DISSERTATION

A BINDING DEFICIT: VALUE-DIRECTED REMEMBERING FOR ITEM-SPECIFIC VS. ASSOCIATIVE INFORMATION

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ABSTRACT

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In a series of four experiments I examined whether value enhanced memory for item-specific or associative information. Value indicated the importance of an item at study (i.e., 1 point = low importance, 12 points = high importance), with memory typically being enhanced for high-value information (e.g., Castel, 2008). Utilizing the feature-conjunction paradigm, in which recognition errors for conjunction lures provide a means of examining whether value-enhanced recognition is a result of recollection or familiarity, the Pilot Experiment revealed through increased conjunction errors that value enhanced memory only for item-specific information. In Experiment 1 participants were permitted to self-pace their study and made confidence learning judgments (CLJs) after each recognition judgment. Learners spent more time studying higher-valued words yet demonstrated a similar pattern of increased conjunction errors by value. In Experiment 2, participants were instructed to use either rote repetition or interactive imagery for all words at study. Under these controlled study strategy conditions, conjunction errors were similar across values. In Experiment 3, I examined the influence of value on feature lures. When both feature lures and conjunction lures were presented at test, learners' susceptibility to lures was similar across values, yet learners correctly recognized more high-value old words. Results indicated that both encoding processes and item-based familiarity may contribute to a deficit in binding components of high-value words. These findings are discussed in terms of the negative effects of value on memory for associative information.

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Introduction

In everyday life people encounter large amounts of information, including names, dates, facts, and procedures, to name just a few. However, not all the information we encounter or attempt to learn is equally important to remember. For example, when studying for an exam, remembering key definitions and concepts may be more important than remembering aspects of class readings word-for-word. Similarly, in our personal lives, remembering certain key information, such as the date a bill is due, may be more important to remember than the date you last had your car's oil changed. Because not all information is equally important to remember, memory should be attuned to the most important information. This issue of selectively remembering highly-important information has been studied through work on value-directed remembering (e.g., Ariel, Dunlosky, & Bailey, 2009; Castel, 2008).

In value-directed remembering, participants study items paired with varying point values that indicate the importance of later remembering those items at test. Participants are told they will receive the points originally paired with each word for correctly recalling it at test, and are given the goal of achieving a high total point score. For example, if a participant studied *shipwreck – 1* and *raintree – 12*, they would receive 1 point for correctly recalling *shipwreck* and 12 points for correctly recalling *raintree*. Although correctly recalling any words would increase the total point score, recalling high-value words would contribute more points towards this goal. Overall, a large body of work has demonstrated that participants show better memory for high-value (vs. low-value) information (e.g., Ariel, et al., 2009; Castel, Benjamin, Craik, & Watkins, 2002; Castel, Farb, & Craik, 2007; Cohen, Rissman, Suthana, Castel, & Knowlton, 2014; McDonough, Bui, Friedman, & Castel, 2015). For example, Castel et al. (2007) had participants study words paired with a range of high and low point values (1-16), followed by a free recall test. Participants remembered a greater proportion of high-value than low-value words, demonstrating enhanced memory for high-value information.

The enhancing effects of value on memory are robust, having been demonstrated across a wide range of characteristics, including age – college students, older adults, and children (Castel et al., 2007; 2011a), different study materials – e.g., faces (DeLozier & Rhodes, 2015), words (Cohen et al., 2014), names and occupations (Festini, Hartley, Tauber, & Rhodes, 2013) and word-pairs (Ariel, Price, & Hertzog, 2015), as well as different test types, such as free recall (Castel et al., 2011a), cued recall (Dunlosky & Thiede, 1998), and recognition (Castel et al., 2007). Overall, the vast majority of the literature examines memory for single-words (tested via free recall) or word-pairs (tested via cued recall). For example, Castel et al. (2011) utilized individual words paired with varying point values and tested learners through a free recall task. Both older adults and younger adults exhibited enhanced recall performance for high-value words, demonstrating the value-based remembering effect.

Although the majority of studies demonstrate the general robustness of value-directed remembering (c.f., DeLozier & Dunlosky, 2015), the mechanisms and consequences of this memory enhancement are not well understood (Bui, Friedman, McDonough, & Castel, 2013; Cohen et al., 2014). In general, value-directed remembering is thought to reflect selective recall and recognition of words via strategic encoding processes, enhanced motivation, and selective rehearsal for those words with higher values at the expense of words with lower values (Castel et al., 2002; Castel, Murayama, Friedman, McGillivray, & Link, 2013). Other explanations for the mechanisms driving value-directed remembering include differential rehearsal, use of imagery, and strategic retrieval operations (Cohen et al., 2014).

Amongst these strategic processes, there is evidence that participants selectively focus on the most important information at the expense of less critical (i.e., less valuable) information (Castel et al., 2002). Castel et al. (2002) utilized a selectivity index to examine participants' total point score in relation to an ideal score in which only the most highly-valued words were recalled. In this formula, the selectivity index (SI) is calculated as follows: SI = subject's score – chance score/ideal score – chance score. Perfect selectivity, or recall of only the highest-valued words, would result in a selectivity index score of 1.0, whereas complete disregard of selectivity (e.g., recalling only the lowest-valued words) would result in a selectivity index score of 0. Across 4 experiments, younger adults recalled more words than older adults, yet demonstrated lower selectivity. For example, in their Experiment 1, younger adults' selectivity index ($M = .58$, $SD = .20$) was significantly lower than older adults' selectivity index ($M = .72$, $SD = .23$), $p < .05$, $d = .65$. However, the selectivity advantage for older adults was eliminated when they were tested after a delay. These results comport with the idea that whereas both older and younger adults may maintain high valued items in primary memory for immediate recall, younger adults retrieve a greater number of low-valued words from secondary memory, thus increasing the number of words recalled, yet reducing their selectivity index.

Additional evidence regarding the selectivity index (and differences between older and younger adults) comes from fMRI data (Cohen, Rissman, Suthana, Castel, & Knowlton, 2016). Older and younger adults studied lists of individually-presented high-value (10, 11, 12) or low-value (1, 2, 3) words and completed a free recall task after each list. For both older and younger adults, memory selectivity was associated with value-related changes in the activation of left-lateralized brain regions involved in semantic processing during encoding (i.e., VLPFC, posterior dorsal medial PFC/pre-supplementary motor area, posterior lateral temporal cortex, associated with deep semantic processing; Binder & Desai, 2011). During encoding, highly selective older adults demonstrated decreased brain activity in these regions for low-value words, whereas highly selective younger adults demonstrated similarly increased brain activity for high-value words, suggesting that selectivity differences are driven by increased processing of high-value words amongst younger adults, and decreased processing (or less attention) for low-value words amongst older adults. For individuals in both age groups, value-related differences in activity of these brain regions correlated with their selectivity index on the subsequent recall test. Overall, these results suggest that selectivity in value-directed remembering occurs during encoding and reflects strategic control of attention.

Further evidence that memory enhancement for high-value information occurs during encoding comes from work suggesting that learners utilize more effective study strategies for high-value (vs. low-value) information (Ariel et al., 2015; Cohen et al., 2016, see supplementary data). For example, after completing a value-directed remembering study procedure for word-pairs utilizing cued-recall tests, Ariel et al. (2015) collected retrospective strategy reports. These strategy reports were categorized into effective (e.g., interactive imagery) vs. ineffective (e.g., repetition) study strategies. Overall, participants utilized more effective study strategies for high-value (i.e., 8, 10, 12) than low-value (i.e., 2, 4, 6) word-pairs. Similarly, Cohen et al. (2016) divided participants into those who used deep or effective encoding strategies (e.g., associating words, visualizing an image) versus those who used shallow or surface-level less effective encoding strategies (e.g., alphabetizing, repetition). Although selectivity and recall of low-value items did not differ significantly between these groups, participants who utilized deep (vs. shallow) encoding strategies remembered more high-value items, $d = 1.03$. Thus, effective study strategies may also play a role in enhanced memory for high-value information.

Some work has suggested that enhanced selectivity for high-value information may occur because low-value items are ignored at encoding. For example, Loftus and Wickens (1970) proposed that participants may rehearse high-value items while ignoring low-value items during study presentation. However, when study time is fixed it appears that this is not the case. To examine the idea of selective attention, after a free recall test (in which participants demonstrated enhanced memory for high and mid-high value words compared to low and mid-low valued words), Castel et al. (2007) gave participants an unexpected recognition test for high-value, low-value, and new (lure) words. Participants correctly recognized the majority of the low-value words (.67 and .68, respectively), indicating that they attended to low-value words at study.

Additional work demonstrates that participants become better at remembering high-value words (or more selective) with task experience (Ariel et al., 2015; Castel et al., 2002, 2013, 2011a; McGillivray & Castel, 2011; Middlebrooks, Murayama, & Castel, 2016; cf. DeLozier & Dunlosky, 2015). For example, Castel et al. (2002) found that, after several study-test cycles, participants became aware they could not remember all the words from each list and began to successfully focus on remembering high-value words (rather than attempting to recall all studied words, regardless of value). Similarly, Castel et al. (2013) reported a multilevel mediation model demonstrating that the positive association between point value and recall performance increased across lists (i.e., with task experience). Increased recall for high-value items was partially associated with increased study time per item, as well as taking advantage of recency effects at encoding – both of which are means of effectively enhancing memory. However, even after controlling for study time and recency effects, the increased memory for high-value items across lists persisted. Additionally, Castel et al. (2011a) demonstrated that the selectivity index also increased with task experience, indicating that participants increasingly focused on recalling the highest-value words. Thus, not surprisingly, participants learned to improve their performance (i.e., increase their total point score or selectivity) with task experience.

Other work suggests that value-directed memory enhancement may reflect salience (i.e., relative prominence; Madan, 2013), rather than value itself (Castel et al., 2016; Madan & Spetch, 2012). For example, Madan and Spetch (2012) presented lists of hidden words in pairs of two; participants selected one for study, at which point the word was revealed. Each word was worth 2, 3, 4, 8, 10, or 12 points, and each pair selection consisted of a higher-valued and a lower-valued word. Regardless of the individual values, participants were more likely than chance to select the higher-valued word in each selection. However, results demonstrated a U-shaped function of recall, in which participants were more likely to recall words from the extreme values within the range of presented values (i.e., 2, 10, and 12-point words). Overall, reward salience (high and low value items) accounted for more of the variability in memory ($R^2 = .70$) than reward value ($R^2 = .22$), indicating that reward salience is relative to the range of values experienced. In a similar paradigm, Castel et al. (2016) paired to-be-studied faces with a range of positive and negative monetary values (i.e., $-100, $-50, $-20, $-10, $-5, $-2, $-1, $1, $2, $5, $10, $20, $50, $100). Participants were told that positive values indicated how much money that individual owed the participant, whereas negative values indicated how much money that participant owed the individual. If participants correctly recalled the positive value paired with a face, they would receive that amount of money, whereas, if they correctly recalled the negative value paired with a face, they would no longer owe that individual money. As in the strictly point-value based paradigms described previously, participants were told their goal was to maximize their total score[1]. Both older and younger adults were most likely to recall extreme values, demonstrating a quadratic or U-shaped curve in memory for the negative values and the positive values.

However, in contrast to these results, the majority of studies utilizing a range of point values have failed to find this U-shaped salience effect, instead simply finding enhanced memory for high-value items (Ariel et al., 2015; Castel et al., 2002, 2007, 2011a, 2011b, 2013; DeLozier & Rhodes, 2015; Hayes, Kelley, & Smith, 2013; Loftus & Wickens, 1970; McGillivray & Castel, 2011; Middlebrooks et al., 2016; Rhodes, Witherby, Castel, & Murayama, 2017). The effects of value versus salience remain an open question, and should be further investigated; however, the present manuscript does not attempt to address this issue.

Learners' beliefs about value may also influence or bias their value-directed remembering, evident in control strategies, metacognitive judgments, and overall memory performance. Soderstrom and McCabe (2011) reported that participants believe high-value information is more likely to be remembered, as evinced by higher predictions of the likelihood of recalling high-value (vs. low-value) word-pairs, even when these values were presented after study and had no influence on ultimate recall performance. Thus, value may bias learners' beliefs about value and memory, even when value is not a diagnostic cue. Conversely, learners also appear to believe that forgotten material is less important than remembered information (Castel, Rhodes, McCabe, Soderstrom, & Loaiza, 2012; Rhodes et al., 2017). For example, Rhodes et al. (2017) found that forgotten words were mistakenly judged as less important (i.e., of lower value). When later asked whether a word had been recalled or forgotten, participants gave higher

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[1] Instructions clarified that this was a game, and participants would not actually receive money, aside from the compensation some individuals received for participating.

value judgments to words deemed as recalled (and lower value judgments to words deemed forgotten). Thus, the perceived status of each item (remembered or forgotten) influenced value judgments rather than the objective status of each item (remembered or forgotten). These results (i.e., Castel et al., 2012; Rhodes et al., 2016; Soderstrom & McCabe, 2011) indicate that monitoring judgments can be influenced by both the actual value and perceived value of information, unrelated to actual memory performance.

Overall, the memory advantage for high-value (vs. low-value) information primarily reflects strategic processes engaged at encoding. In general, these processes include deeper levels of processing, increased attention, and more effective study strategies. Although theories of value-directed remembering differ regarding the contribution of salience to this memory enhancement, the work contributing to these theories is largely based on memory for individual items (e.g., words) rather than memory for associative information (e.g., the relationship between words). Current theories have not yet accounted for a variety of work demonstrating that stimulus parts and stimulus wholes can be miscombined in associative memory (e.g., Jones & Jacoby, 2001b), indicating that stimulus parts are represented independently, restricting current theories of value-directed remembering to item (and not associative) information.

