

Elaborative Processing and Conjunction Errors in Recognition Memory

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Abstract

Four experiments were conducted to examine the influence of elaborative processing at encoding on recognition memory conjunction lure errors. In these experiments, participants generated cues for compound words as wholes (e.g., generate a cue for *haywire*) or as separate entities (e.g., generate a cue for *hay* and a cue for *wire*). Studied words were either re-presented in exact form (old) or recombined to form conjunction lures on the recognition test. Participants were asked to make old-new judgments and to judge whether they rejected items judged new based on recall of a studied item or lack of familiarity. The results suggested that recall-to-reject processing and conjunction lure familiarity increased with both types of generation, although generation of cues for compound words as a whole did not influence conjunction lure error rates. An emphasis on processing each constituent of a compound word during encoding increased the familiarity of those constituents more than generation of a compound word as a whole, resulting in an increase in conjunction lure errors. These results suggest that recollection-based monitoring processes and familiarity both influence conjunction lure errors, and therefore support dual-process theories of recognition memory.

Elaborative Processing and Conjunction Errors in Recognition Memory

In recent years, there has been a substantial increase in research devoted to the study of memory errors in list-learning paradigms (see Roediger, McDermott, & Robinson 1998 for a review). A fundamental question concerns the kinds of processes that produce and limit these errors. The present research addresses the extent to which a relatively automatic process, familiarity, induces errors and to which a controlled process, recollection, can be used to reduce errors, a retrieval strategy often referred to as *recall-to-reject* or *recollection rejection* (Brainerd, Reyna, Wright, & Mojardin, 2003; Jacoby, 1991; Hintzman, Curran, & Oppy, 1992; Rotello, Macmillan, & Van Tassell, 2000). We employed the memory conjunction paradigm (Reinitz, Lammers, & Cochran, 1992; Underwood & Zimmerman, 1973; Underwood, Kapelak, & Malmi, 1976) to study the contribution of familiarity and recollection to recognition memory errors. In this paradigm, participants study compound words (e.g., *haywire* and *smokestack*, referred to as *parents*). On a later memory test, participants make recognition memory judgments for words encountered in the study list, nonstudied lures formed by combining components of parent items (e.g., *haystack*, referred to as *conjunction lures*), and entirely new words.

Substantial evidence supports recognition memory theories that include both familiarity and recollection processes (i.e., dual-process theories, Diana, Reder, Arndt, & Park, 2006). For the conjunction paradigm, dual-process theories propose that conjunction errors arise due to the familiarity of the constituents that make up a conjunction lure (Jones & Jacoby, 2001), which produces a false sense of prior experience for conjunction lures. A dual-process explanation also advocates the idea that the familiarity underlying conjunction lures can be counteracted by the successful recall of parent words (i.e., recall-to-reject processing; Jones & Atchley, 2006; Jones & Jacoby, 2001; Lampinen, Odegard, & Neuschatz, 2004; Odegard, Lampinen & Togliia, 2005).

Thus, conjunction errors have been characterized as reflecting the influence of familiarity in the absence of recollection for the parent words. If recollection for the parent words is at or near zero, the conjunction error rate provides a good measure of familiarity engendered by combining parents' components. However, to the extent that parent words are recollected when conjunction lures are tested, the conjunction error rate will underestimate conjunction lure familiarity.

In contrast to the antagonistic relationship that recollection and familiarity have when assessing conjunction lures, dual process theory suggests that the two processes work in concert when evaluating studied items, such that a studied item can be endorsed based upon familiarity from or recollection of its occurrence during a study list (Jones & Jacoby, 2001). What this arrangement predicts is that manipulations that increase recollection should increase hit rates and decrease conjunction lure errors, provided conjunction lures cue recollection of one of their parents as often as parent words cue recollection of their own occurrence in a study list. However, the cues for recalling a parent item when tested with a conjunction lure are typically poor because there is relatively little semantic overlap between parent items and conjunction lures (Jones & Jacoby, 2001, Odegard et al., 2005). Thus, the influence of recollection to dampen conjunction lure errors is likely to be weaker than the influence of recollection to boost old item recognition. In fact, several studies have found that, relative to the hit rate, the conjunction error rate is less sensitive to study manipulations thought to influence recollection, such as study item repetition (Jones, 2005; Jones & Jacoby, 2001), level of processing (Jones, Brown, & Atchley, 2007), and divided versus full attention (Jones & Jacoby, 2001). Indeed, the typical pattern of results from such studies has shown a dissociation where hits are affected by study manipulations but conjunction errors are not (Jones, et al., 2007; Jones & Jacoby, 2001; Reinitz, Verfaellie, & Milberg, 1996).

Given the tendency for conjunction error rates to be unaffected by study manipulations, it is difficult to determine how, or if, familiarity and recall-to-reject are influenced by encoding conditions. In response to this difficulty, recent approaches have scrutinized the basis for correct rejections of conjunction lures (Jones, 2005; Jones & Atchley, 2006; Lampinen et al., 2004; Odegard et al., 2005). Three measures have been used, sometimes in combination. One measure utilizes characteristics of ROC curves, where recall-to-reject processing will cause the ROC plotting conjunction lures against new items to fall below the major diagonal on probability ROC plots (Lampinen, et al., 2004). A second measure requires participants to judge the memorial basis they used to reject test items (Jones, 2005; Jones & Atchley, 2006). Specifically, participants are asked to indicate whether they rejected a test item based on recall of a studied item, a measure of recall-to-reject processing, or based on lack of familiarity. The third approach is to solicit actual recall of parent words, either during (e.g., Jones & Atchley, 2006) or after the recognition test (Lampinen et al., 2004; see Gallo, 2004 for a similar procedure in the DRM paradigm). While recall of the actual parent words provides the most direct evidence of recall-to-reject processing, recall judgments and actual recall generally produce similar estimates of recall-to-reject processing and respond to experimental manipulations similarly (Jones & Atchley, 2006).

Using recall judgments, Jones (2005) found that although conjunction lure error rates were not influenced by changes in study repetition, judgments of recall-to-reject processing increased with study repetition. Thus, even when encoding conditions did not affect conjunction lure errors, it was shown that the study conditions increased recall-to-reject processing. What is more, direct measures of recall-to-reject can reveal improved recall-to-reject processing even when conjunction errors increase. For example, conjunction lures that semantically overlap with

a parent word (e.g., the conjunction lure *handgun* constructed from parent words *handball* and *shotgun*) have produced a higher conjunction error rate than conjunction lures that do not semantically overlap with a parent word (e.g., the conjunction lure *blackbird* constructed from the parent words *blackmail* and *jailbird*; Odegard et al., 2005). Nevertheless, strong semantic parent-to-conjunction overlap also increased recall of parent words. Both of these results underscore the importance of directly measuring recall-to-reject, because they suggest that conjunction error rates do not necessarily provide a complete or accurate picture of recall-to-reject processing (Odegard, et al., 2005).

By obtaining direct measures of recollection, it is possible to gain leverage on a second issue – measuring familiarity for conjunction lures. Any measure of familiarity derived from dual-process theory depends on the assumed relationship of familiarity and recollection. We considered three possible relationships that have been assumed by dual-process theorists: Independence (Yonelinas & Jacoby, 1995), redundancy (Joordens & Merikle, 1993), and mutual exclusivity (Gardiner, 1988). All of these models have been used either implicitly or directly to derive process estimates of recollection and familiarity from remember-know judgments. We applied the reasoning from remember-know studies for items judged as “old” to the present studies, where we collected direct measures of recall-to-reject processing and familiarity in the absence of recall-to-reject for conjunction lures. For all three models, recollection was measured by the ability to recall a parent item when presented with a conjunction lure. The conjunction error rate provides an index of familiarity, though it is incomplete for two of the relationships, independence and redundancy. For the independence model, the measure of familiarity takes into account how often recollection and familiarity may have co-occurred, such that the basic equation for measuring conjunction lure familiarity is $\text{Familiarity} = \text{Conjunction error rate} / (1 -$

Recall rate). For the redundancy model, items that are recollected are necessarily familiar, so Familiarity = Conjunction error rate + Recall rate. Finally, for the mutual exclusivity model, the measure of familiarity is simply the conjunction error rate because this model assumes familiarity and recollection never co-occur.

