurrence. *Behavior Research Methods, Instruments, & Computers, 28*, 203–208. http://dx.doi.org/10.3758/BF03204766.

McCabe, D. P., Geraci, L., Boman, J. K., Sensenig, A. E., & Rhodes, M. G. (2011). On the validity of remember-know judgments: Evidence from think-aloud protocols. *Consciousness and Cognition, 20*, 1625–1633. http://dx.doi.org/10.1016/j.concog.2011.08.012.

Mickes, L., Wixted, J. T., & Wais, P. E. (2007). A direct test of the unequal-variance signal detection model of recognition memory. *Psychonomic Bulletin & Review, 14*, 858–865. http://dx.doi.org/10.3758/BF03194112.

Mitchell, K. J., & Johnson, M. K. (2009). Source monitoring 15 years later: What have we learned from fMRI about the neural mechanisms of source memory? *Psychological Bulletin, 135*(4), 638–677. http://dx.doi.org/10.1037/a0015849.

Murayama, K., & Kitagami, S. (2014). Consolidation power of extrinsic rewards: Reward cues enhance long-term memory for irrelevant past events. *Journal of Experimental Psychology: General, 1*, 15–20. http://dx.doi.org/10.1037/a0031992.

Rajaram, S. (1998). The effects of conceptual salience and perceptual distinctiveness on conscious recollection. *Psychonomic Bulleting and Review, 5*, 71–78. http://dx.doi.org/10.3758/BF03209458.

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin, 114*, 510–532. http://dx.doi.org/10.1037/0033-2909.114.3.510.

Reder, L. M., Nhouyvanisvong, A., Schunn, C. D., Ayers, M. S., Angstadt, P., & Hiraki, K. (2000). A mechanistic account of the mirror effect of word frequency: A computational model of remember-know judgments in a continuous recognition paradigm. *Journal of Experimental*

Psychology: Learning, Memory, and Cognition, 26, 294–620. http://dx.doi.org/10.1037//0278-7393.26.2.294.

Robison, M. K., & Unsworth, N. (2017). Working memory capacity, strategic allocation of study time, and value-directed remembering. *Journal of Memory and Language, 93*, 231–244. http://dx.doi.org/10.1016/j.jml.2016.10.007.

Roediger, H. L., & Schmidt, S. R. (1980). Output interference in the recall of categorized and paired-associate lists. *Journal of Experimental Psychology: Human Learning and Memory, 6*(1), 91–105. http://dx.doi.org/10.1037/0278-7393.6.1.91.

Rossato, J. I., Bevilaqua, L. R. M., Izquierdo, I., Medina, J. H., & Cammarota, M. (2009). Dopamine controls persistence of long-term memory storage. *Science, 325*, 1017–1020. http://dx.doi.org/10.1126/science.1172545.

Simons, J. S., & Spiers, H. J. (2003). Prefrontal and medial temporal lobe interactions in long-term memory. *Nature Reviews, 4*, 637–648. http://dx.doi.org/10.1038/nrn1178.

Spaniol, J., Schain, C., & Bowen, H. J. (2013). Reward-enhanced memory in younger and older adults. *Journal of Gerontology, 69*, 730–740. http://dx.doi.org/10.1093/geronb/gbt044.

Standing, L. (1973). Learning 10,000 pictures. *The Quarterly Journal of Experimental Psychology, 25*, 207–222. http://dx.doi.org/10.1080/14640747308400340.

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers, 31*, 137–149. http://dx.doi.org/10.3758/BF03207704.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26*, 1–12. http://dx.doi.org/10.1037/h0080017.

Unsworth, N. (2007). Individual differences in working memory capacity and episodic retrieval: Examining the dynamics of delayed and continuous distractor free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(6), 1020–1034. http://dx.doi.org/10.1037/0278-7393.33.6.1020.

Weiland, B. J., Heitzeg, M. M., Zald, D., Cummiford, C., Love, T., Zucker, R. A., & Zubieta, J.-K. (2014). Relationship between impulsivity, prefrontal anticipatory activation, and striatal dopamine release during rewarded task performance. *Psychiatry Research: Neuroimaging, 223*, 244–252. http://dx.doi.org/10.1016/j.pscychresns.2014.05.015.

Wixted, J. T., & Mickes, L. (2010). A continuous dual-process model of Remember/Know judgments. *Psychological Review, 117*, 1025–1054. http://dx.doi.org/10.1037/a0020874.

Yonelinas, A. P. (1994). Receiver-operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*, 1341–1354. http://dx.doi.org/10.1037/0278-7393.20.6.1341.

Yonelinas, A. P., Aly, M., Wang, W.-C., & Koen, D. (2010). Recollection and familiarity: Examining controversial assumptions and new directions. *Hippocampus, 20*, 1178–1194. http://dx.doi.org/10.1002/hipo.20864.

Yonelinas, A. P., & Jacoby, L. L. (1995). The relation between remembering and knowing as bases for recognition: Effects of size congruency. *Journal of Memory and Language, 34*, 622–643. http://dx.doi.org/10.1016/j.pscychresns.2014.05.015.