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Conjunction errors in recognition memory: Modality-free errors for older adults but not for young adults

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Abstract

A dual-process theory of memory was applied to processes in normal aging, with a focus on recognition errors in the feature-conjunction paradigm (i.e., false recognition of *blackbird* after studying parent words *blackmail* and/or *jailbird*). Study repetition was manipulated so that some parent words occurred once and others occurred three times. Age-related differences on hit scores occurred for two experiments. The results for feature and conjunction conditions showed repetition effects but no age-related differences when participants were uninformed of the lures (Experiment 1). However, age-related differences emerged when the retrieval of modality source information created a way to evade conjunction errors (Experiment 2). In the second experiment, study repetition decreased errors for the young adults but increased errors for the older adults, and young adults were better able than older adults to avoid conjunction errors when the parent words had been repeated. For older adults, the conjunction errors were modality-free. The results provide additional evidence that older adults experience difficulty in recollecting aspects of a study experience, and the results from groups of young adults required to respond quickly on the tests provide converging evidence for this conclusion.

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1. Introduction

Dual-process theories offer a useful framework for recognition memory research (for a review, see Yonelinas, 2002), and a dual-process perspective has been applied to help understand changes in memory with the normal aging process (Jacoby, 1999a, 1999b; for a review, see Light, 1991). The basic idea is that older adults exhibit little or no decline in relatively automatic processes (e.g., familiarity) but show a substantial decline in controlled processes (e.g., recollection). A critical aspect of this approach is that familiarity and recollection provide alternative bases for responding on a memory test (Jacoby, 1991, 1999b). Reliance on familiarity or recollection can produce a hit. However, when conditions are created to place evidence from familiarity and recollection at odds with each other, one has an opportunity to observe their separate influences.

For example, Jacoby (1999b) concluded that a variable generally thought to benefit memory—study repetition—increases both familiarity and recollection (also see Jacoby, Jones, & Dolan, 1998; McElree, Dolan, & Jacoby, 1999). An increase in familiarity from study repetition was apparent in Jacoby's (1999b) recognition memory study by an increase in errors for words designated for exclusion from "old" judgments on the basis of study modality/list membership, and an increase in recollection was evident by a reduction in these errors. Study repetition increased exclusion errors for older adults but decreased exclusion errors for young adults. Relative to young adults, older adults suffered from a normal decline in recollection, leaving themselves open to the influence of familiarity.

Other familiarity-based errors, such as feature and conjunction errors (Reinitz, Lammers, & Cochran, 1992; Underwood & Zimmerman, 1973; Underwood, Kapelak, & Malmi, 1976), appear to be good candidates for informing a dual-process theory approach as applied to the normal aging process. In the feature-conjunction memory paradigm, parts of stimuli that are presented in a study phase (e.g., *nighthawk*, *blackmail*, and *jailbird*) are recombined to form challenging lures on a recognition test (*nightcap* and *blackbird*). A test item constructed from an old element and a new element (e.g., *nightcap*) is referred to as a feature lure, whereas a test item constructed with rearranged old components (e.g., *blackbird*) is called a conjunction lure. Error rates for feature and conjunction conditions above false alarms to wholly new words are considered feature and conjunction effects.

In a dual-process explanation, familiarity engendered by the old component(s) of feature and conjunction lures biases one to commit false recognition errors (above chance), but recollection for a parent word presented earlier in the study phase (e.g., *blackmail* was presented, not *blackbird*) can be used to overcome the influence of familiarity to avoid an error (e.g., Jones, in press; Jones & Atchley, 2002; Jones &

Jacoby, 2001; Lampinen, Odegard, & Neuschatz, 2004).[1] This idea is generally consistent with a recall-to-reject hypothesis (e.g., Gallo, 2004; Hintzman & Curran, 1994; Hintzman, Curran, & Oppy, 1992; Rotello & Heit, 2000; Rotello, Macmillan, & Van Tassel, 2000). This position is also consistent with theories that propose separate familiarity and source monitoring mechanisms (e.g., McDermott & Watson, 2001; Rubin, Van Petten, Glisky, & Newberg, 1999), differential access to particular traces (e.g., verbatim and gist traces in fuzzy trace theory, Brainerd, Reyna, & Kneer, 1995), or the differential storage (availability) of particular representations (e.g., features and configurations; Reinitz, Verfaellie, & Milberg, 1996).[2]