Item-Memory versus Associative Memory

The vast majority of research in value-directed remembering has focused on memory for individual items. With few exceptions (e.g., DeLozier & Rhodes, 2015; Festini et al., 2013), the little work which does expand beyond individual items (such as words) consists of studies on cued recall for word-pairs (Ariel & Dunlosky, 2013; Ariel et al., 2009, 2015; Dunlosky & Thiede, 1998; Koriat, Ackerman, Adiv, & Lockl, 2013; Koriat, Ma'ayan, & Nussinson, 2006; Le Ny, Denhiere, & Le Taillanter, 1972; Loftus & Wickens, 1970; Price, Hertzog, & Dunlosky, 2010; Soderstrom & McCabe, 2011; Toppino & Cohen, 2010). However, due to the nature of a cued-recall test, in which participants are provided the context of the to-be-recalled-item via the first half, or cue, of each word-pair as a memory prompt for recalling the second half, or target (e.g., *fresa* - ?), these studies tell us little about whether value influences associative memory, particularly in the absence of cues. Associative recognition requires learners to distinguish between information that has or has not been studied together, for example, intact (*blackberry*) versus re-arranged (*blackbird*) word-pairs (Clark & Shiffrin, 1992). In the present series of experiments, I propose to directly examine the influence of value on associative memory.

A long history of distinction exists between item information and associative information (e.g., Anderson & Bower, 1972, 1974). Item information consists of single units of information such as words, pictures, etc., whereas associative information consists of merging single units of information to form new items (e.g., feature binding, linking amongst items, or integrating events with surrounding context; Castel & Craik, 2003). For example, memory for item information could be memory for an individual face, whereas associative information could be memory for both a face and the context in which a face appeared.

Evidence that item and associative information are different (i.e., involve different mechanisms) comes from a variety of work identifying dissociations in recognition memory (e.g., Clark, 1992; Clark & Shiffrin, 1992; Gronlund & Ratcliff, 1989; Hockley, 1991, 1994). For example, Clark and Shiffrin (1992) had learners study word-pairs at either fast (1.25s/pair) or slow (5s/pair) rates and complete one of four recognition tests: for individual items (half of the word-pair), cues (the first word of each studied word-pair, presented with either an old or a new second word), pairs (two old item word-pairs, or two new-item word pairs), or for associative information (intact vs. rearranged or conjoined word-pairs). Discrimination between old and new information (*d*'), was impaired in the fast condition for associative recognition, compared to all other conditions. Importantly, under both fast and slow presentation times, discrimination did not differ significantly between item, cued, and pair recognition tests. Under slow conditions, *d*' for associative recognition improved to a greater extent than all other types of test. These results indicated that storing associative information required more study time than item information, identifying a dissociation between item and associative information.

To further emphasize that item and associative information involve different mechanisms, a large body of work indicates differential effects of age on item and associative memory, such that older adults exhibit poorer memory for associative information, or "binding" item information into complex memories, termed the *binding deficit* (e.g., Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008). In this age-related associative deficit, although older adults perform more poorly than younger adults when remembering item and associative information, the difference in memory performance by age is greater for associative information than for item information. Indeed, a meta-analysis of 90 studies (Old & Naveh-Benjamin, 2008) confirmed a greater deficit for associative information (*Cohen's d* = .92) than for item information (*Cohen's d* = .73). These results can be explained in terms of recollection (episodic memory of specific details) vs. familiarity (a relatively implicit process without memory of details; Wixted, 2007). In an associative recognition task (e.g., determining whether multiple stimuli were presented in association together), participants can respond using either recollection or familiarity. For example, Rhodes, Castel, and Jacoby (2008) had learners study pairs of faces. At test, faces were either presented in the same intact arrangement as at study (item recognition) or were rearranged with other previously studied faces (associative recognition). Learners successfully recognized intact face pairs, but were susceptible to falsely recognizing rearranged face pairs, demonstrating that recognition was based on familiarity with the individual faces or item-specific information, rather than explicit recollection of the association between faces. This pattern of results (i.e., item recognition in the absence of associative recognition) was particularly pronounced for older adults and is consistent with the finding that aging harms recollection while leaving familiarity intact (Jacoby, 1999).

Consciously-controlled attentional processes appear to play a role in successful binding (Castel & Craik, 2003). For example, under conditions in which attention was divided at encoding (versus full-attention conditions), Castel and Craik (2003) found that recognition was impaired for associative information (i.e., intact and rearranged word-pairs) to a greater extent than for item information, both for older and younger adults. These data further emphasize the differences when encoding item versus associative information.

Theories of item and associative memory have focused on the extent to which learners consciously recall information in a recognition test versus simply being aware that the information is familiar. Much debate concerns whether recognition reflects multiple processes operating independently or whether recognition reflects a continuous memory signal trace or some hybrid combination (Kellen & Singman, 2016; Malmberg, 2008; Parks & Yonelinas, 2009; Wixted, 2007; Yonelinas & Parks, 2007a, 2007b). Although these theories will not be directly tested here, they highlight the importance of contextual details. Context includes a wide range of potential information not directly found in the item, including details present both at study and at test, environmental and mental states, and source or origin (see Smith & Vela, 2001). In recognition tasks where learners are presented with both old and new content that does not share similar features, learners may distinguish between old and new items via memory for features of the word or word-pair, rather than memory for the entire word or association between word-pair components. For example, learners might correctly respond that *airplane* or *air - plane* was old by either implicitly or explicitly remembering content features (e.g., *air*), if no other studied word or word-pair shared that feature (e.g., Shiffrin & Steyvers, 1997). However, this does not indicate whether learners remembered item features (e.g., *plane*, *air*) or the associative relationship between the items (e.g., *air* was paired with *plane*).

The Feature Conjunction Paradigm

One means of distinguishing between memory for item vs. associative information has been through the feature-conjunction paradigm, which examines true and false memories for words with miscombined features (e.g., Reiniz & Lammers, 1992; Jones & Jacoby, 2001b). Initial work utilizing the feature-conjunction paradigm sought to demonstrate that features or stimulus parts could be independently encoded from memory for stimulus wholes and mistakenly recombined in memory. For example, while knowing both one's cell phone number and one's home phone number, it is possible to miscombine these memories and dial the first few digits of one's cell number, followed by the last few digits of one's home phone number – errors referred to as *memory conjunction errors* (Reinitz, Lammers, & Cochran, 1992).

In a typical example of the feature-conjunction paradigm, components of studied words (parent words; e.g., *airstream*, *passport*, *backpack*) are recombined at test either with new components (feature lures; e.g., *backstroke*) or rearranged components from the parent words (conjunction lures; e.g., *airport*). At test, new words may also be presented (e.g., Jones & Jacoby, 2001b), resulting four types of items at test: old (previously-studied) words, new words, feature lures, and conjunction lures. The typical pattern of responses is such that the proportion of words called "old" (i.e., previously-studied) is greatest for old words, then conjunction lures, then feature lures, with new items being incorrectly identified least often. The comparison of false alarms for feature and conjunction lures relative to entirely new items is called the feature effect and the conjunction effect, respectively (Jones & Jacoby, 2001b).

Conjunction errors have been explained by theories focusing on how memories are represented (e.g., Reinitz, Lammers, & Cochran, 1992; Reinitz, Verfaellie, & Milberg, 1996), and by theories focused on the processes involved without making claims regarding memory representations (e.g., Jones, Brown & Atcheley, 2007; Rubin, Van Petten, Glisky, & Newberg, 1999). Representation theories hold that conjunction errors are either due to a failure to bind (or inappropriate binding of) features with their configuration at encoding or to forgetting the configuration at retrieval (e.g., Kroll, Knight, Metcalfe, Wolfe, & Tulving, 1996; Reinitz et al., 1992, 1996)[2]. That is, the association between word features is either forgotten or never learned, resulting in the representation of item memory in the absence of associative memory. Process-based theories have focused on the role of mental processes such as familiarity, either with or without recollection, with the assumption that familiarity is a relatively fast, implicit process, while recollection is a relatively slow, explicit process (e.g., Jones & Jacoby, 2001a), and account for feature errors in addition to conjunction errors. For example, Jones and Jacoby (2001a, Experiment 3) presented participants with compound words (e.g., *blackbird*) at study that would also be presented at test (intact words). Additionally some studied words (e.g., *candlewax*, *slapstick*) were recombined at test to create false "conjunction" lures (e.g., *candlestick*). Finally, some studied words (e.g., *hardware*) were recombined at test with new, never-studied features to create false "feature" lures (e.g., *hardwood*). At test, participants made

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[2] Note that these theories do not account for feature errors, either because inappropriate binding can apply only to old (and not new) information (Kroll et al., 1996), or because feature errors were considered approximately chance (Reinitz et al., 1992, 1996), and therefore were not accounted for.

old/new recognition judgments for intact words, conjunction lures, feature lures and new, never-studied (i.e., baseline) words either under a short deadline (850 ms) or a long deadline (1800 ms). Participants demonstrated increased feature and conjunction errors under the short-deadline condition, providing evidence that errors were driven by time-demanding processes, such as recollection. However, these accounts are subject to many of the same issues of contention involved in recognition memory (e.g., whether accuracy across response times effectively distinguishes between familiarity/recollection, or whether one underlying memory signal strength drives memory performance; see Malmberg, 2008). Notably, for present purposes, both global mechanism-based and process-based accounts hold similar perspectives regarding associative effects (Hanczakowski, Zawadzka, & Coote, 2014; Jones & Jacoby, 2001b). That is, regardless of how feature and conjunction errors occur, it is clear they represent a failure of association while item features remain intact and indicate the importance of integrating item and associative information.

Given that the conjunction effect is greater than the feature effect (i.e., Jones & Jacoby, 2001b), conjunction errors and the conjunction effect will be the primary focus of this manuscript and subsequent experiments. Importantly, the conjunction effect demonstrates that words can be encoded as stimulus parts or items, rather than associative wholes. If stimulus parts and stimulus wholes were not represented independently it would not be possible for these parts to be miscombined in memory. Therefore, the feature-conjunction paradigm provides an ideal platform for examining whether value enhances memory for stimulus parts or for stimulus wholes.

Rationale for Current Study

Prior work on value-directed remembering has focused almost exclusively on memory for individual items. Little work has examined memory for associative information and almost exclusively utilizes cued-recall tasks, which cannot distinguish between familiarity with a stimulus versus binding of stimuli (e.g., Clark & Shiffrin, 1992). Thus, the majority of work on value-directed memory fails to provide information on whether value can enhance associations between items, or memory for contextual information (but see DeLozier & Rhodes, 2015; Festini et al., 2013).

The current experiments will examine the influence of the cueing properties of word features on memory for item and associative information of varying point values (i.e., importance). For the purpose of this work, I examined the association between individual lexical components of a word. For example, *sunspot* is composed of the words, *sun* and *spot*, while the association consists of the fact that these two words were encoded in relation to each other. Overall, memory is typically enhanced when the encoding conditions match retrieval conditions (Smith & Vela, 2001), but is also related to the degree to which the cue uniquely specifies the memory (e.g., SAM/REM; Raaijakers & Shiffrin, 1980, 1981; Shiffrin & Steyvers, 1997; see also Goh & Lu, 2012; Nairne, 2002). Thus, recognition memory should be better for the word "*sun"* when it is presented at test in the context of the word it was studied in (e.g., *sunspot*, rather than *sunset*), provided the word *sun* is not a cue for additional memories, consistent with typical findings within the feature-conjunction paradigm (e.g., Jones & Jacoby, 2001b). What remains unclear is whether value enhances participants' memory for associative information (e.g., words in context of the appropriate word-pair). Such findings are important for any comprehensive theoretical account of value-directed remembering.

The conjunction-error paradigm is an ideal way to examine whether value enhances item vs. associative information via false memories for recombined words (conjunction lures). The subsequent experiments will address the following questions: 1) Does value enhance memory for item-information, associative information, or both? 2) Is the relationship between value and binding altered when participants are permitted control over their study? 3) How confident are participants in their memories (and false memories) and what does this tell us about how confidence influences value-based retrieval processes? 4) Can the value effect be removed when encoding strategy is controlled? 5) Does value influence the degree to which learners utilize explicit recall and familiarity in their recognition judgments?

The primary question of interest is whether value enhances encoding of item information, associative information, or both. Indeed, although a multitude of studies have demonstrated the memory-enhancing properties of value for individual items (see Castel, 2007), it is not clear whether value enhances memory for associative information, an issue of practical import for memory. For example, suppose a babysitter learns a child is allergic to peanuts but not to walnuts. It is important that this individual remembers not just the features of this information (i.e., *pea*, *wal*, *nut*), but also the correct association between these items. If he or she remembers only the item information, that individual may falsely believe the child is allergic to walnuts. Thus, this failure of associative memory could result in severe consequences, demonstrating the importance of remembering not only item, but also associative information.

Although memory experiments frequently constrain learners' study time, under the free study conditions that characterize most learning an individual may allocate time to words as they choose. Thus, permitting participants to self-pace their study may provide a more externally-valid index of whether value can enhance memory for associative information. Indeed, work on value-directed remembering has indicated that participants choose to spend more time studying high-value (vs. low-value) information, resulting in enhanced value-based remembering (e.g., Castel, et al., 2013). In contrast, some work has indicated that increased study time does not enhance memory for associative information (Malmberg & Shiffren, 2005), suggesting that the benefit of self-paced study for high-value information may apply only to item enhancement, and not to associative enhancement.

Learners may believe that highly-important information is more likely to be remembered, even when the importance of information fails to enhance memory (e.g., Soderstrom & McCabe, 2011). One's monitoring or beliefs about memory affects how learning is controlled (Nelson & Narens, 1990; cf., Koriat et al., 2006); thus, believing that high-value information is more likely to be remembered may affect retrieval processes. For example, learners may be less likely to require explicit recall of item-specific details when making a recognition judgment for high-value information, resulting in high confidence for inaccurate judgments (e.g., McDonough et al, 2015). Conversely, if value enhances learners' ability to recall item-specific details (e.g., Hennessee, Castel, & Knowlton, 2017), learners' confidence judgments may be accurate regarding item-specific information, yet fail to account for associative information, resulting in similar high-confidence judgments for falsely endorsed lures.

Yet another question of interest concerns whether value enhancement for associative information is due to better encoding strategies. Prior work has indicated that learners utilize more effective encoding strategies when encoding high-value vs. low-value item information, resulting in enhanced memory performance (e.g., imagery vs. repetition; Ariel et al., 2015). Thus, any value enhancement for associative information may be due to associative strategies at encoding rather than strategic retrieval. Providing a strategy for encoding may prevent learners from using more (or less) effective study strategies, thereby reducing the effect of value on memory for associative information. Repetition (e.g., re-reading) enhances familiarity (Foster Huthwaite, Yesberg, Garry, & Loftus, 2012) and memory for item information without affecting associative information (Cleary, Curan, & Greene, 2001), which should result in greater errors for conjunction lures. In contrast, "deeper" encoding of associative meaning, such as imagery (i.e., levels of processing; Craik & Lockhart, 1972) enhances both item and associative information (e.g., Cohen & Moscovitch, 2007), which should enhance recognition accuracy.