There are two potential concerns that arise from using the conjunction lure paradigm to understand the relationship between recollection and familiarity. First, it may seem that the use of recall to reject conjunction lures necessitates that the lures are also familiar. If this were the case, testing the mutual exclusivity model would be unreasonable, as the model would be fundamentally incompatible with the nature of the processes underlying conjunction lure errors. However, theoretical models of recollection and familiarity (e.g., Diana, et al., 2006; Jacoby, 1991; Reder, Nhouyvansivong, Schunn, Ayers, Angstadt, & Hiraki, 2000) generally assume that the use of recollection is prioritized over the use of familiarity, because recollection is the more reliable and certain basis for determining if a test item was studied. Similarly, because recall-to-reject processing is a certain basis for rejecting conjunction lures, it is likely to be the preferred strategy for assessing their studied status. If recall-to-reject fails, then participants may use familiarity as a basis for evaluating conjunction lures. The important point for present purposes is that conjunction lures need not be familiar in order for recall-to-reject to occur, because recollection, and therefore recall-to-reject, is generally given priority when making recognition judgments, and familiarity will only be consulted in the absence of recall-to-reject.¹

A second concern is that the measures of recollection and familiarity we will use to understand the recollection-familiarity relationship are based upon different items (recall of parent items and conjunction lure errors, respectively). However, in the conjunction lure paradigm, the cueing of familiarity and recall-to-reject are both based upon the encoded

representation of parents, and are both cued by the same elements of conjunction lures at test. Specifically, the familiarity that produces conjunction lure errors arises from the fact that the two components in conjunction lures were encoded as part of the lure's parents during study. Similarly, the recall of parents as a basis for rejecting conjunction lures is cued by the presence of a component of a studied parent item in a conjunction lure at test. Thus, measurement of recollection and familiarity in the conjunction lure paradigm is directly comparable to a standard recognition memory experiment where a test item could be recognized based upon recollection of its occurrence in a study list, or because the test item was familiar, but its occurrence in the study list was not recollected.

In sum, the prior literature provides evidence that dual-process models of recognition can be applied to understand performance in the conjunction lure paradigm. Further, recent work has demonstrated that conjunction error rates often fail to reflect changes in recall-to-reject processing across experimental conditions. This fact could lead to inaccurate conclusions about the role familiarity and recollection play in increasing and decreasing conjunction lure errors unless a direct measure of recall-to-reject processing is collected. Finally, relying on conjunction errors as a full measure of familiarity implicitly assumes that recollection and familiarity are mutually-exclusive processes. Thus, doing so may underestimate conjunction lures' familiarity levels if recollection and familiarity are independent or redundant processes.

In the present experiments, we examined the extent to which elaborative encoding of parent words or the components of parent words affected conjunction lure errors and recall-to-reject processing. In the first two experiments, we compared a condition where participants copied parent words at study to conditions where participants copied the parent words and generated either one or three cues for it. In the second two experiments, we compared a condition

where participants copied parent words at study with conditions where they generated cues for either a parent word as a whole or for the separate components of a parent word. We chose study manipulations that stressed elaborative processing because generation and levels of processing have been shown to influence recollection more than familiarity (see Yonelinas, 2002 for a meta-analysis and review), making elaborative processing a promising candidate to produce large increases in recall-to-reject processing that were not offset entirely by increases in familiarity. We collected direct measures of recall-to-reject processing by asking participants to indicate when they used recall of a studied item to reject a test item. Finally, we verified participants' judgments of recall-to-reject processing by asking them to produce the parent item that was used as a basis for their judgment. Thus, we were able to generate an objective record of recall-to-reject processing, which could then be used to understand the contribution of recollection and familiarity to conjunction lure errors.

Four prior studies provide relevant data regarding the effects of elaborative encoding on conjunction error rates. Ghatala, Levin, Bell, Truman, and Lodico (1978) manipulated the semantic relationship of study words (parents: *bed* and *spread*) to conjunction lure words (conjunction: *bedspread*) by accompanying each study item with a prime that biased the interpretation of the parents toward or away from the meaning of the conjunction lure. They found that study items presented in a semantic context biased toward the meaning of the conjunction lure ("soft" for *bed* and "cloth" for *spread*) increased the likelihood of a conjunction lure error compared to study items presented in a semantic context biased away from the meaning of the conjunction lure ("river" for *bed* and "cheese" for *spread*). Odegard et al. (2005) compared conjunction lure errors when the meanings evoked by parent words (e.g., *handball* and *shotgun*) strongly overlapped that of the conjunction lure (e.g., *handgun*) to when the meanings

evoked by parents (e.g., *blackmail* and *jailbird*) failed to overlap that of the conjunction lure (e.g., *blackbird*). Odegard et al. found that this manipulation either did not influence conjunction lure errors (Experiment 1) or led to more errors when parents and conjunction lures shared meaning (Experiment 2). Finally, two studies have manipulated level of processing (shallow vs. deep) during study (Jones et al., 2007; Reinitz et al., 1996), and both found that a deep level of processing increased hit rates, while conjunction error rates were unaffected.

Given that none of these prior studies obtained a decrease in conjunction error rates with a corresponding increase in hit rates, we had no basis to predict that generating properties for parent items would increase recall-to-reject processing enough to reduce conjunction error rates relative to a control condition. If anything, these prior studies suggest that conjunction errors should be higher in conditions that stress semantic processing (Ghatala et al., 1978; Odegard et al., 2005, Experiment 2). However, because changes in conjunction error rates do not appear to provide an accurate assessment of recall-to-reject processing, it is possible for recall-to-reject processing to increase across the same conditions where conjunction error rates are invariant (Jones, et al., 2007; Reinitz, et al., 1996) or even when conjunction lure errors increase (Odegard et al., 2005). Thus, collecting recall-to-reject judgments in the present studies allowed us to better understand how elaborative encoding influenced recall-to-reject processing and familiarity for conjunction lure errors regardless of whether conjunction lure errors increased, decreased, or remained invariant across encoding conditions.

Experiments 1A and 1B

In the first pair of experiments, we implemented elaborative encoding conditions that required participants to generate cues for whole parent items. We used encoding conditions where participants were asked to produce zero, one, or three cues for each parent word. Mäntylä

(1986) and Mäntylä and Nilsson (1983) have demonstrated the substantial benefit of generating cues for study words during encoding on later recall. As a result, it is likely that this study manipulation will produce high levels of parent word recollection, which will improve the opportunity to observe differences in the ability to use recall of parent items to reject conjunction lures.

Evidence that generation at encoding can enable memory editing processes has been reported recently (Jones, 2006). In Jones's (2006) Experiment 1, participants generated some conjunction stimuli from parent words during the study task but did not generate others. On a later recognition test, participants were instructed to exclude all conjunction stimuli from "old" judgments regardless of whether or not they had been generated during the study phase. Under a short response signal delay (RSD) test procedure, generated conjunction words produced a higher error rate than nonstudied conjunction lures, but under a long RSD procedure, generated conjunction words produced a lower error rate than nonstudied conjunction lures. These results suggest that relative to non-studied conjunction lures, study generation of the conjunction lures increased familiarity, evidenced by the higher error rate in the short RSD condition, as well as recollection, evidenced by the lower error rate in the long RSD condition. The present experiments further investigated the extent to which generation at study enabled memory editing processes by assessing whether or not generation of cues related to *parent words* (rather than the direct generation of *conjunction lures* studied by Jones, 2006) also improved the ability to reject conjunction lures due to recall of their parent words.

Minor differences for Experiments 1A and 1B included the participants, slightly different item sets, and the test instructions and procedures. The participants were in different countries (New Zealand vs. U.S.A.), thus the materials were adjusted slightly to be appropriate for New

Zealanders and Americans. The test instructions and procedure included standard “old-new” recognition memory instructions and procedures for both experiments. For Experiment 1B, additional instructions and responses were solicited to assess the use of recall-to-reject processing. For all items judged “new,” participants were asked to indicate if they reached that judgment because they recalled a related parent word that was studied (a “recall” response) or if the test item was not familiar (a “know” response). Further, if a test item was judged new due to “recall,” the participant was asked to recall the parent word that was used as the basis for the recall response (Jones, 2005; Jones & Atchley, 2006). The rationale for this pairing of studies was to ensure that conjunction lure error rates were comparable when participants were simply asked to discriminate old and new items and when they were asked to judge the basis for rejecting a test item.