Recent experiments on compound words have provided evidence for recollection-based rejections of feature or conjunction lures by using (a) young adult participants, (b) multiple study presentations, and (c) test instructions that inform participants of the lures (Jones, in press; Jones & Jacoby, 2001; Lampinen et al., 2004; for a different procedure, see Jones & Atchley, 2002). Lampinen and colleagues found that participants uninformed of the presence of conjunction lures showed little evidence for recollection-based rejections. Our first aim was to consider performance of young and older adults on compound word stimuli when the test instructions did not mention the presences of feature and conjunction lures. Based on Lampinen et al.'s finding, and for reasons described below, we predicted that feature and conjunction effects for compound words would be similar for older and younger adults if the test instructions did not mention the lures. A second aim was to verify whether information regarding the presentation of parent compound words is accessible even though the parent compound words themselves might not be retrieved. A third and final goal was based on the premise that certain source information (e.g., presentation modality) related to the parent words might be retrieved by young adults but not older adults. The rationale was that conditions could be created whereby retrieval of modality information might circumvent the production of errors for young adults but not older adults.

A number of dissociations have been obtained that show effects on hit scores but not feature and conjunction scores (e.g., Jones & Atchley, 2002; Jones & Jacoby, 2001; Reinitz et al., 1996; Rubin et al., 1999). Thus, in general, recollection-based acceptance of old words appears to be more effective than recollection-based rejections of feature and conjunction lures. Consistent with this pattern, older adults have produced lower hit scores on verbal stimuli than young adults but have produced similar feature and conjunction scores to young adults (Kroll, Knight, Metcalfe, Wolf, & Tulving, 1996; Rubin et al., 1999). We reasoned that, regardless of their

[1] At present, the source or type of information underlying familiarity in these cases is unclear (Jones, Jacoby, & Gellis, 2001), though conceptual information can contribute to the errors (Ghatala, Levin, Bell, Truman, & Lodico, 1978). Information at the syllable level may also be important (Underwood & Zimmerman, 1973).

[2] For a limitation of this recollection-based rejection aspect of fuzzy trace theory, see Wallace, Malone, Swiergosz, and Amberg (2000). For a criticism on the simple storage (availability) idea by Reinitz et al. (1996), see Jones and Jacoby's (2001) discussions on available and accessibility and Jones and Atchley's (2002) thought experiment in their footnotes.

age, participants may not spontaneously employ a recollection-based strategy for the rejection of feature and conjunction lures (e.g., Jones, in press; Lampinen et al., 2004). In such a case, feature and conjunction error rates should be similar for young and older adults regardless of the material. We attempted to extend prior work with syllable recombinations (e.g., parent words *pardon, vodka*; conjunction lure, *parka;* Kroll et al., 1996; Rubin et al., 1999) to morpheme recombinations (i.e., compound words) in Experiment 1. Our intuition was that syllable conjunctions provide particularly ineffective retrieval cues to guide recollection of a parent word. We used compound words because we believed they would provide a stronger test of the idea that recollection-based rejection is not likely to occur spontaneously.

Presumably, conditions might exist where older adults would be more susceptible to conjunction errors than young adults. We reasoned that young adults might be able to retrieve modality information connected to the parent words of conjunction lures (Marsh, Hicks, & Davis, 2002), and that the use of such information could allow young adults to escape an error. Older adults, in contrast, should have difficulty retrieving modality information connected to the parent words and should be relatively prone to making familiarity-based errors. This reliance should translate into an increased probability of an error for conditions in which the components of conjunction lures impart relatively strong familiarity (e.g., multiple study presentations). These ideas were examined in Experiment 2.