In the subsequent series of experiments, I propose to utilize the feature-conjunction paradigm to examine whether value enhances memory for item-specific or association-specific information. If value enhances item-specific information, conjunction errors should be greater for high-value than low-value words. In contrast, if value enhances association-specific information, conjunction errors should be lower for high-value than low-value words. Lastly, consistent with the finding that value enhances memory, I expect to find a higher proportion of hits for high-value (vs. low-value) old (intact) word-pairs.

In a pilot study, I first examined the effects of value on associative recognition for high-value and low-value compound words under fixed study-time conditions, utilizing the feature-conjunction paradigm. These results will provide an initial basis for understanding whether value enhances memory for item-specific or association-specific information, as demonstrated by conjunction errors.

Pilot Study

Participants

Fifty-four college students from Colorado State University participated for partial course credit. An a priori power analysis was conducted to compute the required sample size for matched-pair *t*-tests examining discrimination between old vs. conjunction words for high-value versus low-value words, with power ($1 - \beta$) set at 0.80, and $\alpha = .05$, two-tailed. For an effect size of $d = .35$, 52 participants were recommended.

Materials

Materials came from Jones (2005). Each target compound word (e.g., *candlestick*) was part of a triplet, such that two other compound words (e.g., *candlewax*, *slapstick*) contained the first and second components of the target. For the study/test phase, there were 60 sets of word triplets. An additional set of 10 compound words were used during a practice study-test phase, and another set of 8 compound words were used as primacy and recency buffers at study only. Target compound words were divided into 3 sets and counterbalanced, such that each target word was presented as old, new, or conjunction an equal number of times at test (see Appendix for stimuli).

Methods and Procedure

A 2 (Point Value: 1, 12) x 3 (Test Item Type: old, conjunction, new) within-subjects design was used[3].

Participants were informed that they would be studying a series of compound words,

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[3] Note that “new” items were not studied and, therefore, not paired with point values.

paired with point values of 1 or 12 indicating the importance of later recognizing that intact compound word at test. The point values for correctly recognized words would add up towards their goal of achieving a high total point score; thus, it would be most important to remember the high-value words, although remembering any words would add to their score. They were given the following instructions about the types of the words they would study:

> "In the following task, you are about to see a series of compound words, each presented one-at-a-time in the center of the screen. Please do your best to remember them, such that if given a compound word at test you would be able to remember whether or not you had seen that compound word before. After a series of the compound words have been presented for study, your memory for these compound words will be tested with each compound word presented alone."
>
> "…At test, 1/3 of the compound words will have been studied (INTACT), 1/3 will have been re-arranged (MIXED), and 1/3 will have never been studied (NEW). You should only respond that you remember INTACT compound words (NOT compound words that are MIXED, or NEW). For example, if you studied "sidekick" and "catwalk" at study, but see "sidewalk" at test, since you did not study this exact compound word you should not say you recognize it at test."

Participants studied 60 compound words (e.g., *blackbird*) paired with point values of 1 or 12. Each word was presented for 5 seconds, followed by a 500 ms blank inter-stimulus interval. Test stimuli consisted of 60 words – 20 "old" or previously-studied, 20 "conjunctions" or combined words from the study conjunction phase (e.g., if the conjunction words at study were *candlewax* and *slapstick*, the test item would be *candlestick*). An additional 20 words at test were new or not presented at study. All words were presented in a random order at test and the test phase was self-paced. After all study words had been presented the recognition test phase began. Participants were informed that, during the test, 1/3 of the presented compound words would be "old" or previously-studied, 1/3 would be "new" or never-before-studied, and 1/3 would be "mixed" or recombined words from study (e.g., if the study words were *candlewax* and *slapstick*, the test item would be *candlestick*, to which they should respond "no", as they had not studied this exact compound word before). The entire experiment took 15-20 minutes to complete.

Results

The primary analyses of interest focus on comparing recognition performance for high-value (12-point) vs. low-value (1-point) compound words. In particular, these analyses focus on examining the conjunction errors, or false alarms for conjunction words, compared to false alarms for new words. Recognition for old words is expected to parallel the typical findings of value enhancement for high-value words (e.g., Castel et al., 2002) but will provide additional evidence as to whether value effects can be found in a recognition paradigm in which both familiarity and recognition can contribute to correct recognition, or hits. All pairwise comparisons are two-tailed, $\alpha = .05$.

Recognition. Recognition data for the pilot experiment is presented in Table 1 and Figure 1. A pairwise comparison indicated that hits (i.e., correctly calling a studied word "old") were greater for high-value words ($M = .76$, $SE = .03$) than for low-value words ($M = .66$, $SE = .03$), $t(53) = 3.78$, $p < .001$, $d = .48$. False alarms to conjunction lures (i.e., incorrectly identifying a conjunction lure as "old") were also greater for high-value words ($M = .40$, $SE = .03$) than for low-value words ($M = .34$, $SE = .03$), $t(53) = 2.52$, $p = .015$, $d = .29$.

Signal Detection Analyses. Discriminability, comparing hits and false alarms for old words vs. conjunctions (high-value and low-value), and hits and false alarms for old vs. new words[4] (note: “new” words did not include values), were calculated via the measure *d’*. Pairwise comparisons indicated discrimination between old words and conjunction words did not differ significantly for high-value words ($M = .89$, $SE = .12$) and low-value words ($M = .92$, $SE = .12$), $t(53) = .21$, $p = .831$, $d = .03$. The ability to discriminate (*d’*) between old words and new words was greater for high-value words ($M = 1.76$, $SE = .15$) than for low-value words ($M = 1.44$, $SE = .15$), $t(53) = 2.98$, $p = .004$, $d = .29$ (Table 2).

Response criterion was also calculated using the measure C, which calculates the degree to which learners are more likely to respond “old” vs. “new”, based on the distance from the intersection of the old/new distributions. A neutral response criterion is indicated by a value of 0, with values below 0 indicating liberal responses, and values above 0 indicating conservative responses. Responses were more liberal for high-value words ($M = -.07$, $SE = .05$) than for low-value words ($M = .16$, $SE = .07$) $t(53) = 4.34$, $p < .001$, $d = .53$ (Table 2).

Conjunction Effect. The conjunction effect is calculated by comparing the mean conjunction error rate to the new error rate (Jones & Atchley, 2006). Because new items were never presented with values the new error rate was the same across values. Nevertheless, for consistency, I present the conjunction error rate for both high and low value conjunction lures compared to the new error rate (Figure 2). The size of the conjunction effect was greater for high-value words ($M = .24$, $SE = .02$), $t(53) = 10.84$, $p < .001$, $d = 1.31$, than for low-value words ($M = .18$, $SE = .03$), $t(53) = 6.92$, $p < .001$, $d = .84$. That is, learners were more likely to incorrectly identify conjunction lures as “old” if the studied compound word had been paired with a high- (vs. low) point value, consistent with the hypothesis that value enhances item-specific information.

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[4] False alarms for new words were modest ($M = .17$, $SE = .02$).

Discussion

Overall, participants demonstrated enhanced recognition for high-value (vs. low-value) old (previously-studied) compound words, but also demonstrated more false alarms for high-value (vs. low-value) conjunction words. Further analyses indicated that the ability to discriminate between old (intact) words and conjunction words at test did not differ by value. Finally, the conjunction effect, or comparing false alarms for conjunction words vs. false alarms for new words (Jones & Jacoby, 2001b), was greater for high-value (vs. low-value) words. These results suggest that although value may enhance memory for individual items (e.g., word components), it does not enhance memory for these items as associative wholes (i.e., compound words), consistent with the idea that the information binding stimulus features is independent from the features themselves. That is, memory for global structure (e.g., old compound words) is impaired, whereas memories for the features themselves (e.g., conjunction words) is intact (Reintiz, Lammers, & Cochran, 1992). Thus, value may enhance memory for individual features, but not enhance the ability to bind these individual features together.

Experiment 1

Results from the pilot study indicated that participants were more likely to make conjunction errors for high-value relative to low-value information. I further examined this finding in Experiment 1 by permitting participants to self-pace their study. One possible account of the greater false alarms to high-value conjunctions is that people simply need to control their time spent studying in order to "bind" these compound words together. For example, prior work has found that, when studying other-race faces under fixed study time conditions, value does not enhance recognition memory (DeLozier & Rhodes, 2015). When permitted to self-pace study, memory has been enhanced for high-value information (Castel et al., 2013; DeLozier & Rhodes, 2015). If control over study enhances associative information, conjunction effects should be reduced for high-value (vs. low-value) compound words. However, if value does enhance only item-specific information, conjunction effects should be higher for high-value (vs. low-value) compound words regardless of time spent studying.

Additionally, after each recognition judgment, participants were asked to make a confidence learning judgment (CLJ) utilizing a scale of 0-100% to indicate how confident they were that they correctly identified whether or not that compound word had been previously studied. McDonough and colleagues (2015) have utilized similar confidence judgments to evaluate the interplay between confidence and value for implicit and explicit retrieval processes using item information. Results demonstrated that participants gave higher confidence judgments to lures that had been studied as high-value (vs. low-value) words even when their recognition judgments were incorrect, indicating that value may inflate confidence and reduce learners' reliance upon explicit recall at retrieval. By extension, value may have inflated participants' confidence. Due to these value effects on confidence, learners may have been less likely to explicitly retrieve details for high-value information, instead relying on relatively implicit familiarity (e.g., McDonough et al., 2015). Indeed, recall of high-value item information in the absence of associative information may even increase learners' susceptibility to high-confidence conjunction errors. If value-enhanced confidence contributes to learners' conjunction errors by reducing explicit retrieval, I would predict that conjunction errors would be greater for high-confidence, high-value (vs. low-value) words. However, if value-enhanced confidence instead reduces explicit retrieval of item information, I would not expect conjunction errors for high-value words to differ as a function of confidence.

Experiment 1 thus proposes the following questions of interest: How are confidence judgments and retrieval processes for associative information affected by value – does value increase confidence, and does confidence result in increased susceptibility to conjunction errors? Finally, does self-paced study enable participants to be more or less susceptible to conjunction lures and does this differ as a function of value?

Participants

In order to achieve a comparable effect size to that achieved in the pilot study for discrimination (*d*') between old and conjunction words as a function of value ($d = .29$), an a priori power analysis was conducted to compute the required sample size for matched-pair t-tests, with power ($1 - \beta$) set at 0.80, and $\alpha = .05$, two-tailed. For an effect size of .29, 96 participants were recommended. Ninety-six college students from Colorado State University participated for partial course credit. Twenty-seven participants were excluded either because their study times were less than 1s for more than half of the studied materials or because of failure to comply with instructions for confidence learning judgments ($M = 81.43\%$, $SE =$

3.28%); all twenty-seven participants were replaced. Due to experimenter error, an additional five participants were collected and included, for a total of 101 participants.

Materials

Materials were identical to those from the pilot study.

Methods and Procedure

The procedure was identical to the pilot study, except that participants could self-pace their study. They were given the following instructions:

> "Please study each compound word for as long as you feel that you need to (but no longer) so that you will be able to remember it later."

Additionally, after identifying each test item as old/new, participants made a confidence learning judgment (CLJ), indicating on a scale from 0-100%, how confident they were that a response was correct.

Results

Recognition and Self-Paced Study Time. Pairwise comparisons were conducted examining mean recognition performance for high- and low-value old words[5]. These analyses indicated that hits were greater for high-value words (*M* = .82, *SE* = .02) than for low-value words (*M* = .70, *SE* = .02), *t*(100) = 5.48, *p* < .001, *d* = .65 (Table 1, Figure 3). Additionally, there were significantly more false alarms for high-value (*M* = .30, *SE* = .02) than for low-value (*M* = .25, *SE* = .02) conjunction lures, *t*(100) = 2.23, *p* = .028, *d* = .21. The mean proportion of false alarms to new words was similar to that from the pilot experiment.

Median time spent studying (in ms) was examined for high-value and low-value words through pairwise comparison. Because learners were unaware which words would be presented

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[5] As in the pilot study, false alarms for new words were modest (*M* = .12, *SE* = .01).

as old (intact) or conjunction lures at test, analyses are not separated by the type of word at test. Overall, learners spent slightly more time studying high-value words (*M* = 3651.40, *SE* = 315.32) than low-value words (*M* = 2750.04, *SE* = 279.12), *t*(100) = 5.96, *p* < .001, *d* = .29 (Figure 4).

The item-by-item association between time spent studying and memory performance was examined as a function of point value via the commonly used nonparametric gamma correlations, reporting this association on a scale between -1 +1 (Nelson, 1984). Gamma correlations approaching +1 would indicate that recognized words had been studied longer than unrecognized words, whereas correlations approaching -1 would indicate that unrecognized words had been studied longer than unrecognized words. Gamma correlations of 0 would indicate no relationship between memory performance at test and time spent studying.

For each conjunction word at test, two compound words had been studied; accordingly, the mean study time of these two words was used for the test-accuracy correlations. Across word types and point values, the relationship between study time and test performance was not significant, (*G* = -.02, *SE* = .03), *t*(92) = .52, *p* = .607. Gammas examined separately for each point value and word type were also not significantly different from zero, and high-value gammas were similar to low-value gammas, both for old words and conjunction lures (Figure 5), indicating that increased time spent studying was not reliably associated with recognition performance.

Signal Detection Analyses. Measures of discriminability (*d*') indicated that, as in the pilot experiment, learners discriminated between old words and conjunction lures to a similar extent for both high-value words (*M* = 1.49, *SE* = .09), and low-value words (*M* = 1.37, *SE* = .10), *t*(100) = 1.30, *p* = .198, *d* = .12. Additionally, discrimination between old words and new words was greater for high-value words (*M* = 2.20, *SE* = .09), than for low-value words (*M* = 1.86, *SE* = .09), *t*(97) = 5.01, *p* < .001, *d* = .34 (Table 2). Measures of response criterion (*C*') indicated that learners responded more liberally at test for high-value words (*M* = .03, *SE* = .04) than for low-value words (*M* = .29, *SE* = .05), *t*(100) = 5.10, *p* < .001, *d* = .59 (Table 2).