Method

Participants

Twenty-four students at Victoria University of Wellington participated in Experiment 1A, and 24 students at Middlebury College participated in Experiment 1B.

Materials and Equipment.

The stimulus materials were 72 compound word triplets taken from Jones (2005). An additional six compound words were used as primacy and recency buffers. Each triplet was composed of two parent words (*watchtower* and *sheepdog*) and one offspring word (*watchdog*), which was created by combining the first portion of one parent word and the second portion of the other parent word. None of the lexical-morpheme constituents of the compound words (parents and offspring) was repeated across triplets. Sheets of paper (A4 in size) were supplied to the participants for the study phase. The sheets had numbered lines (1 – 114) with four blanks

next to each numeral.

For all experiments reported in this paper, computer programs were composed using E-prime software (Schnieder, Eschman, & Zuccolotto, 2002), and the programs were run on IBM-compatible computers interfaced with VGA monitors. Further, in all experiments reported in this paper, only parent words were presented during encoding, while both parent items and offspring were presented during the recognition memory test. Finally, the method for constructing item triplets (two parents and one offspring) was identical in all experiments.

Design and Study-Test List Construction.

Table 1 illustrates the basic design of Experiments 1A and 1B. A 2 (Test Item Type: parent words vs. offspring) x 4 (Study Task: copy vs. generate one cue word vs. generate three cue words vs. nonstudied) within-participants design was employed. The 72 word triplets were assigned to one of eight stimulus sets with nine word triplets in each set. Each of the eight stimulus sets was assigned to one of the experimental conditions formed by the combination of Test Item Type and Study Task. Thus, parents from six of the stimulus sets were shown at study, while parents or offspring from all eight stimulus sets were shown in the test phase. The eight stimulus sets were rotated through the eight experimental conditions formed by the crossing of Test Item Type and Study Task, which ensured that each set occurred equally often in each of the experimental conditions across participants.

For Experiment 1A, a single study order based on Test Item Type was constructed such that no more than two items from the same level of Test Item Type were presented in succession. There were 108 study trials containing 54 parent words to be presented on the recognition memory test and 54 study primes for the conjunction lures. Three primacy and three recency buffers were included in the study list, with one compound word from each of the primacy and

recency buffers assigned to each of the three Study Tasks (copy word, generate one cue, generate three cues), producing an overall study list length of 114 words. For Experiment 1B, studied parent items were presented entirely randomly, with the exception of the items designated as primacy and recency buffers.

The test list for each experiment included the studied parent words from half of the stimulus sets presented during the study list (54 items total, one third from each of the copy study condition, the one cue generated study condition, and three cues generated study condition), the conjunction lures corresponding to the other half of the stimulus sets presented during the study list (27 items total, one third from each of the copy study condition, the one cue generated study condition, and three cues generated study condition), the parent words from one of the nonstudied stimulus sets (18 items), and the conjunction lures from one of the nonstudied stimulus sets (nine items), yielding a test list length of 108 words.

Procedure.

In the study phase, all participants were instructed to read each of the study words presented on a computer screen in preparation for a later memory test. The participants were directed to follow any written instructions that appeared beneath the study word. On each study trial, a word was displayed for 3 s followed by instructions below the word prompting the participant to write the study word itself (e.g., *daredevil*), write the study word plus one self-generated word as a cue to the study word (e.g., *daredevil* followed by *adventurous*), or write the study word plus three self-generated words as cues (e.g., *daredevil* followed by *adventurous*, *stuntman*, *crazy*). Up to 30 s were given for participants to accomplish the writing aspect of each trial, but the participants were able to start the next trial before the 30 s time limit by pressing the *N* key. There was a 250-ms ITI between trials.

The recognition memory test commenced immediately after the study phase. In the recognition memory test instructions, participants were warned about the presence of conjunction lures, given an example of a conjunction lure and its parent words, instructed about the difference between them, and asked to avoid conjunction lure errors. Items were presented in a random order at test. In Experiment 1A, participants were asked to make a single old-new recognition judgment for each test item. In Experiment 1B, participants were prompted to make up to three judgments for each word presented on the recognition memory test. The first prompt asked participants to indicate if a test item was old or new, which replicated the judgment required in Experiment 1A. The second prompt asked participants to indicate why they judged a test item new – due to recall of a parent item (a *recall* response), or due to the test item being unfamiliar (a *know* response). The third prompt asked participants who judged an item to be new because of recalling a parent item to type the parent item into a response box.

Results

The baseline false alarm rate was similar for parent words ($M = .04$) and offspring ($M = .06$) in Experiment 1A, as well as in Experiment 1B ($M = .10$ for both parents and offspring). Corrected parent word recognition scores and conjunction lure error rates were computed by subtracting the baseline false alarm rates from the parent recognition hit rates and conjunction lure false alarm rates.² Corrected recognition scores are displayed in Figure 1 for Experiment 1A (top panel) and Experiment 1B (bottom panel). Hits, false alarms to conjunction lures, and false alarms to baseline items are presented in Table 2.

As can be seen in Figure 1, the two experiments produced very similar results: Generating cues for parent words during the study phase produced a dramatic increase in parent recognition but had a negligible impact on conjunction lure errors. A 3 (Study Task) x 2 (Test

Item Type) repeated-measures ANOVA on the corrected recognition scores confirmed this interaction (Exp 1A: $F(2, 46) = 24.88, MSE = 0.011$; Exp. 1B: $F(2, 46) = 28.04, MSE = 0.011$). The main effects of Study Task, (Exp. 1A: $F(2, 46) = 36.77, MSE = 0.012$; Exp. 1B: $F(2, 46) = 28.21, MSE = 0.012$) and Test Item Type (Exp. 1A: $F(1, 23) = 361.24, MSE = 0.048$; Exp. 1B: $F(2, 46) = 426.87, MSE = 0.042$) were also significant. To explore the interaction, separate repeated-measures ANOVAs were conducted on parent recognition and conjunction lure errors using Study Task as the experimental factor. These analyses produced a reliable effect of Study Task for parent word recognition (Exp. 1A: $F(2, 46) = 76.98, MSE = 0.009$; Exp. 1B: $F(2, 46) = 66.97, MSE = 0.010$), but not for conjunction lure errors, (Exp. 1A: $F(2, 46) = 0.71, MSE = 0.014$; Exp. 1B: $F(2, 46) = 0.21, MSE = 0.013$). Bonferroni-adjusted comparisons showed that each of the two study conditions where a cue was generated produced significantly higher parent recognition than the copy condition. The two cue conditions were not significantly different from one another, although performance was close to ceiling in both conditions. Thus, whether the generation of multiple cue words provides an additional benefit to parent word recognition cannot be ascertained from the present data. Mäntylä's (1986) results, however, did show a benefit of generating multiple cue words during the study phase. Regardless, the pattern of central importance from these two experiments is that despite the very large jump in accuracy of parent word recognition in the cue generation conditions, this advantage was not associated with fewer conjunction lure errors. Indeed, if anything, the pattern of the means for conjunction lure errors suggest that conjunction lures produced higher levels of false memory in the three cues generated condition relative to the copy condition.

Recall Responses

Because the conjunction error rates were not affected by encoding conditions in

Experiments 1A and 1B, they do not provide a strong indication of how (or if) recall-to-reject processing was influenced by elaborative encoding conditions. However, the recall judgments and actual recall from Experiment 1B provide a more complete picture of the processes engaged during retrieval. Before turning to the data of interest, it is important to note that the probability of making a recall response to items for which no competing episodic memory existed was low. Recall responses to parent items (largest $M = .04$ in the copy study condition) and new items that served to measure baseline error rates for both parent items ($M = .06$) and conjunction lures ($M = .05$) were rare. Further, the conditional probability of making a recall response given that a conjunction lure was called new was greater than 50%, while the conditional probability of making a recall response given that any other test item was called new was less than 9%. Thus, when participants' memory was tested for old or unstudied items, they largely deemed those items new based on lack of familiarity (i.e., they gave a *know* response). In comparison, participants regularly reported the use of parent item recall as a basis for rejecting conjunction lures, suggesting they were able to use recall and know judgments accurately.