Two age groups, young and older adults, participated in each experiment, and this age group factor was partially crossed with a response deadline variable on the recognition test to yield three groups: young adults—long response deadline, young adults—short response deadline, older adults—long response deadline. The young adult-short response deadline group was included to show that patterns of data for older adults could be produced by young adults under conditions thought to attenuate recollection. For the sake of readability, we will refer to the response deadline descriptions for the young adult groups in an abbreviated form (e.g., "long deadline" instead of "long response deadline") and refer to the older adult groups without the response deadline description.

Most of the predictions were straightforward. First, the young adult-short deadline groups were expected to produce data similar to the older adult groups. Second, these groups of young and older adults were expected to show relatively poor recognition performance for hits relative to young adults with relatively little response time pressure. Third, all groups were expected to commit feature and conjunction error rates above a baseline level.

Study repetition was manipulated in both experiments to influence familiarity and recollection, and the predictions for the effects of study repetition on feature or conjunction error rates were more complex. When the test instructions omitted any mention of the feature or conjunction lures (Experiment 1), study repetition was expected to increase the feature and conjunction error rates for all groups. When the test instructions omitted mention of conjunction lures but provided an avenue to avoid conjunction errors (Experiment 2), study repetition was expected to increase conjunction error rates for the older adults and young adult-short deadline group but not the young adult-long deadline group.

2. Experiment 1

This first experiment consisted of a traditional study-test memory procedure where participants knew that their memory would be tested. In the study phase, compound words were presented once or thrice. On a subsequent old–new recognition test, no mention of the feature and conjunction lures was made until the debriefing phase. With the expectation for a very limited rate of recollection-based rejections of features and conjunction lures came a prediction that the three groups would produce similar feature and conjunction effects and that study repetition would increase these effects. Although the groups were expected to produce similar error rates induced by familiarity, differences in the hit scores were expected to reflect differences in the ability to use recollection to accept old words as "old".

2.1. Method

2.1.1. Participants

Older adults. The older adults (all 60 years or older) were drawn from a participant pool for a program, Memory Function in Normal Aging, at New York University. Participation was voluntary. The mean age was approximately 71 years (standard deviation of about 5 years) and the mean education level was about 17 years (standard deviation of about 2 years; range: high school diploma with an additional art degree—Ph.D., with nearly all participants receiving at least some university education). All of the older adults were healthy with no apparent visual or auditory impairment that would compromise the results. Sixteen older adults participated in Experiment 1.

Young adults. The young adults for both Experiments 1 and 2 were undergraduates at New York University. Participation was compensated by credit toward an introductory course. The mean age was approximately 19 years (standard deviation of about 1.4 years), and the mean education level was about 13 years (all participants had a high school diploma plus a small amount of university). Sixty-four students participated in Experiment 1.

2.1.2. Materials

Two hundred fifty-eight compound words were used: 240 words were critical items, and the remaining 18 words were primacy or recency buffers for the study list and/or items for a practice test. The 240 words comprised 80 sets of triplets. Each triplet comprised a target word (e.g., *blackbird*) and two parent words (e.g., *blackmail*, *jailbird*).[3] A few of these triplets were used by Reinitz et al. (1996), and the rest were constructed. Micro Experimental Laboratory (MEL) software (Schneider, 1995) was used to run the experiments on IBM-compatible computers.

[3] The stimuli may be obtained by contacting the first author. A set of similar materials also appears in a recent paper by the first author (Jones, in press).

2.1.3. Design and procedure

The experiment employed a 3 (Group) × 7 (Item type) mixed design. The groups were: young adult-long deadline, young adult-short deadline, and older adult-long deadline. Six of the item types on the test corresponded to words or components of words presented in the study phase and the seventh condition corresponded to wholly new words. For the six study conditions, two were old word conditions (one or three study presentations), two were feature lure conditions (one or three study presentations of a parent word), and two were conjunction conditions (one or three study presentations of both parent words).