Conjunction Effect. The conjunction effect was examined as a function of value. The conjunction effect for incorrectly identifying a conjunction lure as old (compared to the error rate for new words) indicated that learners had greater difficulty in correctly identifying conjunction lures (vs. new words) as old, both when the conjunction lure consisted of recombined high-value words (*M* = .18, *SE* = .02), *t*(100) = 9.69, *p* < .001, *d* = .97, than when the conjunction lure consisted of recombined low-value words (*M* = .13, *SE* = .02), *t*(100) = 7.96, *p* < .001, *d* = .70 (Figure 6). The effect size (Cohen's *d*) for the conjunction effect was slightly larger for high-value than for low-value words.

Confidence Judgments. A 2 (Word Type: old, conjunction) x 2 (Point Value: 1, 12) repeated-measures ANOVA examined the relationship between CLJs for the type of word studied and the points each word was worth. Learners gave higher CLJs to old words (*M* = 82.88, *SD* = 1.49) than to conjunction words (*M* = 75.8, *SD* = 1.73), *F*(1, 95) = 52.02, *p* < .001, η^2 = .354, and gave higher CLJs to high-value words (*M* = 77.24, *SE* = 1.77) than to low-value words (*M* = 74.36, *SE* = 1.85), *F*(1, 95) = 21.70, *p* < .001, η^2 = .186. The interaction between word type and point value was not significant, *F*(1, 95) = 1.32, *p* = .253, η^2 = .014, indicating that CLJs for high-value and low-value words were similar for both old and conjunction word types (Table 4). CLJs for new words (*M* = 76.67, *SE* = 1.94) were similar to those for conjunction words.

Gamma correlations revealed a significant relationship between confidence learning judgments (CLJs) and recognition accuracy (*G* = .34, *SE* = .04), such that gamma correlations differed from zero, i.e., higher CLJs were given to correctly recognized words, $t(93) = 8.16$, $p < .001$ (Table 5). A similar effect was found for high-value words, $t(93) = 4.18$, $p < .001$, low-value words, $t(93) = 3.67$, $p = .001$, old words, $t(93) = 6.10$, $p < .001$, and new words, $t(93) = 3.84$, $p < .001$, but was not significantly different from zero for conjunction words ($M = .02$, $SE = .08$), $t(93) = .26$, $p = .793$.

A 2 (word type: old, conjunction) x 2 (point value: 1, 12) mixed-factor ANOVA was conducted to examine whether gamma correlations differed between word types and point values. Results indicated that gammas were greater for old words ($M = .56$, $SE = .06$) than for conjunction words ($M = -.03$, $SE = .07$), $F(1, 51) = 36.28$, $p < .001$, $\eta^2 = .42$, and were similar between high-value words ($M = .28$, $SE = .05$) and low-value words ($M = .25$, $SE = .06$), $F(1, 51) = .47$, $p = .540$. The word type by point value interaction was not significant, $F(1,51) = .38$, $p = .54$, indicating that the effect of word type on gamma correlations was similar for both high-value and low-value words.

Discussion

Overall, the results from Experiment 1 were similar to the pattern of findings from the Pilot study. Namely, value increased hits and false alarms to conjunction items, providing further evidence that value enhances item-specific (but not associative) information. Although learners spent more time studying high-value than low-value words, indicated by a small effect size, this additional time was not significantly related to test performance. Thus, studying words longer did not affect recognition performance (cf. Nelson & Leonesio, 1988).

CLJs indicated that learners' confidence was greater for old words than for conjunction words and for high-value than low-value words. Gamma correlations between CLJs and recognition accuracy indicated a significant relationship for old words, yet a nonsignificant relationship for conjunction lures. Overall, Experiment 1 indicated that self-paced study did not directly enhance memory for individual components of each word (c.f., Malmberg & Shiffrin, 2005), nor did it appear to enhance encoding the associations between the individual components of each word (i.e., enhancing susceptibility to conjunction lures), regardless of point value.

Experiment 2

Why are participants failing to bind or associate individual word components particularly for high-value items? One possibility is that, regardless of the time spent studying, participants are failing to use study strategies that focus on learning the association between word components. A wide variety of work demonstrates that certain study strategies (e.g., distributed practice, imagery) are more effective than others (e.g., repetition or re-reading); (for reviews, see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Dunlosky, Rawson Marsh, Nathan, & Willingham, 2013; Karpicke & Roediger, 2008) and some strategies are particularly helpful for creating associations between item materials (e.g., Pyc & Rawson, 2010). Thus, it is possible that using an associative study strategy may reduce or diminish participants' difficulty in binding individual components of high-value information.

To test this, Experiment 2 manipulated participants' encoding strategy. Specifically, half of the participants were instructed to study using a rote repetition strategies (i.e., mentally repeating words to self), whereas the other half of participants were instructed to study using interactive imagery (i.e., imagining a mental picture for each studied word). Repetition should enhance item familiarity, but without necessarily enhancing the association between word components. In contrast, interactive imagery requires participants to create a visual image connecting the individual word components, thereby enhancing memory for the association between components. I expect that learners in the interactive imagery condition should not only outperform learners in the rote repetition condition but should also demonstrate similar conjunction errors and a similarly-sized conjunction effect across values.

Participants

An a priori power analysis was conducted to compute the required sample size for a repeated-measures ANOVA, within-between interaction to examine our primary analysis of interest: discrimination between old and conjunction words as a function of study strategy, and point value, with power (1 - β) set at 0.80, $\alpha = .05$, correlation between measures set at .65, based upon the correlation found in the pilot study. For an F effect size of .15 (comparable to $d = .30$);, critical $F = 4.00$, number of groups set at 2, number of measurements set at 2, 64 participants were recommended. Due to counterbalancing, seventy-two college students from Colorado State University participated for partial course credit. Twenty participants were excluded and replaced due either to failure to comply with the instructions (8), or because at the end of the experiment, they failed to report remembering the study strategy they were instructed to use (12).

Materials

Materials were identical to those used in Experiment 1.

Methods and Procedure

A 2 (Study strategy: repetition, interactive imagery) x 2 (Point value: 1, 12) x 3 (Test Item: Intact, Conjunction Lure, New) mixed-factor design was used, with study strategy manipulated between-subjects and point value and test item manipulated within-subjects. For study strategy, prior to beginning the experiment, participants were instructed that they would be asked to exclusively use a particular study strategy while learning information and were subsequently provided with an example of their designated study strategy - either the study strategy of rote repetition, or the strategy of interactive imagery. When asked to use rote repetition, participants were given the following instructions:

> "While studying, you will use ONE specific study strategy: REPETITION. That is, when studying each compound word, you will repeat it over and over again in your head to help you remember the word on the screen. For example: if the word on the screen is "beeline", you would then mentally rehearse "beeline, beeline, beeline..." to help you remember the studied word when you are tested later."

When asked to use interactive imagery, participants were given the following instructions:

> "While studying, you will use ONE specific study strategy: IMAGERY. That is, when studying each compound word, you will imagine a detailed image to help you remember the word on the screen. For example: if the word on the screen is "beeline", you might then imagine a bee flying forward in a straight line, to help you remember the studied word when you are tested later."

After completing a practice study-test phase, participants were again reminded of their study strategy and the importance of using only that study strategy and the procedure began. All other aspects of the procedure were identical to Experiment 1, except that, as in the pilot study, participants studied each word for 5 seconds. Following the final test item, participants were asked to report the study strategy they used and whether they exclusively used this strategy.

Results

Recognition. A 2 (study strategy) x 2 (point value) mixed factor analysis of variance (ANOVA) with strategy as a between-subject variable was conducted on hits for old (intact) words (Table 1, Figure 7). Recognition performance did not differ significantly as a function of assigned study strategy, $F(1, 70) = 3.46$, $p = .067$, $\eta^2 = .05$. Recognition performance was also similar for both high-value and low-value words, $F(1, 70) = 1.35$, $p = .249$, $\eta^2 = .02$, and the point value by study strategy interaction was not significant, $F(1, 70) = .22$, $p = .643$, $\eta^2 < .01$. Thus, participants correctly recognized a similar proportion of old words regardless of assigned study strategy or point value.

A 2 (study strategy) x 2 (point value) mixed factor ANOVA conducted on false alarms to conjunction lures (see Table 5) revealed similar levels of false alarms between the repetition and interactive imagery study strategies conditions, $F(1, 70) = .35$, $p = 554$, $\eta^2 < .01$, between high-value and low-value words, $F(1, 70) = .19$, $p = .662$, $\eta^2 < .01$, and the point value by study strategy interaction was not significant, $F(1, 70) = .09$, $p = .770$, $\eta^2 < .01$. Thus, the mean proportion of false alarms to conjunction lures was similar for learners assigned either repetition or interactive imagery as a study strategy, and for both high-value and low-value words. False alarms to new words were comparable to those from prior experiments, ($M = .13$, $SE = .02$).

Conjunction Effect. The size of the conjunction effect was similarly substantial for both low-value words ($M = .15$, $SE = .02$), $t(35) = 6.58$, $p < .001$, $d = .87$, and high-value words ($M = .14$, $SE = .02$), $t(35) = 6.54$, $d = .80$. In the imagery condition, the conjunction effect was also similar for both low-value words ($M = .13$, $SE = .03$), $t(35) = 4.95$, $p < .001$, $d = .73$, and high-value words ($M = .13$, $SE = .02$), $t(35) = 5.52$, $d = .73$ (Figure 8). The size of the conjunction effect in the repetition condition was also similar for high-value words ($M = .14$, $SE = .02$), $t(35) = 6.54$, $p < .001$, $d = 1.09$, and low-value words ($M = .15$, $SE = .02$), $t(35) = 6.58$, $p < .001$, $d = 1.10$.

Signal Detection Analyses. Discriminability (d') did not differ between repetition and imagery conditions, $F(1,70) = 2.18$, $p = .145$ (Table 2), or between high-value and low-value words, $F(1,70) = .93$, $p = .339$. In addition, study strategy did not interact with point value, *F*(1,70) = .01, *p* = .921. Thus, participants in the imagery and repetition conditions were similarly able to discriminate between old words and conjunction lures, and these results were similar for both high and low values.

Measures of response criterion indicated that learners' response bias was similar between the repetition and imagery conditions, *F*(1, 70) = .41, *p* = .523 (see Table 2), and between high-value and low-value words, *F*(1, 70) = .33, *p* = .569, and was similar for repetition and imagery conditions across point values, *F*(1, 70) = .36, *p* = .550. Overall, response bias was similar for participants studying using either repetition or imagery and this relationship was unaffected by point values.

Confidence Judgments. A 2 (study strategies) x 2 (point value) x 2 (studied word type) mixed-factor ANOVA was conducted on mean confidence judgments, with study strategies as a between-subject variable (see Table 3). Confidence judgments were similar between learners using either repetition or interactive imagery study strategies, *F*(1, 69) = 1.31, *p* = .257, η^2 = .02. Confidence judgments were also similar for high- and low-value words, *F*(1, 69) = 1.62, *p* = .207, η^2 = .02. A significant difference in confidence judgments was found between old words and conjunction lures, such that, on average, learners were more confident in their recognition decisions for old words (*M* = 87.58, *SE* = 1.37), than for conjunction lures (*M* = 80.24, *SE* = 1.88), *F*(1, 69) = 37.41, *p* < .001, η^2 = .35. No interactions were significant, all *F*s < 1. Thus, although learners were more confident in their decisions for items they had studied (vs. conjunction lures), they did not change their confidence judgments as a function of point value, nor did these judgments differ as a function of study strategy.

Gamma correlations demonstrated a significant relationship between confidence learning judgments (CLJs) and recognition accuracy (*G* = .45, *SE* = .04), *t*(69) = 11.01, *p* < .001, such that greater confidence judgments were given to words accurately identified (Table 4). Assigned study strategy resulted in similar gammas and did not differ for high-value words or low-value words, *t*s < .81, for old words, conjunction words, or new words, *t*s < .5, or for high-value old words or high-value conjunction words, *t*s < .6. Collapsed across study strategy, gamma correlations were similar for high-value and low-value words, *t*s < 1.1, and did not differ for old, conjunction, or new words, *t*s < 1.81. Comparing word types (old, conjunction, new) across point values (1, 12, none), resulted in only one significant difference – gamma correlations for low-value old words (G = .56, *SE* = .09) were significantly greater than those for low-value conjunction words (G = .07, *SE* = .12), *t*(42) = 2.90, *p* = .006. Several other correlations approached but did not reach significance, such that gamma correlations trended towards being greater for high-value old words (G = .31, *SE* = .12) than for high-value conjunction words (G = -.03, *SE* = .11), *t*(39) = 1.99, *p* = .054, and for old low-value words (G = .57, *SE* = .09) than for old high-value words (G = .31, *SE* = .12), *t*(39) = 1.94, *p* = .059.

Discussion

Contrary to prior work, value did not affect recognition of old words, or false alarms to conjunction lures, and study strategy additionally failed to affect recognition performance. The conjunction effect was likewise similar across all variables. Thus, rather than eliminating the conjunction effect by enhancing encoding of associative information, giving learners assigned study strategies appeared to eliminate the effects of point value on performance.

Experiment 3

The results of the prior experiments demonstrated that, whereas value might enhance memory for item-specific information, it does not enhance memory for item associations, or differentiate memory performance between learners utilizing effective vs. ineffective assigned study strategies. One question that has not yet been addressed is whether value alters the effect of familiarity on recognition judgments. Familiarity, at least in part, is presumed to affect learners' feature and conjunction errors. Since both components of conjunction lures are familiar (i.e., they were both studied, albeit not together), and only one component of a feature lure is familiar (i.e., feature lures consist of one previously-studied item and one new item), conjunction lures possess a higher familiarity strength than feature lures (Jones & Jacoby, 2001b). Thus, feature lures permit examination of the influence of different degrees of familiarity on value-based recognition.

Mixed evidence suggests that value either impairs or enhances learners' usage of explicit recall (and subsequent reliance on familiarity), at least for item information (Henessee et al., 2017; McDonough et al., 2015). In Experiment 3, participants studied compound words and, in addition to entirely new items, had two different types of lures at test: conjunction lures (i.e., two studied, familiar components recombined into one unstudied word combination), and feature lures (i.e., with one unstudied word component combined with one familiar component). If value reduces learners' reliance on explicit recall, learners should rely more on familiarity and be more susceptible to feature than conjunction errors, such that they will be more likely to commit conjunction errors than feature errors for high-value (vs. low-value) words. However, if value increases learners' usage of explicit recall, learners should rely less upon familiarity, and commit fewer feature and conjunction errors for high-value (vs. low-value) words.