The probability of rejecting a conjunction lure due to the self-judged recall of a parent item and the probability of actually recalling a parent item when tested with a conjunction lure are presented in Figure 2 as a function of Study Task. Participants were able to use recall-to-reject processing to judge lure items correctly as "new" more often in the generate one cue condition than in the copy condition, and more often in the generate three cues condition than in the generate one cue condition. Further, the ability to produce a parent item to justify a recall response generally supported the validity of recall judgments (Jones, 2005; Jones & Atchley, 2006). Although the probability of accurately recalling a parent item as a basis for rejecting a conjunction lure was less than the probability of a recall response, the pattern of performance

across the study tasks was similar. These observations were supported by a reliable effect of Study Task on recall judgments and actual recall (recall judgments: $F(2,46) = 26.05$, $MSE = .023$; actual recall: $F(2,46) = 21.64$, $MSE = .022$). For both the recall judgments and actual recall, Bonferroni-adjusted comparisons demonstrated that the one cue generated study condition produced a higher rate of recall-to-reject than the copy condition, and the three cues generated condition produced a higher rate of recall-to-reject than both the copy condition and the one cue generated condition.

Familiarity underlying conjunction errors

Given that we collected measures of recall-to-reject processing and familiarity in the absence of recollection (the conjunction lure error rate), the data from these studies also allow us to estimate how conjunction lure familiarity was affected by generating cues for parent items. For three different assumptions about of the relationship of recollection and familiarity (independence, redundancy, mutual exclusivity), the recall judgment rate or the actual recall rate provides an index of recollection. Because the actual recall rate is a bit more accurate, we used it instead of the recall judgment rate in our calculations of familiarity (see Table 3). Of central importance is the pattern of familiarity scores across the study conditions. The independence and redundancy approaches suggest that, as more cues were generated for parent words, conjunction lure familiarity increased (Independence: $F(2,46) = 5.81$, $MSE = 0.08$; Redundancy: $F(2,46) = 17.82$, $MSE = 0.06$). Under the mutual exclusivity approach, the measure of familiarity is simply the conjunction error rate, which suggests the conclusion that familiarity was unaffected by an increase in elaborative processing at study, because conjunction errors were not influenced by Study Task.

Discussion

The results of these two studies clarify the contribution of elaborative encoding to conjunction lure errors, as well as the use of strategic retrieval processes to limit conjunction lure errors. The results show that participants were better able to use recall-to-reject processing when they engaged in elaborative processing during encoding and that the more elaborative processing that was completed, the more recall-to-reject processing was used. Therefore, the finding that conjunction lure error rates were comparable across the three encoding conditions does not imply that familiarity and recall-to-reject processing were unaffected by elaborative encoding conditions. Instead, more sensitive measures indicate that elaborative encoding increased recall-to-reject processing. Within the context of dual-process theory, these two findings suggest that a second factor, such as familiarity, must have also increased with elaborative processing. Because dual-process theory views recall-to-reject and familiarity as antagonistic when judging conjunction lures, increased recall-to-reject processing should have produced lower conjunction lure error rates as more properties were generated if familiarity did not also increase with property generation. Thus, the data favor the view that familiarity is best measured by a model where recollection and familiarity are either independent or redundant processes, because those two models suggested familiarity increased with elaborative processing at encoding.

Experiments 2A & 2B

In this second pair of experiments, we investigated how conjunction lure errors were influenced by generating a cue for each component of a compound parent word. Thus, instead of generating cues that referred to each studied parent word as a whole, participants sometimes generated cues that referred to each of the components that made up a parent word. For example, when presented with the word *daredevil* to study, they might generate *truth* (for dare) and *angel* (for devil). This manipulation therefore explored how elaboratively encoding the individual

components of parent items influenced recall-to-reject processing and conjunction lure errors.

Prior research provides mixed evidence regarding how this manipulation should influence conjunction lure errors. Jones et al. (2007) found that studying components of later compound word conjunction lures in isolation produced a lower conjunction error rate compared to a condition where the components were studied as a part of compound words. However, Ghatala et al. (1978) found that when participants studied the components of conjunction lures in a context that biased interpretation toward the meaning of the conjunction lure, they committed more conjunction lure errors compared to a condition where the components of conjunction lures were studied in a context that biased interpretation away from the meaning of the lure. Finally, Odegard et al. (2005) showed that when conjunction lures were formed from parent words that shared meaning with them, recall-to-reject processing increased, although conjunction lure errors that shared meaning with parents still produced more errors than conjunction lures formed from parent words that did not share meaning with the lures.

Given the variability in prior studies' findings, it is not clear whether generating properties for the components of parent items will increase or decrease conjunction lure errors. Further, as reviewed in the introduction, it is possible for conjunction lure errors to increase (Odegard, et al., 2005), decrease (Jones, 2006) or remain the same (Jones, 2005) as recall-to-reject processing increases. Thus, it is difficult to generate firm predictions regarding how generating cues for the components of parent items should influence familiarity and recall-to-reject processing. For example, conjunction lure errors could increase because generating cues for the components of parent items increases the familiarity of each component (and therefore the familiarity of later conjunction lures), or because attending to the components of parent items reduces the ability to recollect a conjunction lure's parents as unitized entities (and thus the

ability to employ recall-to-reject processing). Alternatively, this manipulation could reduce conjunction lure errors if elaboratively processing each component of a parent item better enabled participants to use conjunction lures as a cue for recalling parent items on the recognition memory test, enhancing recall-to-reject processing. Despite the ambiguity in expectations for the results of this manipulation, measures of recall-to-reject processing allowed us to assess the impact of component generation on familiarity and recall-to-reject processing.

As with the first two experiments, the subjects came from different countries and the test instructions and procedures were different in Experiments 2A and 2B. Again recall judgments and actual recall of parent items were collected in Experiment 2B. Also, the experiments differed slightly with regard to the copying of study words. In Experiment 2A, subjects copied the study words twice (*en masse*) in the control condition and did not copy the study word in either of the cue generation conditions. In Experiment 2B, all subjects copied the study word once in each study condition but also supplied cues in the generation conditions. These minor study task differences failed to produce any noticeable differences in the results between Experiments 2A and 2B.

Method

Participants

Twenty-four students at Victoria University of Wellington participated in Experiment 2A, and 24 students at Middlebury College participated in Experiment 2B as part of an introductory psychology research appreciation requirement.

Materials and Equipment. The materials and stimuli were the same as those used in Experiments 1A and 1B, except for the sheet given to participants for copying study items and generating cues for study items in the encoding phase of the experiment. The sheet contained

either two (Experiment 2A) or three (Experiment 2B), instead of four, lined spaces on each numbered line.

Design and Procedure

A 2 (Test Item Type: parent word vs. offspring) x 4 (Study Task: copy, generate two cues for each parent word, generate a cue for each component of a parent word, nonstudied) within-participants design was employed. The assignment of stimulus sets to experimental conditions and stimulus counterbalancing procedures were the same as those used in Experiments 1A and 1B. The study instructions and procedure for the study phase were the same as for Experiments 1A and 1B, except for the instructions concerning the writing of cues. In Experiment 2A, participants were instructed to write down either the study word twice (e.g., *daredevil* twice), two cues for the study word (e.g., *adventurous* and *stunt* when presented with *daredevil*; referred to as the *parent generation condition* below), or one cue for each of the components of the study word (e.g., *truth* [for the dare component] and *angel* [for the devil component] when presented with *daredevil*; referred to as the *component generation condition* below). In Experiment 2B, participants were instructed to write down either the study word once (e.g., *daredevil*), the study word plus two cues for the study word (e.g., *daredevil* followed by *adventurous* and *stunt*), or the study word plus one cue for each of the components of the study word (e.g., *daredevil* followed by *truth* [for the dare component] and *angel* [for the devil component]). Both the test instructions and procedure for the test phase were the same as for Experiments 1A and 1B, respectively, such that Experiment 2A only required an old-new judgment for each test word, while Experiment 2B required participants to make an old-new judgment, a recall vs. know judgment on items judged new, and to produce recall of a parent item for items judged new due to recall of a parent item.