A study list of 160 critical trials with six primacy and six recency buffers was constructed such that the words corresponding to the different item types were distributed equally throughout the list. For repeated items, the mean spacings were 8.4, 9.1, and 10.0 items for the old words, feature parents, and conjunction parents, respectively. The mean spacing between a pair of parent words for the conjunction conditions was 3 words (range: 1–5 words). Each of six lists (of 10 triplets) corresponded to conditions where some part of the word appeared during the study phase. Two other lists were used as new items on the recognition test. Thus, in total, eight lists of 10 triplets were used, and the different lists were rotated through each of the conditions across participants. The presentation of the parent words for feature lures (e.g., *blackmail* or *jailbird*) and the order of the parent words for conjunction lures were balanced across participants. The study items were presented on the computer screen for 2.5 s with a 500-ms intertrial interval (ITI). Participants were told to read each word aloud and that some of the words would be repeated. Immediately after the study phase, participants were given test instructions for an old–new recognition test. One key on the keyboard (F) was pressed for a "new" judgment; one key (J) was pressed for an "old" judgment. A short practice test without feature or conjunction lures preceded the actual test. The participants were not informed of the feature and conjunction lures and were to guess "old" if they were unsure whether a word was old. The liberal criterion instruction was meant to encourage the use of familiarity as a basis for responding and to help prevent floor effects for the three false alarm conditions. For the short deadline procedure, participants were required to respond within 850 ms after the onset of a test word. For the long deadline procedure, after a test word was displayed for 1400 ms a response signal (*****) appeared below the test word for 850 ms. Participants were required to respond while the response signal was present (in total, a 2250-ms deadline). Responses were not allowed before the appearance of the response signal. If a response was not made before a deadline, the computer beeped, and the next trial began. The ITI was 1 s.

2.2. Results and discussion

The mean proportions of "old" responses for each group are shown by item type in Table 1. These proportions are based on all trials, regardless of whether a response was made within the allotted time. (The mean time-out rate varied little across the three groups: young adult-long deadline = .02, young adult-short deadline = .04, older adult-long deadline = .05.)

Table 1
Experiment 1: mean proportion of "old" responses for each group as a function of item type

Age group	Deadline	Hit (old)		False alarm				
				Conjunction		Feature		New
		1P	3P	1P	3P	1P	3P	
Older adult	Long	.54 (.38)	.74 (.58)	.31 (.15)	.43 (.27)	.26 (.06)	.29 (.13)	.16
Young adult	Short	.55 (.36)	.71 (.52)	.41 (.22)	.50 (.31)	.26 (.07)	.34 (.15)	.19
Young adult	Long	.69 (.51)	.82 (.64)	.36 (.18)	.48 (.30)	.25 (.07)	.32 (.14)	.18

Scores with the new word false alarm rate subtracted (i.e., corrected scores) appear in parentheses.
Note: P = study presentation(s).

The typical pattern of "old" responses across item types was obtained for all three groups (old > conjunction > feature > new; Jones & Jacoby, 2001). As predicted, the group of older adults and the group of young adults with a short response deadline produced a lower corrected hit rate compared to the young adult-long deadline group. In general, as expected, the performances for the young adult-short deadline and the older adult groups were similar, though the older adults' hit scores were slightly better than those for the young adult-short deadline group. The feature and conjunction effects were similar for the three groups. Thus, discrimination of old words from feature lures or conjunction lures was relatively low for the older adult and young adult-short deadline groups compared to the young adult-long deadline group. For all groups, study repetition increased memory performance as evaluated in terms of hits. On the other hand, study repetition hurt memory performance as evaluated by feature and conjunction effects. That is, study repetition boosted hit scores but also raised feature and conjunction error scores.

Statistical analyses supported these observations. A 2 (Repetition) × 3 (Item type: old, conjunction, feature) × 3 (Group) mixed ANOVA on the corrected recognition scores produced significant effects of Item type and Repetition ($F(2,154) = 202.50$, MSE = .03, and $F(1,77) = 78.11$, MSE = .02, respectively), and a Newman–Keuls test showed that each of the pair-wise comparisons of item types was significant. The two-way interactions of Group × Item type and Item type × Repetition also were significant ($F(4,154) = 4.08$, MSE = .03, and $F(2,154) = 3.23$, MSE = .02, respectively). The Item type × Repetition interaction simply reflected a larger repetition effect for old words compared to feature and conjunction lures.