Participants

An a priori power analysis was conducted to compute the required sample size for matched-pair t-tests for the primary variable of interest (feature errors by value: high, low), with power ($1 - \beta$) set at 0.80 and $\alpha = .05$, two-tailed. For an effect size of .29, 96 participants were recommended. Ninety-six college students from Colorado State University participated for partial course credit.

Materials

Word stimuli were identical to those used in prior experiments, with the addition of 20 feature lures at study and at test (i.e., study words which contain only one previously studied feature, and one new feature; e.g., *buckshot*, *buckwheat*). Components of feature lures were counterbalanced at study, such that the previously-studied feature and the new feature were present as the first component of the word an equal number of times. Thus, study materials consisted of 80 compound words, whereas test materials consisted of 80 compound words – 20 studied compounds, 20 conjunctions, 20 feature lures and 20 new words with no features presented at study. At test, the order of each feature lure as the first or second component of each word was counterbalanced within participants, such that the previously-studied feature was present as the first or last component of the test lure an equal number of times for each learner.

Methods and Procedure

Participants studied each compound word for 5s, as in the pilot study. At test, participants made recognition judgments for each word (old, new, conjunction, feature), followed by CLJs for each recognition judgment (as in Experiments 1-2). Instructions about the different word types were explained as follows:

> "At test, 1/4 of the compound words will have been studied (INTACT), 1/4 will have been re-arranged (MIXED), 1/4 will have parts of words you studied combined with parts you never saw (PARTS) and 1/3 will have never been studied (NEW). You should only respond that you remember INTACT compound words (NOT compound words that are MIXED, PARTS or NEW)."

Results

Recognition. Pairwise comparisons revealed more hits for high-value words (*M* = .72, *SE* = .02) than for low-value words (*M* = .65, *SE* = .02), *t*(91) = 2.52, *p* = .014, *d* = .34 (Table 1, Figure 9), and that learners were more susceptible to conjunction lures (*M* = .30, *SE* = .02) than to feature lures (*M* = .23, *SE* = .02), *t*(91) = 4.62, *p* < .001. However, unlike Experiment 1 or the Pilot Study, false alarms for conjunction lures did not differ between high-value words (*M* = .30, *SE* = .02) and low-value words (*M* = .30, *SE* = .02), *t*(91), = .105, *p* = .916, or between feature lures for high-value (*M* = .23, *SE* = .02) and low-value (*M* = .23, *SE* = .02) words, *t*(92) = .322, *p* = .748. False alarms for new words were comparable to those of prior experiments (*M* = .19, *SE* = .02).

Signal Detection Analyses. Discrimination (*d*') was better for new words (*M* = 1.5, *SE* = .11) than for feature lures (*M* = 1.35, *SE* = .09), *t*(91) = 2.19, *p* = .031, *d* = .15 (see Table 2), or conjunction words (*M* = 1.13, *SE* = .10), *t*(91) = 4.91, *p* < .001, *d* =.34, and was better for feature lures than conjunction lures, *t*(91) = 3.92, *p* < .001, *d* = .24. Learners were also better able to discriminate between old and new high-value words (*M* = 1.55, *SE* = .11) than low-value words (*M* = 1.38, *SE* = .10), *t*(91) = 2.52, *p* = .014, *d* = .17, but this discrimination did not differ between high-value conjunction lures (*M* = 1.18, *SE* = .10) and low-value lures (*M* = 1.04, *SE* = .10), *t*(91) = 1.48, *p* = .143, *d* = .14, or high-value feature lures (*M* = 1.43, *SE* = .11) and low-value lures (*M* = 1.29, *SE* = .10), *t*(91) = 1.51, *p* = .134, *d* = .14.

Overall, learners' response criterion tended to be conservative, with more conservative response criterion for new words (*M* = .32, *SE* = .04) than for feature lures (*M* = .24, *SE* = .03), *t*(91) = 2.19, *p* = .031, *d* = .22, or conjunction lures (*M* = .13, *SE* = .04), *t*(91) = 4.91, *p* < .001, *d* = .51. Feature lures also led to a more conservative response criterion than conjunction lures *t*(91) = 3.92, *p* < .001, *d* = .32.

Response criterion was less conservative when distinguishing between old words and high-value conjunction lures (*M* = .16, *SE* = .04; see Table 2) than low-value lures (*M* = .26, *SE* = .05), *t*(91) = 2.08, *p* = .041, *d* = .23, and for high-value new words (*M* = .35, *SE* = 04) than low-value new words (*M* = .43, *SE* = .05), *t*(91) = 2.52, *p* = .014, *d* = .29. Response criterion did not differ as a function of value between high-value feature lures (*M* = .29, *SE* = .04) and low-value feature lures (*M* = .39, *SE* = .05), *t*(91) = .29, *p* = .084, *d* = .22.

Feature-Conjunction Effect. In addition to the conjunction effect, I also report the feature effect. Similar to the conjunction effect, the feature effect is calculated by comparing the mean feature lure error rate to the new error rate (Jones & Atchley, 2006). The conjunction effect was found for both high-value words (*M* = .11, *SE* = .02), *t*(91) = 5.87, *p* < .001 (see Figure 10), and low-value words (*M* = .11, *SE* = .02), *t*(91) = 6.00, *p* < .001. The feature effect was also found for high-value words (*M* = .04, *SE* = .02), *t*(91) = 2.86, *p* = .005, and low-value words (*M* = .04, *SE* = .01), *t*(91) = 2.31, *p* = .023. Thus, the feature effect was somewhat smaller than the conjunction effect, and neither was substantially affected by point value.

Confidence Judgments. A 3 (Word Type: old, feature, conjunction) x 2 (Point Value: 1, 12) repeated-measures ANOVA examined the relationship between type of word studied and the points each word was worth (Table 3). Learners gave differing CLJs as a function of word type, $F(2, 172) = 53.85$, $p < .001$, $\eta^2 = .39$, and gave higher CLJs to high-value words ($M = 76.48$, $SE = 1.93$) than to low-value words ($M = 74.82$, $SE = 2.0$), $F(1, 86) = 8.64$, $p = .004$, $\eta^2 = .09$. However, the word type and point value interaction was not significant, $F(2, 172) = 2.04$, $p = .133$, $\eta^2 = .02$. Pairwise comparisons indicated that learners gave higher CLJs to old words ($M = 81.87$, $SE = 1.61$) than to feature lures ($M = 72.79$, $SE = 2.19$), $t(87) = 8.69$, $p < .001$, $d = .43$, or to conjunction lures ($M = 73.01$, $SE = 2.22$), $t(88) = 8.17$, $p < .001$, $d = .42$, but that no other comparisons were significant.

Gamma correlations we calculated examining the relationship between confidence learning judgments and accuracy. Gamma correlations demonstrated a significant relationship between confidence learning judgments (CLJs) and recognition accuracy ($G = .26$, $SE = .05$), $t(88) = 5.63$, $p < .001$, such that greater confidence judgments were given to words accurately identified. Gammas did not differ significantly between words studied as high-value ($G = .18$, $SE = .05$) and low-value words, $G = .21$, $SE = .04$, $t(58) = .65$, $p = .519$ (Table 4).

Gammas were higher for old words ($G = .59$, $SE = .06$) than for new words ($G = .18$, $SE = .06$), $t(58) = 3.76$, $p = .001$, conjunction lures ($G = -.07$, $SE = .07$), $t(58) = 6.64$, $p < .001$, or feature lures ($G = .08$, $SE = .07$), $t(58) = 5.07$, $p < .001$. Gammas for new words were higher than for conjunction lures, $t(58) = 3.40$, $p = .001$, but did not differ significantly between new words and feature lures, $t(58) = 1.33$, $p = .189$. Gammas for conjunction lures were higher than for feature lures, $t(58) = 2.30$, $p = .025$. Gammas for each word type were similar between high and low values, *t*s < 1.5. Thus, across all word types value did not affect the relationship between recognition accuracy and confidence learning judgments.

Discussion

As in the pilot experiment and Experiment 1, recognition performance for old words was more accurate for high-value than low value words. As expected, susceptibility to conjunction lures was greater than that for feature lures, yet in contrast to the pilot study and Experiment 1, value failed to influence this susceptibility to either conjunction lures or the newly included feature lures. A further prediction, that value would diminish false alarms to conjunction lures, was also not supported.

General Discussion

In the present series of 4 experiments, I utilized a point-based reward paradigm to investigate whether the memory-enhancing properties of value (e.g., Castel et al., 2002) also enhances memory for associations. Through the feature-conjunction paradigm (Jones & Jacoby, 2001b), I examined errors for recombined compound words (conjunction lures) or compound words recombined with new word elements (feature lures). Overall, the present experiments revealed that value either increased conjunction errors or had no effect on such errors. For example, learners committed more memory errors for conjunction lures when these lures had been high-value information during the study phase (Pilot Study), with the increase in conjunction errors persisting even when learners were permitted to self-pace their study (Experiment 1). The detrimental effects of value on memory were reduced or eliminated when learners were instructed to use the same study strategies for both high-value and low-value words (Experiment 2) and when memory lures consisted of both recombined elements of previously-studied words and of elements of previously-studied words recombined with new, never-before-studied word elements (Experiment 3). In three of four experiments, value failed to enhance associative memory performance, indicating that the beneficial effects of value on memory apply to item and not associative information.

Theoretical accounts suggest that conjunction errors represent a failure of association while item information remains intact (e.g., Hanczakowski et al., 2014; Jones & Jacoby, 2001b). The present series of experiments demonstrates that this associative failure can be enhanced or increased– rather than reduced– by value. In the present experiments, learners falsely identified words created by recombining item information at study. This increased susceptibility to high-value lures provides initial evidence that the memory-enhancing effects of value previously demonstrated for item information (e.g., Castel et al., 2002) fails to enhance or can even harm memory for associative information; henceforth referred to as the *item-enhancing* and *binding-deficient* properties of value.

Theoretical Accounts of Value-Directed Remembering

Theoretical accounts of value-directed remembering effects have posited that the beneficial effects of value occur due to processes engaged at encoding, with different regarding the specific nature of these encoding processes. The present work examined potential contributions of encoding processes in Experiments 1 and 2. In Experiment 1, learners demonstrated some encoding selectivity by spending slightly more time studying high-value words, although this increased study time failed to translate into differences in memory performance across point values (see also, DeLozier & Dunlosky, 2015; DeLozier & Rhodes, 2015; Thiede & Dunlosky, 1999).

However, study time is not the only means of demonstrating selective encoding, given that time spent studying may be less indicative of future memory performance than how that study time is spent (e.g., Cepeda et al., 2006; Rohrer & Pashler, 2007; see also Nelson & Leonesio, 1988). When attempting to learn high-value item information, learners self-report using normatively more effective study strategies (Ariel et al., 2015; Cohen et al., 2017). Pursuing the possibility that learners were driven to use better study strategies for higher-valued information (e.g., Ariel et al., 2015), learners in Experiment 2 were instructed to use the same study strategy for both high-value and low-value words. When study strategies were controlled across values, both beneficial and detrimental effects of value on memory performance disappeared. Thus, consistent with prior work on value-based item information (for a review, see

Castel, 2008), encoding strategies may also affect memory for value-based associative information. These results suggest the need for continued exploration of the hypothesis that value-based effects are driven by differential strategies for high-value and low-value information (Ariel et al., 2015).

These data suggest that any strategic encoding processes have selective benefits (e.g., Castel, 2007; Sahakyan & Delaney, 2003). For example, in a value-based item paradigm, older adults learn with task experience to selectively focus on learning high-valued information (thus achieving the goal of remembering highly-important information), yet this enhanced memory performance for high-valued words comes at an expense or memory deficit for low-valued words (Castel, 2007). Thus, although strategic encoding may benefit memory performance, this benefit does not necessarily come without costs.

Theoretical Accounts of Deficits in Associative Memory

The predominance of item-based theories for value effects cannot fully address the distinctively different current results for associative information. Indeed, the failure of value to enhance memory for associative information might be explained in part by theoretical accounts of binding deficits, or memory deficits for associative information. Process-based memory training in the absence of strategic instruction has also failed to reduce the binding deficit, a finding primarily driven by false alarms and failure to utilize strategic processes (Bellandar et al., 2017; Naveh-Benjamin et al., 2009; Naveh-Benjamin, Brav, & Levy, 2007). In the present Experiment 3 (and in Experiment 2), neither false alarms nor the feature-conjunction effects differed between high-value and low-value words. Importantly for the present findings, Naveh-Benjamin and colleagues (2009) found that, compared to explicit instructions for attending to associations between items, the binding deficit was reduced under incidental learning conditions and was attributed to differences in encoding and retrieval processes. That is, reduced associative deficits were found when learners did not selectively attend to and enhance item-specific information at a rate higher than that of associative information. Similarly, Experiment 2 indicated the importance of employing different strategies for encoding high-value and low-value information. However, another hypothesis is that the encoding mechanism of attention to item information at the expense of associative information could also play a role in the value-binding deficit.

Although strategic processes at encoding clearly play an important role in value-based associative memory, the present work does not provide a clear explanation as to why false alarms failed to differ between high-value and low-value words in Experiment 3. Experiment 3 and the pilot study were identical except that Experiment 3 included two new manipulations, yet found distinctly different results. The pilot study found value-based deficits for associative memory, whereas Experiment 3 found moderate value-based enhancement. The differences between these studies were that Experiment 3 added CLJs as well as feature lures, or lures consisting of one previously-studied item combined with one never-before seen item (conjunction lures, also resent, consist of two studied, but recombined items). Thus, both feature lures and CLJs are potential explanations for the failure to find value-based deficits.