Results

In Experiment 2A, the baseline false alarm rates for parents ($M = 0.06$) and offspring ($M = 0.10$) were similar, although the difference was significant, $t(23) = 2.18$, $SE = 0.018$. In Experiment 2B, the baseline false alarm rates for parents ($M = 0.07$) and offspring ($M = 0.07$) did not differ reliably, $t(23) = 0.13$. Figure 3 depicts the corrected parent word recognition rates and corrected conjunction lure error rates as a function of Study Task for Experiment 2A (top panel) and Experiment 2B (bottom panel). Hits, conjunction lure false alarms, and baseline item false alarms are presented in Table 4.

The type of study task had a large influence on both parent recognition and conjunction lure error rates, although it did not affect parent and conjunction lure recognition in the same way. As in Experiments 1A and 1B, generating cues to parent words as a whole considerably enhanced later parent word recognition but produced only a very slight increase in conjunction errors. The generation of cues based on components of parent words also substantially increased parent word recognition compared to the copy condition. In fact, generating cues for each component of parent words produced similar parent word recognition to generating cues for parent words as a whole. Importantly, the component generation task also increased the conjunction lure error rate compared to the copy condition and the parent generation condition.

A 3 (Study Task) x 2 (Test Item Type) repeated-measures ANOVA on corrected recognition scores revealed significant interactions in both studies (Exp. 2A: $F(2, 46) = 11.81$, $MSE = 0.019$; Exp. 2B: $F(2, 46) = 23.76$, $MSE = 0.017$). In addition, the main effects of Study Task (Exp. 2A: $F(2, 46) = 45.27$, $MSE = 0.024$; Exp. 2B: $F(2, 46) = 52.19$, $MSE = 0.022$), and Test Item Type (Exp. 2A: $F(1, 23) = 200.48$, $MSE = 0.048$; Exp. 2B: $F(1, 23) = 284.78$, $MSE = 0.044$) were significant. To pursue the interaction, we conducted separate repeated-measures ANOVAs on parent word recognition and conjunction lure errors, using the factor of Study Task

as the independent variable. For parent word recognition, the effect of Study Task was significant, (Exp. 2A: $F(2, 46) = 82.64$, $MSE = 0.010$; Exp. 2B: $F(2, 46) = 106.60$, $MSE = 0.010$). Bonferroni-adjusted comparisons showed that, while the generation conditions produced similar levels of parent recognition, both produced higher parent recognition rates than the copy condition. As was the case in Experiments 1A and 1B, the very high scores for the generation conditions hamper interpretation of the relative levels of performance in those conditions. The effect of Study Task also was significant for conjunction lure errors, (Exp. 2A: $F(2, 46) = 14.34$, $MSE = 0.033$; Exp. 2B: $F(2, 46) = 15.40$, $MSE = 0.028$). Bonferroni-adjusted comparisons showed that the conjunction lure error rates were higher in the component generation condition than in the two other study conditions, which did not differ.

Recall Responses

The probability of making a recall response to items for which no competing episodic memory existed was low. Recall responses were rare for parent items (largest $M = .05$ in the copy study condition) as well as new items that served to measure baseline error rates for both parent items ($M = .04$) and conjunction lures ($M = .04$). Further, the conditional probability of making a recall response given that a test item was called new was greater than 46% for lure items, while the conditional probability of making a recall response given that a test item was called new was approximately 8% for old and non-lure new items. Thus, when participants' memory was tested for old or unstudied items, they largely deemed those items new based on lack of familiarity (i.e., they gave a *know* response). In comparison, participants regularly reported using recall to reject conjunction lures.

Of central importance is the memorial basis participants used to judge conjunction lures as unstudied. The probability of rejecting a conjunction lure due to recall of a parent item (i.e.,

recall responses) and the probability of correctly recalling a parent item when tested with a conjunction lure are presented in Figure 4. As with Experiment 1B, the ability to produce a parent item to justify a recall response generally supported the validity of recall judgments (Jones, 2005; Jones & Atchley, 2006). Both measures indicate that participants were able to use recall of a parent item to reject conjunction lures better in the generation conditions than in the copy condition. However, the two generation conditions did not differ in the use of recall-to-reject processing. These observations were supported by a reliable effect of Study Task (recall judgments: $F(2,46) = 11.92$, $MSE = .029$; actual parent recall: $F(2,46) = 9.41$, $MSE = .037$). For both measures, Bonferroni-adjusted comparisons revealed that while the two generation study conditions produced a higher rate of recall-to-reject than the copy condition, the two generation study conditions did not differ reliably.

Familiarity underlying conjunction errors

As with Experiment 1B, we calculated measures of familiarity based on assumptions of the independence, redundancy, and mutual-exclusivity models using the actual recall rate as a measure of recall-to-reject processing and the conjunction lure false alarm rate as a measure of familiarity without recollection (see Table 3). All three approaches suggested that familiarity was higher in the component generation condition compared to the other two encoding conditions (smallest $t(23) = 3.78$). However, the three approaches differed with regard to how the parent generation condition and copy condition influenced familiarity relative to one another. Under redundancy assumptions, cue generation for parents increased familiarity relative to the copy condition ($t(23) = 4.96$), whereas under the independence ($t(23) = 1.48$, $p > .15$) and mutual exclusivity ($t(23) = 0.50$, $p > .50$) model assumptions, parent cue generation did not reliably increase familiarity relative to the copy condition. Despite the non-significant change in

measured familiarity across the copy and parent generation conditions, the independence model did produce a qualitative increase in familiarity of a reasonable magnitude ($M = .07$), suggesting it makes claims that are qualitatively consistent with the redundancy model.

Discussion

The results of this study replicate and extend the findings from Experiments 1A and 1B. Both cue generation study conditions produced large increases in the hit rates relative to the copy control condition. Although a slight, nonsignificant increase in the conjunction error rate was observed for the parent generation condition, a large, significant increase in the conjunction error rate was found for the component generation condition relative to both the copy condition and cue generation from whole parent words. Thus, the results are generally consistent with the findings of Ghatala et al. (1978) and Odegard et al. (2005). These results also show that the generation of cues at encoding, whether for parent items as a whole or for each component of a compound parent word, increased the ability to use recall-to-reject processing to limit conjunction lure errors. Interestingly, the method of cue generation (for parents vs. components of parents) did not substantially impact the ability to use recall-to-reject processing. What perhaps is most unexpected is that the study condition that produced the highest conjunction error rate also produced a considerable increase in successful recall-to-reject processing relative to copying parent items during study. Odegard et al. (2005) found a similar result, and we take their findings and the present findings to be highly informative. Both results suggest that even when recall-to-reject processing increases across conditions, it is still possible for conjunction lure errors to increase if familiarity was increased by the same condition that improved recall-to-reject processing. This result underscores the importance of collecting measures that separate the influence of recall-to-reject and familiarity on conjunction lure errors in order to fully understand

the processes underlying recognition decisions for conjunction lures. For purposes of comparison, the standard interpretation of an increase in conjunction lure errors from the dual-process perspective would be that familiarity increased without considering the possible effects of the same experimental condition on recall-to-reject processing. Thus, not collecting a measure of recall-to-reject processing would lead one to underestimate how much the condition influenced both familiarity and recall-to-reject processing.

Considering how recall-to-reject processing and the conjunction lure error rates were influenced by the encoding conditions, the redundancy and independence models provide the most reasonable characterization of familiarity processes. Similar logic to that outlined following Experiment 1B suggests that familiarity increased when cues were generated for parent items compared to when parent items were copied. Thus, because recall-to-reject processing was higher in the parent generation condition than the copy condition, but the conjunction lure error rate did not differ across those two conditions, dual-process theories must claim that a second factor (e.g., familiarity) also was higher in the parent generation condition. Comparing the general dual-process characterization of the results of Experiment 2B to the estimates of familiarity derived from each dual-process model, only the views that recollection and familiarity are redundant or independent processes suggested that familiarity increased with parent generation.