The Group × Item type interaction was followed up by a one-way ANOVA for the hit scores and a 2 (Item type) × 3 (Group) mixed ANOVA on the feature and conjunction scores. (Because the three-way interaction in the initial analysis was not significant, the scores were collapsed across study repetition.) The one-way ANOVA with a follow-up Newman–Keuls test showed that all three corrected hit rates were significantly different ($F(2,77) = 6.51$, MSE = .02). In contrast, for the feature and conjunction scores neither the effect of Group nor the Group × Item type interaction was significant (Fs < .48).

To summarize, despite differences in the hit scores across groups, the feature and conjunction effects were comparable across the three groups. This dissociation—an

effect on corrected hit rates but not feature and conjunction effects—is consistent with a general dual-process theory. In this case, a diminished ability to utilize recollection, either by a short response deadline or older age, lowered the ability to accept old words as "old" but did not affect the ability to reject feature or conjunction lures as "old." This difference reflects a difference in recollection (or recall) to accept old words relative to recollection (or recall) to reject feature and conjunction words (cf., Rotello et al., 2000). At the same time the similar feature and conjunction scores provide additional evidence that familiarity is relatively unaffected by the normal aging process. These findings extend previous results on aging and errors in the feature-conjunction memory paradigm from syllable recombinations (e.g., parent words: *pardon* and *vodka*; feature/conjunction lure: *parka*) to compound words (Kroll et al., 1996; Rubin et al., 1999). The study repetition effects on feature and conjunction error rates for uninformed participants are consistent with other research (Lampinen et al., 2004), and a new finding is that these study repetition effects extend to older adults. The results also support the idea that feature and conjunction errors reflect a gradient of familiarity (Jones & Jacoby, 2001; Rubin et al., 1999). Finally, the results bolster the case that recollection (Jacoby, 1999b) or a monitoring check (Rubin et al., 1999), but not familiarity, is attenuated in the normal aging process, and the results for the young adult-short deadline group provide converging evidence for this proposal.

3. Experiment 2

In Experiment 1 older adults produced comparable feature and conjunction error scores to young adults in a circumstance where a spontaneous strategy of rejecting feature and conjunction lures on the basis of recollection (of parent words) would appear to be unlikely. One important question is whether any information concerning the parent words might be retrieved accurately when a participant is faced with a feature or conjunction lure. Jones et al. (2001) found no effect of study modality on feature and conjunction error effects when the study words were presented once. However, their participants were not instructed to indicate whether they could remember the study modality of a word or to use source modality information to help accept or reject words as "old." One possibility is that participants may remember that they have seen or heard something like the lure (i.e., *blackbird*) without recollecting that a particular parent word (*blackmail* or *raindrop*) was presented (Marsh et al., 2002). This possibility receives some support from Marsh et al.'s finding that participants are able to identify above chance whether the parts of conjunction lures presented once during study have been seen or heard without this modality information influencing conjunction error rates.

Marsh et al. (2002) suggested that retrieval of source information (e.g., the study modality of parent words) could exacerbate conjunction errors. We reasoned that this suggestion could be borne out for some circumstances but not others. Specifically, we reasoned that modality source information could help participants avoid