Prior work has suggested that value-directed remembering may reflect more than just differences in encoding. Rather, accounts of value-directed remembering have theorized or provided evidence that value-driven effects occur at least partially at retrieval (Ariel et al., 2015; Bui et al., 2013; Castel, 2007; Castel et al., 2002, 2007, 2011a, 2011b; McDonough et al., 2015). In this vein, it is known that making metacognitive monitoring judgments at study may change memory performance (Mitchum, Kelley, & Fox, 2016; Witherby & Tauber, 2017), the criterion used when making judgments of future memory performance (Zawadzka & Highman, 2016), and that making CLJs at test affect at least one form of memory performance (Double & Birney, 2017). I speculate that the lack of a value-driven binding deficit in Experiment 3 was influenced at least in part by the act of making CLJs at retrieval. However, this question cannot be directly investigated in the present work, providing a question of future interest as to whether the act of making CLJs may affect memory performance overall. Regardless of whether the lack of a value-driven binding deficit was due to CLJs or feature lures, both these potential explanations were introduced at retrieval, indicating that value-driven effects may also due to processes during retrieval in addition to processes during encoding.

Due to the finding that no other study detected beneficial effects for value-based associative memory (i.e., increased hits or old-new discrimination without increasing feature-conjunction effects), the influence of feature lures must also be examined. One hypothesis of feature-conjunction effects presumes that feature-conjunction lures are ineffective retrieval cues for individual items from study (i.e., Jones & Jacoby, 2001; Reintz et al., 1999). Supporting this hypothesis, dividing attention at retrieval (i.e., leaving recollection intact while reducing the effects of familiarity) enhanced recognition for old words while failing to affect feature-conjunction lures, indicating that feature-conjunction errors are based on familiarity rather than recollection (Jones & Jacoby, 2001 – Experiment 1). Given these findings, the presence of feature lures may have increased the influence of recollection and reduced the reliance on familiarity by enhancing the realization that some components of each word had not been seen before. Thus, eliminating feature-conjunction errors suggests that the value-binding deficit may be due to the influence of item-based familiarity.

Limitations

Several limitations exist in the present work. First, the pilot study and Experiment 3 used similar manipulations, with the addition of CLJs and feature lures in Experiment 3, yet learners' performance was very different. With more than one change between experiments, it cannot be fully determined whether learners' performance was affected by CLJs or by feature lures, and the resulting import for theories of value-directed remembering. Considering the potential explanation that feature lures changed learners' recognition performance, the inclusion of feature lures in all experiments may have illuminated this issue. However, finding that reductions in familiarity have previously eliminated feature-conjunction effects (e.g., Jones & Jacoby, 2001) suggest that familiarity rather than the presence of monitoring judgments at retrieval drives value-based binding deficits. Additionally, although prior work has indicated that learners may use different strategies when encoding high-value and low-value information, the Experiment 2 manipulation of controlled study strategy was not the most direct way to address this question. Instead, the influence of learners' study strategies on value-directed effects could have been examined through self-reported study strategies at the end of each experiment. This manipulation would have provided a more direct measure of learners' study strategies, and could have provided an additional measure of support for the role of strategies at encoding.

Summary

Overall, the current experiments reveal that the memory-enhancing properties of value (Castel, 2008) are not as all-encompassing as previously suggested. Instead, value appears to enhance memory only for item information while simultaneously harming or failing to benefit memory for associative information. Value-based deficits for associative memory are driven by strategic processes at encoding that enhance memory for item information at the expense of item association. Value also appears to play a role at retrieval- i.e., most likely through the contribution of item familiarity, although this role is less distinctly defined. This work divides research on value-directed remembering into two focus areas: 1) the beneficial effects of value for item information, and 2) the harm or absence of benefits for associative information. Future work should continue to examine the depth and breadth of these issues, examining questions such as whether boundary conditions exist that can preemptively define whether value effects will be beneficial. Applied in a broader sense, people may indeed be more likely to remember individual pieces of information when it is highly important. However, when it becomes necessary to remember surrounding associated information, we are instead more susceptible to false memories, calling into question the practical utility of importance as a tool for memory enhancement.

Table 1. Mean proportion called old.

		Old		Conjunction		Feature		New	
		M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Pilot Study									
	High	.76	.03	.40	.03				
	Low	.66	.03	.34	.03				
								.17	.02
Experiment 1									
	High	.82	.02	.30	.02				
	Low	.70	.02	.25	.02			.12	.01
Experiment 2									
	High	.77	.02	.27	.02				
	Low	.74	.02	.28	.02				
								.13	.02
Experiment 3									
	High	.72	.02	.30	.02	.23	.02		
	Low	.65	.02	.30	.02	.23	02	.19	.02

Table 2. Means and standard error for discriminability (*d'*) and response criterion (C) across experiments. Parentheses indicate standard error of the mean.

		d'		C	
		Value 1	Value 12	Value 1	Value 12
Pilot Study	Conjunction	.92 (.12)	.89 (.12)	.16 (.07)	-.07 (.05)
	New	1.44 (.15)	1.76 (.15)	.47 (.06)	.36 (.06)
Experiment 1	Conjunction	1.37 (.10)	1.49 (.09)	.29 (.05)	.03 (.04)
	New	1.86 (.09)	2.20 (.09)	.53 (.04)	.38 (.04)
Experiment 2	Conjunction	1.36 (.11)	1.45 (.11)	.16 (.05)	.13 (.05)
	New	1.92 (.12)	2.00 (.12)	.45 (.05)	.41 (.04)
Experiment 3	Conjunction	1.04 .(10)	1.18 (.10)	.26 (.05)	.16 (.04)
	Feature	1.29 (.10)	1.43 (.11)	.39 (.05)	.29 (.04)
	New	1.38 (.10)	1.55 (.11)	.43 (.05)	.35 (.04)

Table 3. Mean confidence learning judgments across experiments. Parentheses indicate standard error of the mean.

		Value 1	Value 12	None
Experiment 1 - *Self-Paced Study*				
	Old	80.87 (1.68)	85.64 (1.43)	
	Conjunction	74.45 (1.82)	77.30 (1.71)	
	New			77.04 (1.89)
Experiment 2 - *Instructed Strategies*				
	Old	86.52 (1.54)	88.15 (1.55)	
	Conjunction	79.95 (1.99)	79.73 (1.94)	
	New			81.38 (2.02)
Experiment 3 - *Feature-Conjunction*				
	Old	80.13 (1.78)	83.38 (1.61)	
	Conjunction	72.08 (2.32)	73.95 (2.23)	
	Feature	72.87 (2.23)	72.71 (2.26)	
	New			71.76 (2.38)

Table 4. Mean gamma correlations between test accuracy and confidence learning judgments across experiments. Parentheses indicate standard error of the mean.

		Value 1	Value 12	None
Experiment 1 - *Self-Paced Study*				
	Old	.50 (.07)	.52 (.06)	
	Conjunction	.06 (.09)	.08 (.08)	
	New			.33 (.08)
Experiment 2 - *Instructed Strategies*				
	Old	.54 (.09)	.36 (.11)	
	Conjunction	.13 (.11)	.09 (.10)	
	New			.39 (.09)
Experiment 3 - *Feature-Conjunction*				
	Old	.57 (.06)	.54 (.08)	
	Conjunction	-.06 (.08)	-.15 (.09)	
	Feature	.15 (.10)	-.06 (.09)	
	New			.22 (.08)

Table 5. Mean false alarms for conjunction lures in Experiment 2. Parentheses indicate standard error of the mean.

	Imagery	Repetition
High-Value	.26 (.03)	.28 (.03)
Low-Value	.26 (.03)	.29 (.03)

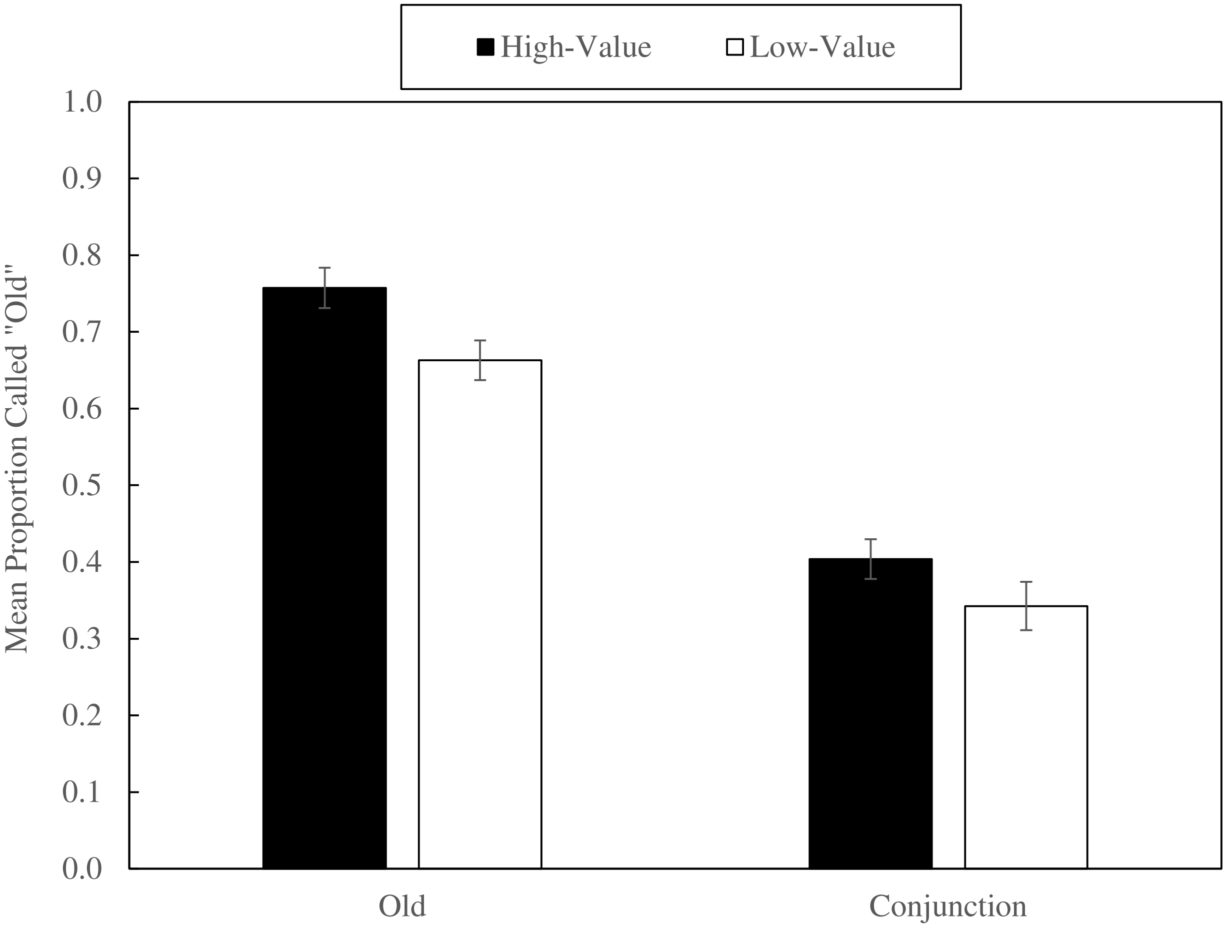

Figure 1. Mean proportion called “old” as a function of word type (old, conjunction) and point value (high, low) in the Pilot Study. Error bars represent standard error of the mean.

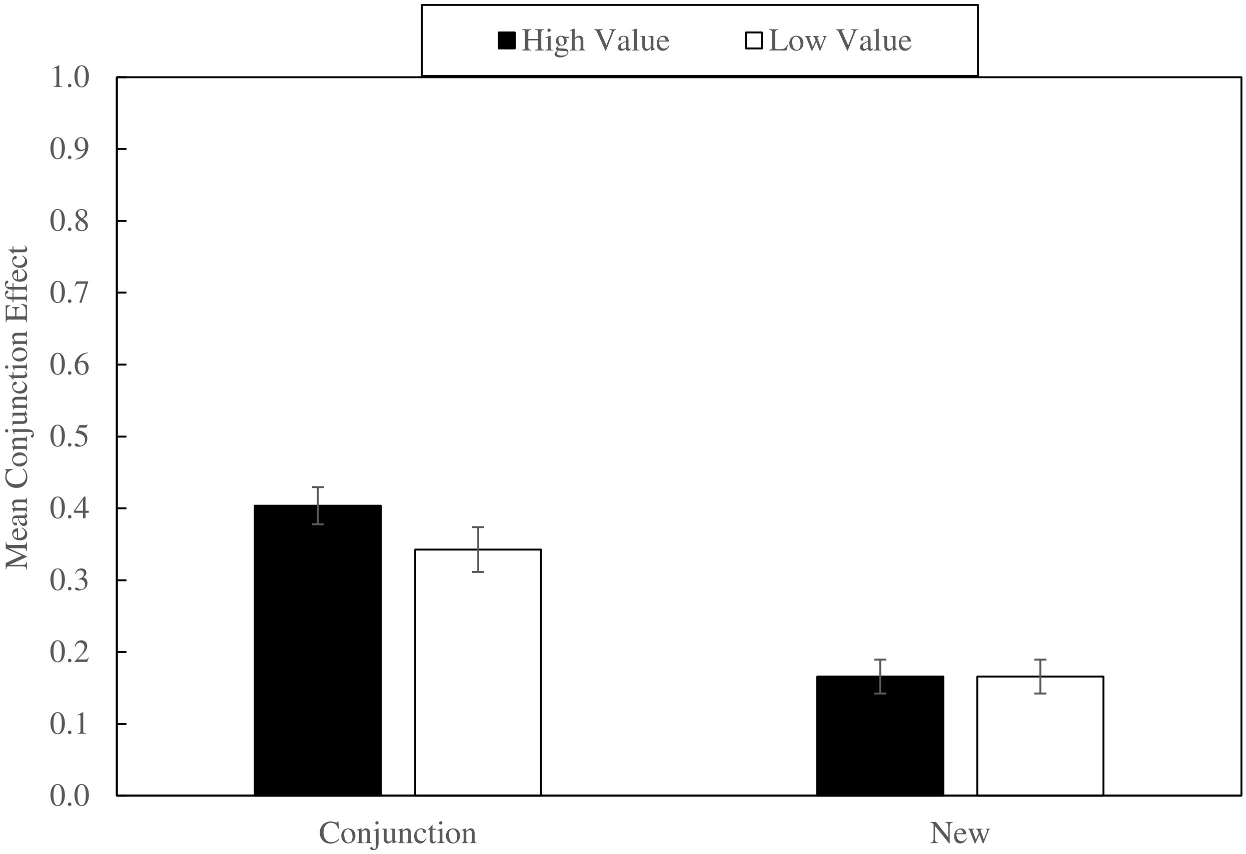

Figure 2. Mean conjunction effect (mean conjunction error rate vs. new error rate) as a function of item type (conjunctions, new) and point value (high, low) in the Pilot Study. Error bars represent standard error of the mean.