General Discussion

The results of these studies provide clear support for dual-process views of conjunction lure errors (Jones & Jacoby, 2001; Jones & Atchley, 2002, 2006; Lampinen et al., 2004; Odegard et al., 2005). Specifically, the results of two measures of recall-to-reject processing, coupled with the patterns of conjunction lure errors, provide support for the roles of familiarity and

recollection in producing and limiting conjunction lure errors. For example, measures of recall-to-reject processing used in these studies indicated that as the amount of elaborative processing during encoding increased, recall-to-reject processing also increased. This result is consistent with prior work suggesting that the ability to recollect studied items increases with elaborative encoding (Curran & Hildebrandt, 1999; Gardiner, 1988; Yonelinas, 2002) and extends the influence of elaborative encoding on recollective processes to memory editing functions (c.f., Jones, 2006). Further, the notion that recollection (and therefore recall-to-reject processing) increased with elaborative processing explains the influence of cue generation on parent item recognition, where parent recognition was substantially greater when cue generation occurred compared to when parents were copied.

Two results provide evidence of the contribution of familiarity to conjunction lure errors. First, conjunction error rates were always above the baseline false alarm rate, despite test instructions that informed subjects of the conjunction lures and evidence that subjects often were able to reject conjunction lures based on the retrieval of a parent word. The conjunction effect implies that experimentally-induced familiarity kept conjunction lures from being suppressed to levels at or below baseline error levels by memory editing processes (Brainerd, Reyna & Kneer, 1995). Second, although levels of recall-to-reject processing were similar when cues were generated for each part of a parent item and for whole parent items (Experiment 2B), conjunction error rates were higher when cues were generated for each part of a parent item (Experiments 2A and 2B). Taken together, these two results suggest that a second factor (i.e., familiarity) increased conjunction lure errors more when cues were generated for each part of a parent item. Thus, these results reinforce the substantial literature suggesting that conjunction lure errors arise due to recognition memory familiarity (Jones & Atchley, 2002; 2006; Jones et al., 2001; Jones &

Jacoby, 2001; Lampinen et al., 2004; Odegard et al., 2005; Rubin, Van Patten, Glisky, & Newburg, 1999).

The collection of objective measures of recollection (i.e., recall-to-reject judgments or recall of parent items when tested with conjunction lures) allowed us to test of models of the relationship between recollection and familiarity. Based upon the general claim of dual-process theory that recollection and familiarity oppose one another to produce conjunction lure errors, we concluded that 1) property generation for parents increased familiarity (Experiments 1B and 2B); and 2) property generation for the components of parents increased familiarity more than property generation for parents as whole entities (Experiment 2B). Of the three models we tested (redundancy, independence, mutual exclusivity), only the redundancy model (Joordens & Merikle, 1993) produced estimates of familiarity that fully aligned with these two conclusions. The independence model (Yonelinas & Jacoby, 1995; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996) produced estimates of familiarity that were qualitatively consistent with the conclusions, but failed to produce an estimate of familiarity's increase with parent generation that was statistically reliable in Experiment 2B. Finally, the mutual exclusivity model (Gardiner, 1988) was inconsistent with the general account offered by dual-process theory, claiming that only component generation in Experiment 2B increased familiarity. Thus, the present data favor the conclusion that familiarity and recollection are best viewed as redundant or independent processes. In addition, while not explicitly tested, the data are consistent with the view that recollection and familiarity are correlated, but not entirely redundant, processes (e.g., Curran & Hintzman, 1997).

Interestingly, the conclusion that elaborative encoding increased both recall-to-reject (recollection) and conjunction lure familiarity is consistent with how generation and other types

of elaborative processing (e.g., levels of processing) influence recollection and familiarity for studied items. Yonelinas (2002) conducted an extensive review of studies from which separate measures of recollection and familiarity could be derived. He found that, on average, generation and levels of processing encoding manipulations increased estimates of both recollection and familiarity as measured by the independence model. That the same conclusions were reached when the independence model was applied to the present data suggests that measurement models of recollection and familiarity can accurately estimate familiarity supporting conjunction lure errors, and that our application of those models to measure familiarity in these studies was appropriate.

One concern readers may have about the claim that conjunction lure error rates were not diminished by parent cue generation is that conjunction error rates were relatively low (generally less than .15 above baseline in the copy condition). There are three reasons that we believe these low overall error rates, sometimes observed in the conjunction lure paradigm, do not compromise the interpretation that elaborative encoding failed to decrease conjunction lure errors. First, the pattern of means in all four experiments suggests that generating cues for whole parent items *increased* conjunction lure errors, even though none of the mean differences was statistically reliable (consult Figures 1 & 3). Second, evidence exists that it is possible for recall-to-reject processing to suppress lure false alarm rates below the false alarm rate to unstudied and unrelated test foils (Brainerd et al., 1995). Thus, the range of recognition scores between the *corrected* recognition score for conjunction lures in the copy condition and zero does not represent the entire plausible range for corrected conjunction lure recognition scores. Instead, the plausible range for corrected conjunction lure recognition scores extends below zero, such that suppression of conjunction lure false alarms with recall-to-reject processing could have produced

scores as low as -0.10 in Experiments 1B and 2A, -0.06 in Experiment 1A, and -0.07 in Experiment 2B, where the lower bound of the plausible range of conjunction lure recognition scores is represented by the false alarm rate to baseline items for a given experiment subtracted from zero. Indeed, the false alarm rates reported by Brainerd et al. (1995) were exceedingly low when recall-to-reject processing was used (typically less than .10), while the baseline false alarm rates were considerably higher (typically greater than .20), suggesting that recall-to-reject processing can produce dramatic decreases in false alarm rates even though it did not in the present studies. Third, we observed a substantial increase in the use of recall-to-reject processing between the copy condition ($M = .24$) and the three cues generated condition ($M = .56$) in Experiment 1B. Despite this very large increase in recall-to-reject processing, conjunction lure error scores were actually slightly higher in the three cues generated condition ($M = .09$) than in the copy condition ($M = .07$). Taken together, these three factors suggest that it is unlikely that floor effects compromised the ability of these studies to observe a decrease in conjunction lure errors.

A second concern readers may have regarding these results is the use of recall judgments to measure recall-to-reject processing. In particular, our use of phenomenological judgments to measure recall-to-reject processing may cause concern due to the debate over the proper interpretation of remember and know judgments for items judged “old” (e.g., Donaldson, 1996; Dunn, 2004; Gardiner, Richardson-Klavehn, & Ramponi, 1998; Hirshman, 1998; Jacoby, Jones, & Dolan, 1998; Yonelinas, 2002). There are three primary reasons we believe recall judgments provide a valid measure of strategic retrieval processes, and thus our dual-process interpretation of the present data is appropriate. First, in this case, recollection is defined at the item level as retrieval of a parent word, not as an unverifiable thought that a participant claims to have had

during the study phase. Second, we verified participants' recall judgments by asking them to produce the parent item that led them to make a recall judgment. In both experiments, actual recall of parent items corresponded closely with recall judgments to conjunction lure items across all of the encoding conditions. Third, participants showed considerable selectivity in their use of recall judgments. When participants judged a test item to be new, it was accompanied by a recall judgment less than 10% of the time if the test item was studied or was a new item used to measure baseline error rates. In contrast, conjunction lures judged new were accompanied by a recall judgment nearly 50% of the time. Thus, when a test item was judged new and could not have been rejected based upon recall of a studied item (i.e., it was a baseline item or a studied item), participants overwhelmingly claimed the item was unfamiliar. However, when a test item was judged new and it was possible to use recall of a studied item as a basis for the new judgment (i.e., the test item was a conjunction lure), participants regularly reported using recall-to-reject processing.

To this point, we have emphasized an explanation of these data offered by dual-process theories of recognition memory. However, in the literature on conjunction lure errors, there is a second view, feature-configuration or binding theory (Reinitz, et al., 1996). In its original form, which is most applicable to the present data, this approach proposes that conjunction lure errors occur when participants fail to bind together the features (component words) of a parent item at encoding, leading each feature to be stored separately. When a conjunction lure is presented during retrieval, the features in the conjunction lure are sometimes conjointly retrieved, leading participants to judge that the lure was studied.

At a general level, the binding account is consistent with the dual-process approach in that errors can be avoided via the retrieval of a configuration from the study episode (i.e., a

parent item). However, in binding theory it is assumed that if a configuration is stored, then no error will be made for its corresponding conjunction lure (Reinitz et al., 1996; for criticism of this assumption see Jones & Jacoby, 2001 and Footnote 1 of Jones & Atchley, 2002). Thus, factors that boost memory for configurations should increase hits but decrease conjunction errors and factors that hurt memory for configurations should decrease hits but increase conjunction errors.