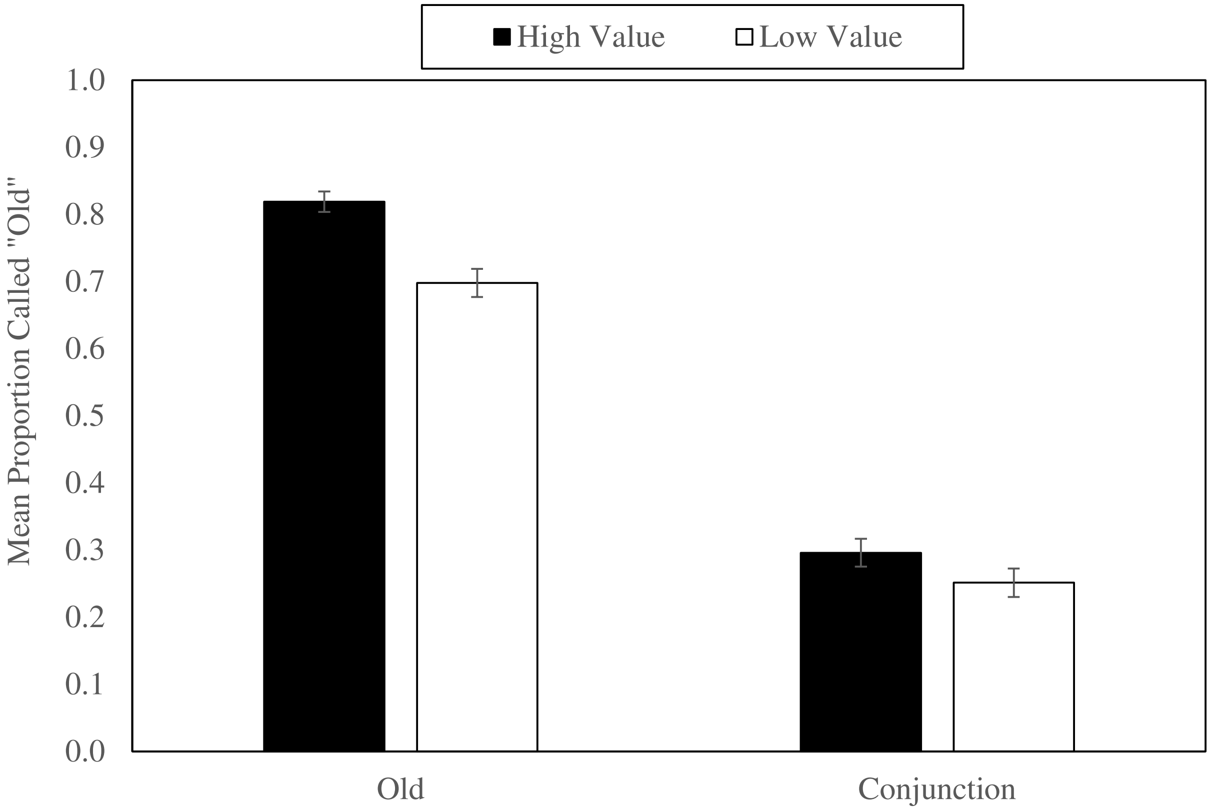

Figure 3. Mean proportion called “old” as a function of word type (old, conjunction) and point value (high, low) in Experiment 1. Error bars represent standard error of the mean.

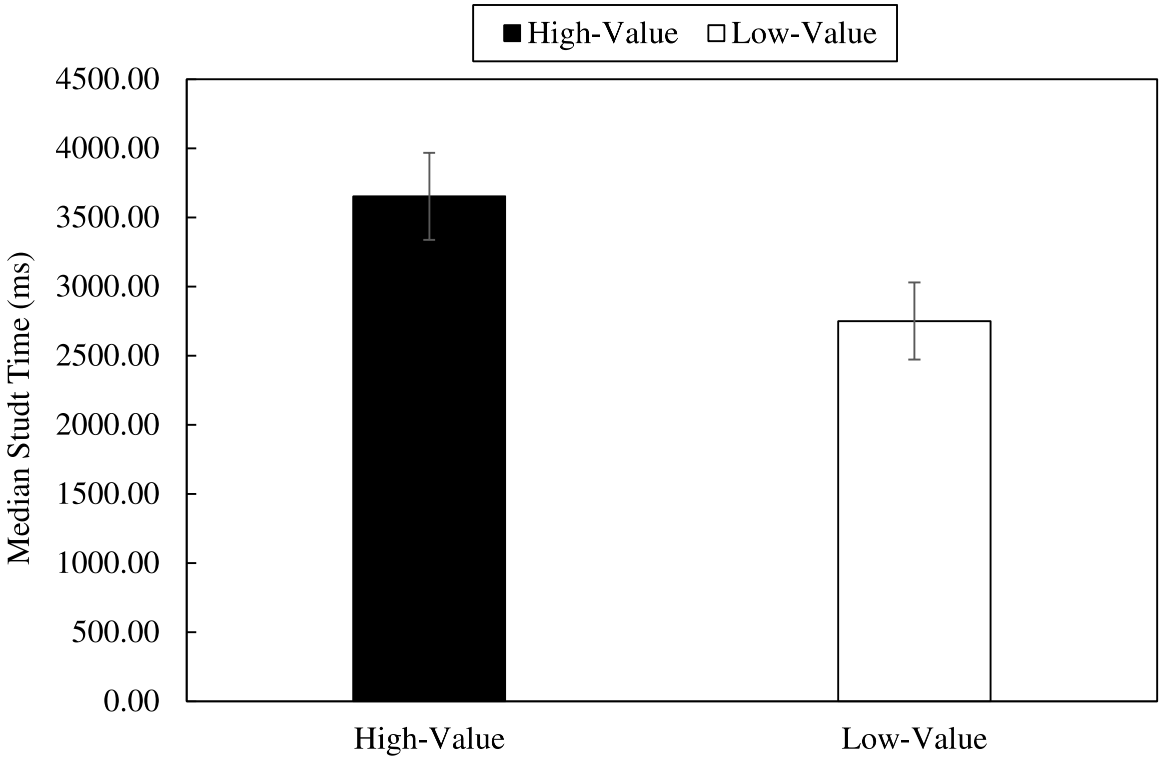

Figure 4. Median study time for both old words and conjunction lures as a function of point value (high, low) in Experiment 1. Study time for conjunction lures is presented as the aggregate average of study time for both conjunction lure components. Error bars represent standard error of the mean.

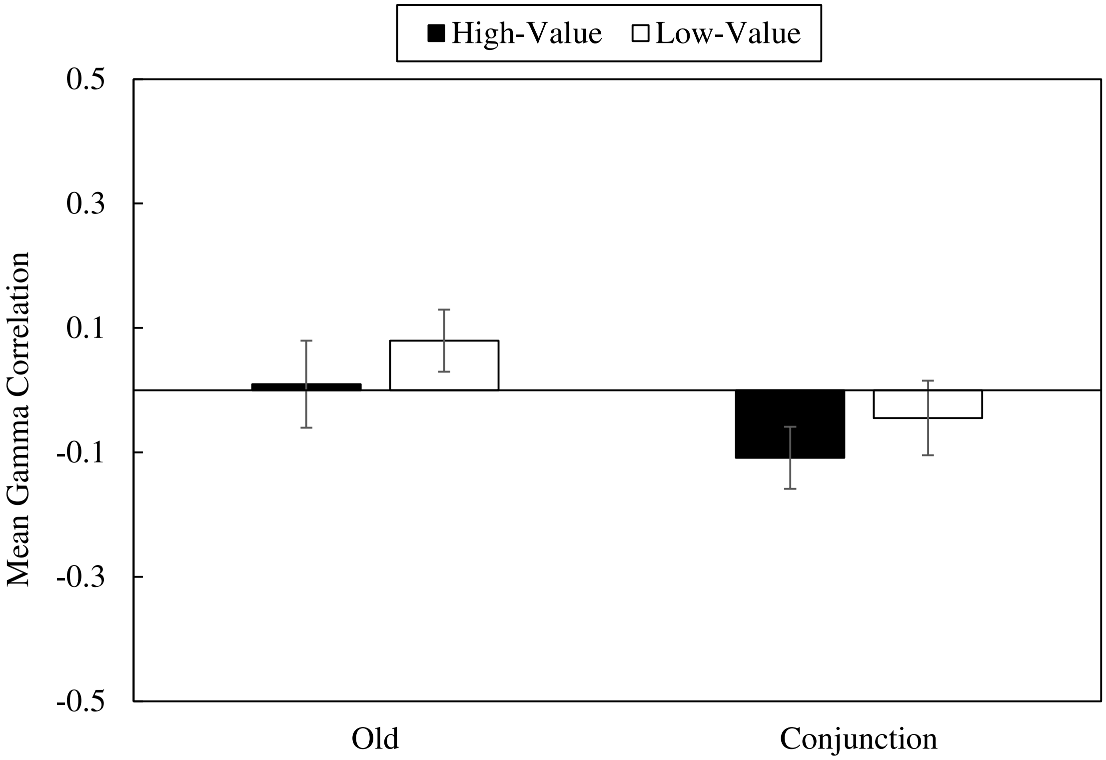

Figure 5. Mean gamma correlations between study time and recognition performance. Error bars indicate standard error of the mean.

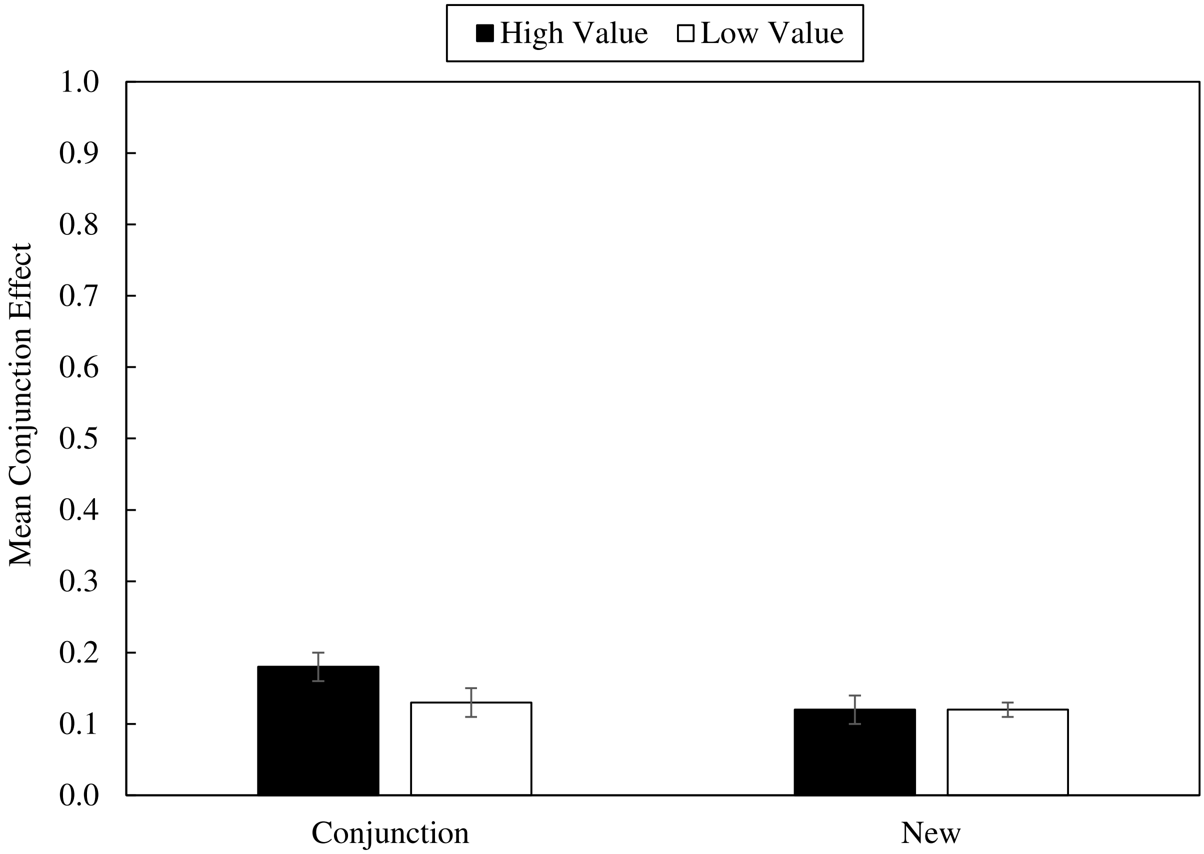

Figure 6. Mean conjunction effect (mean conjunction error rate vs. new error rate) as a function of item type (conjunctions, new) and point value (high, low) in Experiment 1. Error bars represent standard error of the mean.

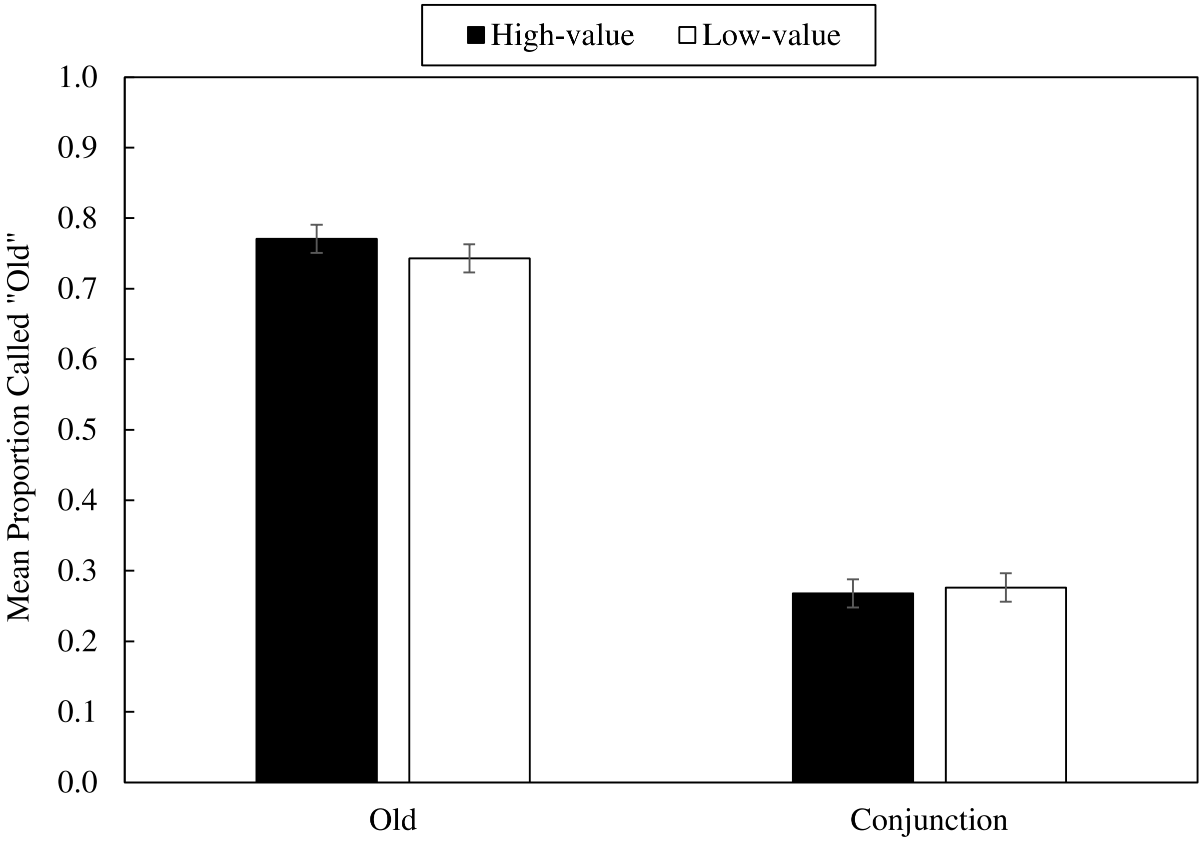

Figure 7. Mean proportion called “old” as a function of word type (old, conjunction) and point value (high, low) in Experiment 2. Error bars represent standard error of the mean.

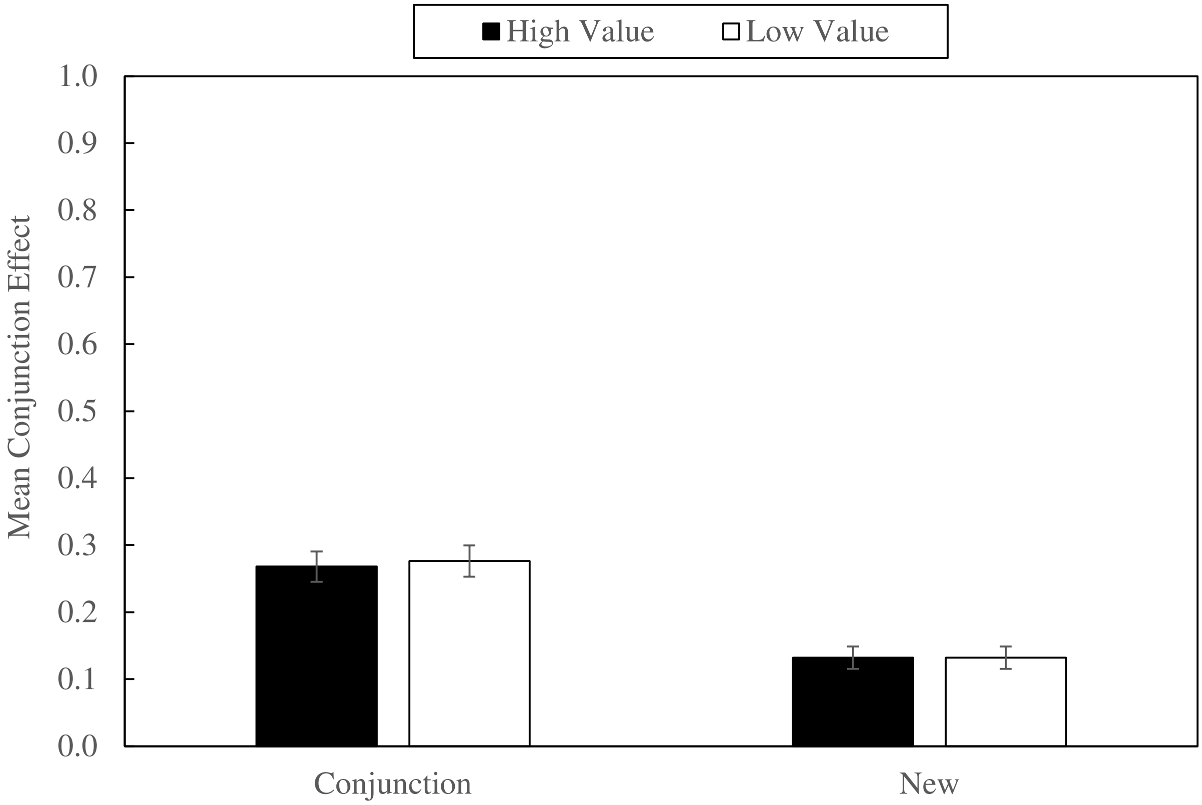

Figure 8. Mean conjunction effect (mean conjunction error rate vs. new error rate) as a function of word type (conjunctions, feature) and point value (high, low) in Experiment 2. Error bars represent standard error of the mean.

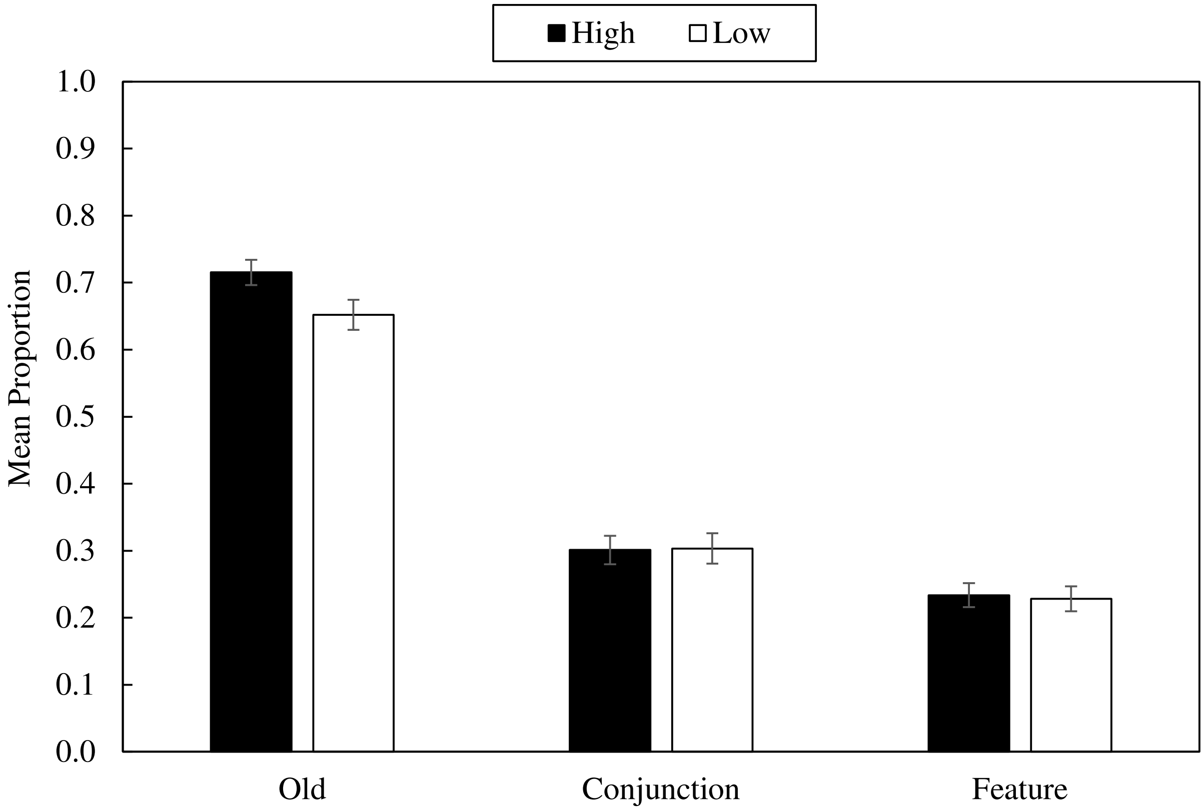

Figure 9. Mean proportion called "old" as a function of word type (old, conjunction) and point value (high, low) in Experiment 3. Error bars represent standard error of the mean.

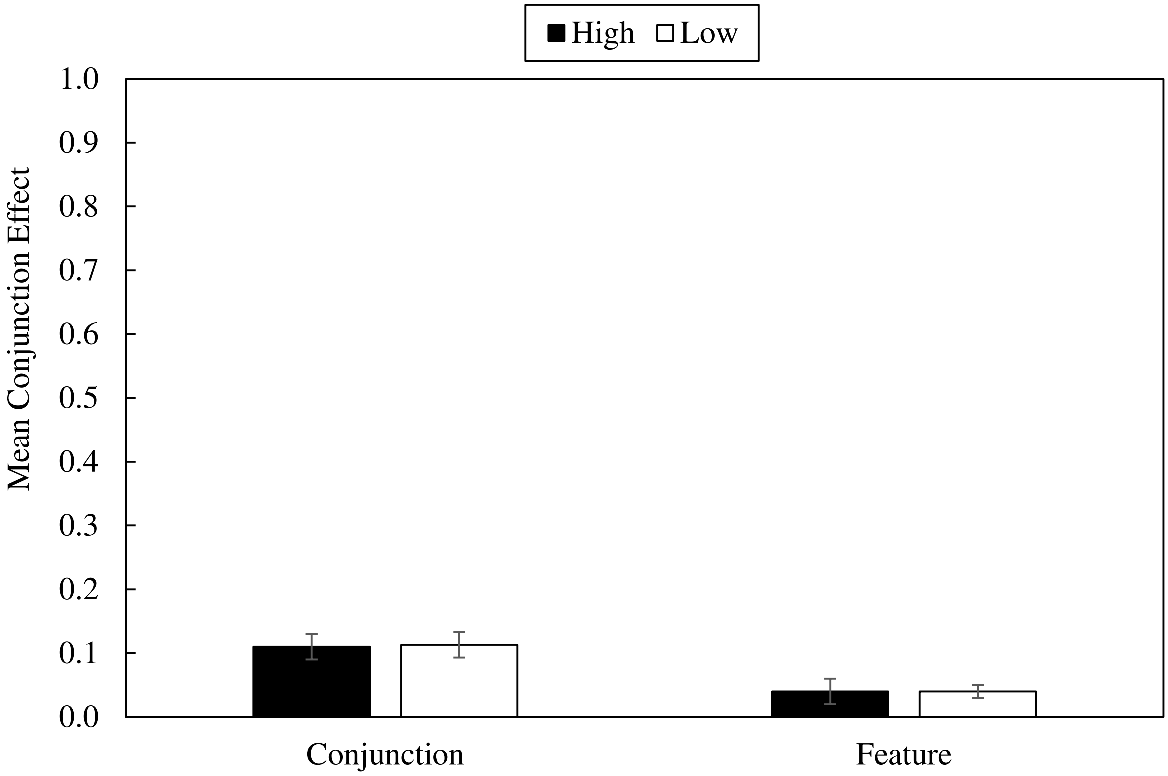

Figure 10. Mean conjunction effect (mean conjunction error rate vs. new error rate) as a function of word type (conjunctions, feature) and point value (high, low) in Experiment 3. Error bars represent standard error of the mean.

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APPENDIX

Appendix. Compound-Word Stimuli

	Set 1				Set 2				Set 3		
	Target	Parent 1	Parent 2		Target	Parent 1	Parent 2		Target	Parent 1	Parent 2
1	candlestick	candlewax	slapstick	1	sweatshirt	sweatshop	teeshirt	1	lawsuit	lawmaker	jumpsuit
2	homework	homesick	guesswork	2	steamboat	steamroller	tugboat	2	sandbox	sandman	pillbox
3	footstool	footrest	barstool	3	switchboard	switchblade	billboard	3	watchdog	watchtower	sheepdog
4	nightshade	nightmare	lampshade	4	childhood	childbirth	brotherhood	4	drawstring	drawbridge	hamstring
5	nosedive	nosebleed	skydive	5	storehouse	storekeeper	greenhouse	5	haircut	hairbrush	crewcut
6	tightrope	tightwad	towrope	6	airport	airstream	passport	6	armchair	armpit	wheelchair
7	newsprint	newsletter	blueprint	7	necklace	necktie	shoelace	7	moonlight	moonshine	limelight
8	bathroom	bathrobe	bedroom	8	doorway	doorstep	motorway	8	hedgehog	hedgerow	warthog
9	outcast	outlaw	downcast	9	foresight	forefather	hindsight	9	seashore	seaworthy	offshore
#	peppercorn	peppermint	popcorn	#	stockbroker	stockyard	pawnbroker	#	teacup	tealeaf	buttercup
#	blowgun	blowtorch	speargun	#	tablespoon	tablecloth	soupspoon	#	undertaker	underground	caretaker
#	soundproof	soundtrack	foolproof	#	sunspot	sunset	inkspot	#	highland	highbrow	wetland
#	waterfall	waterfront	freefall	#	bandstand	bandwagon	grandstand	#	overcoat	overlap	topcoat
#	checkpoint	checklist	needlepoint	#	gumdrop	gumboot	teardrop	#	witchcraft	witchhunt	spacecraft
#	snowball	snowplow	mothball	#	bullfrog	bullfight	leapfrog	#	earthworm	earthquake	silkworm
#	backstroke	backpack	heatstroke	#	wallflower	wallpaper	wildflower	#	fingernail	fingertip	thumbnail
#	hardwood	hardware	driftwood	#	bookmark	bookshelf	trademark	#	toothache	toothpick	earache
#	playmate	plaything	cellmate	#	tailgate	tailspin	floodgate	#	firefly	fireplace	dragonfly
#	starfish	stardust	swordfish	#	brainstorm	brainwash	hailstorm	#	flagship	flagpole	friendship
#	snakebite	snakeskin	frostbite	#	heartbeat	heartburn	drumbeat	#	postcard	postmaster	scorecard