The binding account can explain some aspects of the present data. Specifically, conditions that produced higher hit rates, presumably due to the better storage of configurations, also produced higher rates of recall responses. Despite this general support for binding theory, several elements of these data are not easily explained by binding theory. For example, it is not clear why conjunction error rates were unaffected by parent generation if configurations were stored better in some conditions than others (as indexed by changes in hit rates and recall responses). More problematic are the data for the component generation condition in Experiments 2A and 2B. A focus on the components of a parent word during encoding should discourage the binding of the two features of a parent item, leading to an increase in conjunction errors but a decrease in recall responses and, likely, hits. Yet, the component generation condition increased the hit, conjunction error, and recall response rates relative to the copy condition. Finally, the component generation condition increased conjunction error rates relative to the parent generation condition, despite similar hit and recall response rates in those two conditions. Thus, binding theory's assumption that configuration storage increases hits and decreases conjunction lure errors appears to be too restrictive to explain the present data.

A second alternative to dual-process theory's explanation of the present data is that recall of the components of parent items may have produced some conjunction lure errors. If this were

the case, conjunction lure error rates were driven by a combination of familiarity and recalled components, and the dual-process assumptions we used to derive estimates of familiarity would not be accurate. This hypothesis is similar to the concern that nondiagnostic, or noncriterial recollection influences estimates of familiarity in the process-dissociation procedure (Mulligan & Hirshman, 1997; Yonelinas & Jacoby, 1996). Thus, because our task only measured recollection as recall-to-reject processing, it is not possible to know if, or the extent to which, recollection may have *increased* conjunction lure errors. As with noncriterial recollection's potential effect on process-dissociation estimates of familiarity, if recall contributed to conjunction lure errors, it would be measured erroneously as familiarity by our estimation procedures.

One way to evaluate if component recall invalidates the dual-process claims we have made is to assess whether a model assuming *only* component recall and recall-to-reject can accommodate our data. In essence, by testing this restricted theory, we can assess the necessity of positing familiarity differences across experimental conditions to explain conjunction lure errors. This theory can explain the results from the copy condition and the component generation condition by proposing that component generation inspires both greater component recall, producing more conjunction lure errors, and greater parent recall, producing higher rates of recall-to-reject and hits. However, this theory is unable to explain why generating properties for whole parent items did not decrease conjunction lure errors. Specifically, there is no reason to believe that parent generation would increase recall of conjunction lure components relative to copying parent words. Thus, because the data suggest that parent generation increased recall-to-reject processing compared to the copy condition, this theory would expect a decrease in conjunction lure errors when parents were generated relative to when parents were copied, a result that was not observed in any of our experiments. We take this erroneous prediction to

indicate that a component recall process is not sufficient to explain the conjunction lure data from these studies and that a familiarity process is necessary to explain conjunction lure errors. Although it is plausible that recall-based processes may contribute to conjunction lure false alarm rates, parsimony considerations favor the standard dual-process theory because it can explain all of the data without positing recall-based conjunction lure errors.

Despite the data favoring dual-process theory in general, it is important to realize that to the extent component recall contributes to conjunction lure errors, our estimates of familiarity would be in error. However, even if some conjunction lure errors were due to component recall, it is not necessarily the case that component recall occurred sufficiently often to change the conclusions that familiarity increased following parent generation and that familiarity increased to a greater extent following component generation than parent generation. Further, the possible contribution of component recall to conjunction lure errors does not undermine the other primary conclusions from these studies – that recall-to-reject processing increased following generation of both whole parent items and components of parent items, and that these increases in recall-to-reject processing did not reduce conjunction lure error rates.

Conclusion

In closing, we wish to emphasize the utility of measures of recall-to-reject processing for understanding recognition memory errors and the contribution of recollection and familiarity to conjunction lure errors. The collection of such measures allows precise examination of the bases of recognition memory errors, and therefore, the extent to which participants use strategic processes to limit conjunction lure errors. Furthermore, the collection of recall-to-reject measures allows one to compute a measure of familiarity for conjunction lures that is based upon an objective, verifiable measure of recollection, mollifying common concerns over the use of

recollection judgments as a measure of recollection (e.g., Donaldson, 1996; Dunn, 2004).

Finally, collecting recall-to-reject measures would appear to be useful in other paradigms as well, such as plurality discrimination and associative recognition, where recall-to-reject processing is encouraged and perhaps likely to occur. Indeed, given that the evidence for recall-to-reject in the plurality and associative recognition paradigms is sometimes open to multiple interpretations (e.g., Rotello & Heit, 1999; 2000), the addition of another measure of recall-to-reject processing could prove to be a useful tool for understanding the contribution of recollection and familiarity to recognition of similar test lures.

References

- Brainerd, C.J., Reyna, V.F., & Kneer, R. (1995). False-recognition reversal: When similarity is distinctive. *Journal of Memory and Language, 34*, 157-185.
- Brainerd, C. J., Reyna, V. F., Wright, R., & Mojardin, A. H. (2003). Recollection-rejection: False memory editing in young and older adults. *Psychological Review, 110*, 762-784.
- Curran, H.V., & Hildebrandt, M. (1999). Dissociative effects of alcohol on recollective experience. *Consciousness & Cognition, 8*, 497-509.
- Curran, T., & Hintzman, D. L. (1997). Consequences and causes of correlations in process dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 496-504.
- Diana, R., Reder, L.M., Arndt, J., & Park, H. (2006). Models of recognition: A review of arguments in favor of a dual process account. *Psychonomic Bulletin & Review, 13*, 1-21.
- Donaldson, W. (1996). The role of decision processes in remembering and knowing. *Memory & Cognition, 24*, 523-533.
- Dunn, J.C. (2004). Remember-know: A matter of confidence. *Psychological Review, 111*, 524-542.
- Gallo, D.A. (2004). Using recall to reduce false recognition: Diagnostic and disqualifying monitoring. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 120-128.
- Gardiner, J.M. (1988). Functional aspects of recollective experience. *Memory & Cognition, 16*, 309-313.
- Gardiner, J.M., Richardson-Klavehn, A., & Ramponi, C. (1998). Limitations of the signal detection model of the remember-know paradigm: A reply to Hirshman. *Consciousness &*

Cognition, 7, 285-288.

Ghatala E., Levin, J., Bell, J., Truman, D., & Lodico, M. (1978). The effect of semantic and nonsemantic factors on the integration of verbal units in recognition memory. *Journal of Experimental Psychology: Human Learning and Memory*, 4, 657-655.

Hintzman, D. L., Curran, T., & Oppy, B. (1992). Effects of similarity and repetition on memory: Registration without learning? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18, 667-680.

Hirshman, E. (1998). On the utility of the signal detection model of the remember-know paradigm. *Consciousness & Cognition*, 7, 103-107.

Jacoby, L.L. (1991). A process-dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, 30, 513-541.

Jacoby, L.L., Jones, T.C., & Dolan, P. (1998). Two effects of repetition: Support for a dual-process model of knowledge judgments and exclusion errors. *Psychonomic Bulletin & Review*, 5, 705-709.

Jones, T. C. (2005). Study repetition and the rejection of conjunction lures. *Memory*, 13, 499-515.

Jones, T.C. (2006). Editing (out) generated study words in a recognition exclusion task: Effects of response signal delay and generation procedure. *Memory*, 14, 712-729.

Jones, T. C., & Atchley, P. (2002). Conjunction error rates on a continuous recognition memory test: Little evidence for recollection. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28, 374-379.

Jones, T. C., & Atchley, P. (2006). Conjunction errors, recollection-based rejections, and forgetting in a continuous recognition task. *Journal of Experimental Psychology: Learning,*

Memory, and Cognition, 32, 70-78.

Jones, T. C., Brown, A. S., & Atchley, P. (2007). Feature and conjunction effects in recognition memory: Toward specifying familiarity for compound words. *Memory & Cognition*, 35, 984-998.

Jones, T. C., & Jacoby, L. L. (2001). Feature and conjunction errors in recognition memory: Evidence for dual-process theory. *Journal of Memory and Language*, 45, 82-102.

Joordens, S., & Merikle, P.M. (1993). Independence or redundancy: Two models of conscious and unconscious influences. *Journal of Experimental Psychology: General*, 122, 462-467.

Lampinen, J. M., & Odegard, T. N., & Neuschatz, J. S. (2004). Robust recollection rejection in the memory conjunction paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 30, 332-342.

Mäntylä, T. (1986). Optimizing cue effectiveness: Recall of 500 and 600 incidentally learned words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 12, 66-71.

Mäntylä, T., & Nilsson, L. (1983) Are my cues better than your cues? Uniqueness and reconstruction as prerequisites for optimal recall of verbal materials. *Scandinavian Journal of Psychology*, 24, 303-312.

Mulligan, N.W., & Hirshman, E. (1997). Measuring the bases of recognition memory: An investigation of the process dissociation framework. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 23, 280-304.

Odegard, T.N., Lampinen, J.M., & Toglia, M.P. (2005). Meaning's moderating effect on recollection rejection. *Journal of Memory and Language*, 53, 416-429.

Reder, L.M., Nhouyvansivong, A., Schunn, C.D., Ayers, M.S., Angstadt, P., & Hiraki, K. (2000). A mechanistic account of the mirror effect for word frequency: A computational

model of remember/know judgments in a continuous recognition paradigm. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 26, 294-320.

Reinitz, M. T., Lammers, W. J., & Cochran, B. P. (1992). Memory conjunction errors: Miscombination of stored features can produce illusions of memory. *Memory & Cognition*, 20, 1-11.

Reinitz, M.T., Verfaellie, M., & Milberg, W. P. (1996). Memory conjunction errors in normal and amnesic subjects. *Journal of Memory and Language*, 35, 286-299.

Roediger, H.L. III, McDermott, K.B., & Robinson, K.J. (1998). The role of associative processes in producing false remembering. In M. Conway, S. Gathercole, & C. Cornoldi (Eds.), *Theories of Memory II*. (pp. 187-245). Hove, Sussex: Psychological Press.

Rotello, C.M., & Heit, E. (1999). Two-process models of recognition memory: Evidence for recall-to-reject? *Journal of Memory and Language*, 40, 432-453.

Rotello, C.M., & Heit, E. (2000). Associative recognition: A case of recall-to-reject processing. *Memory & Cognition*, 28, 907-922.

Rotello, C.M., Macmillan, N.A., & Van Tassel, G. (2000). Recall-to-reject in recognition: Evidence from ROC curves. *Journal of Memory and Language*, 43, 67-88.

Rubin, S.R., Van Patten, C., Glisky, E.L., & Newburg, W.N. (1999). Memory conjunction errors in younger and older adults: Event-related potential and neuropsychological data. *Cognitive Neuropsychology*, 16, 459-488.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-prime User's Guide*. Pittsburgh: Psychology Software Tools, Inc.

Underwood, B. J., Kapelak, S. M., & Malmi, R. A. (1976). Integration of discrete verbal units in recognition memory. *Journal of Experimental Psychology: Human Learning and Memory*,

2, 293-300.

Underwood, B. J., & Zimmerman, J. (1973). The syllable as a source of error in multisyllable word recognition. *Journal of Verbal Learning and Verbal Behavior*, *12*, 701-706.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, *46*, 441-517.

Yonelinas, A.P., Dobbins, I., Szymanski, M.D., Dhaliwal, H.S., & King, L. (1996). Signal-detection, threshold, and dual-process models of recognition memory: ROCs and conscious recollection. *Consciousness & Cognition*, *5*, 418-441.

Yonelinas, A.P., & Jacoby, L.L. (1995). The relationship between remembering and knowing as bases for recognition: Effects of size congruency. *Journal of Memory and Language*, *34*, 622-643.

Yonelinas, A.P., & Jacoby, L.L. (1996). Noncriterial recollection: Familiarity as automatic, irrelevant recollection. *Consciousness and Cognition*, *5*, 131-141.

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Footnotes

¹ The claim here is not that recollection is *available* earlier in retrieval than familiarity, but that when both processes are available, as is typically the case in recognition memory experiments using untimed testing conditions, participants will preferentially use recollection.

² Data from all four experiments were also analyzed using d' and A' to correct hits and conjunction lure false alarms for baseline false alarm rates. These analyses led to the same conclusions as those using corrected recognition scores, with one exception. The A' analyses of Experiment 1A did not produce a significant interaction between Study Task and Test Item Type ($F(2,46) = 2.72, p < .08$). Despite the interaction only approaching significance, Bonferroni-adjusted comparisons showed the same patterns of performance that were found with analyses of corrected recognition and d' .

Table 1.

Schematic of study and test conditions with example stimuli for Experiments 1A and 1B.

<u>Study Word(s)</u>	<u>Study Task</u>	<u>Test Word</u>	<u>Test Item Type</u>
blackmail	copy	blackmail	old (parent)
lawsuit	generate 1 cue	lawsuit	old (parent)
nightmare	generate 3 cues	nightmare	old (parent)
----	----	passport	new (parent baseline)
<u>crossroad</u> , <u>rainbow</u>	copy	crossbow	conjunction lure
<u>watchtower</u> , <u>sheepdog</u>	generate 1 cue	watchdog	conjunction lure
<u>switchblade</u> , <u>billboard</u>	generate 3 cues	switchboard	conjunction lure
----	----	shortcut	new (conjunction baseline)

Table 2.

Hits for parent items, false alarms for conjunction lures, and false alarms for baseline items in Experiments 1A and 1B.

		Study Task							
		Copy		Generate 1 Cue		Generate 3 Cues		New	
<i>Experiment 1A</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
	Parent	.64	.03	.94	.01	.94	.01	.04	.02
	Conjunction Lure	.15	.03	.17	.04	.19	.03	.06	.02
		Study Task							
		Copy		Generate 1 Cue		Generate 3 Cues		New	
<i>Experiment 1B</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
	Parent	.69	.03	.97	.01	.98	.01	.10	.02
	Conjunction Lure	.17	.03	.17	.03	.19	.04	.10	.03

Table 3.

Familiarity estimates for Experiment 1B and Experiment 2B based on the assumptions of the independence model, redundancy model, and mutual exclusivity model. Standard error of the mean is reported in parenthesis.

		Study Task					
		Copy		Generate 1 Cue		Generate 3 Cues	
<i>Experiment 1B</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
	Independence Model	.17	.03	.24	.04	.35	.06
	Redundancy Model	.37	.04	.54	.04	.67	.04
	Mutual Exclusivity Model	.17	.03	.17	.03	.19	.04
		Study Task					
		Copy		Generate 2 Cues --Whole Word		Generate 2 Cues --Components	
<i>Experiment 2B</i>		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
	Independence Model	.16	.04	.23	.04	.51	.05
	Redundancy Model	.27	.04	.51	.04	.70	.03
	Mutual Exclusivity Model	.14	.03	.16	.03	.38	.05

Table 4.

Hits for parent items, false alarms for conjunction lures, and false alarms for baseline items in Experiments 2A and 2B.

<i>Experiment 2A</i>		Study Task							
		Copy		Parent Generation		Component Generation		New	
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Parent	.62	.04	.94	.02	.94	.01	.06	.01	
Conjunction Lure	.24	.04	.30	.05	.51	.05	.10	.02	

<i>Experiment 2B</i>		Study Task							
		Copy		Parent Generation		Component Generation		New	
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Parent	.57	.03	.95	.01	.94	.02	.07	.01	
Conjunction Lure	.14	.03	.16	.03	.38	.05	.07	.02	

Figure Captions

Figure 1. Parent word and conjunction lure recognition as a function of Study Task in Experiment 1A (Top Panel) and Experiment 1B (Bottom Panel). Error bars depict the standard error of the mean.

Figure 2. “Recall” responses and actual recall to conjunction lures judged new in Experiment 1B as a function of Study Task. Error bars depict the standard error of the mean.

Figure 3. Parent word and conjunction lure recognition as a function of Study Task in Experiment 2A (Top Panel) and Experiment 2B (Bottom Panel). Error bars depict the standard error of the mean.

Figure 4. “Recall” responses and actual recall to conjunction lures judged new in Experiment 2B as a function of Study Task. Error bars depict the standard error of the mean.