a conjunction error in an exclusion procedure where the criterion for exclusion centered on the study modality. Several studies have shown that study repetition increases the likelihood of retrieving study modality information (e.g., Jacoby, 1999b; Jacoby et al., 1998; McElree et al., 1999). In addition, these studies have used an exclusion procedure where words in a study list presented visually are to be excluded from "old" judgments, whereas words in a study list presented auditorily are to be included in "old" judgments. Thus, for Experiment 2, we used Jacoby's (Jacoby, 1991, 1999b; Jacoby et al., 1998) exclusion procedure in which two lists of study words were presented in different modalities. The first study list was presented visually and the second study list was presented auditorily. All of the parent words corresponding to later conjunction lures were presented in the visual study list and, to increase the likelihood of later retrieval of modality information, some of the words on the visual study list were repeated. On the exclusion test, participants were told to identify words as "old" if they had been heard but not seen (read). Failure to exclude visually-presented items from "old" judgments were considered exclusion errors. With this design, if modality information connected to a conjunction lure (i.e., the presentation modality of a parent word) can be retrieved, then a conjunction error can be avoided. In this case, retrieval of information regarding the modality of the parent words could clearly prevent, instead of potentially fuel, conjunction errors.

Based on Marsh et al.'s (2002) findings we expected that, given a long response deadline procedure, young adults should be able to avoid a conjunction error through the recollection of modality source information. The retrieval of modality source information was predicted to be more likely for the conjunction lures with additional study presentations of the components in the study phase. Jacoby's (1999b) results, as well as others' results on ageing (Light, La Voie, Valencia-Laver, Albertson-Owens, & Mead, 1992), also suggested that older adults and young adults with a short response deadline procedure should be relatively unable to retrieve and use modality source information to reject conjunction lures. In this sense, conjunction errors should be modality-free errors for older adults, as well as for young adults in a condition meant to compromise recollection.

3.1. Method

3.1.1. Participants

Eighteen older adults and 36 young adults participated. The young adults were assigned randomly to the short or long response deadline conditions.

3.1.2. Materials

The stimuli included 72 of the compound word triplets from Experiment 1 plus 78 compound words not used in Experiment 1. The additional compound words were used as stimuli for the auditory study phase and primacy and recency buffer stimuli for the visual study phase.

3.1.3. Design and procedure

There were three participant groups, young-long response deadline; young-short response deadline; older adults (long response deadline), and six item types on the test (read word, 1 visual presentation; read word, 3 visual presentations; conjunction, 1 visual presentation of the parent words; conjunction, 3 visual presentations of the parent words; heard word, or new word). The overall design was a 3 (Group) × 6 (Item type) mixed design, though the stimuli from the heard list were not included in the counterbalancing of the lists corresponding to read, conjunction, and new words. The item types of greatest interest were in the visual conditions.

Six lists of 12 triplets were used for the critical conditions. Twenty-four words (two lists of 12 items) appeared in each of the read word, conjunction lure, and new word conditions. For the read word and conjunction conditions, 12 words were used in each of the repetition conditions (one or three presentations). The six lists were rotated through each of the item types across subjects. A single study order of 154 trials (144 critical trials and 10 buffer trials) based on item type was composed for the visual study phase. For the repetition conditions, the mean spacing was 7 words for the old condition and 6 words for the conjunction conditions (i.e., a mean of 6 words intervened re-presentation of the parent words). The mean spacing within a pair of parent words was 2.5 words (range: 2–3 words). (The order of the parent words was not balanced.) Each word was presented for 2 s followed by a 250-ms ITI. The participants read each word aloud and tried to commit the words to memory for a later, unspecified memory test. The words in the auditory study phase were read in a single order by the experimenter from a computer screen out of view of a participant. The presentation rate was the same as that for the visual list. The participants were told to repeat the words aloud and to try to remember them for later. Immediately after the study phase ended, the exclusion test instructions were given. The participants were instructed to judge whether a word was heard (''old'') in the second study list by pressing one of two keys. If a participant was unsure whether a word was heard, a guess of ''old'' was encouraged. The response deadline procedures were nearly identical to the procedures used in Experiment 1. The only difference was that a focal point was shown for 500 ms immediately before the presentation of each test word.

3.2. Results and discussion

The mean proportions of ''old'' responses for the three groups, broken down by the different item types, are shown in Table 2. The time-out rates were similar across the different item types and a bit higher for the older adult-long deadline group (.08) than the young adult-long deadline group (.02) and young adult-short deadline groups (.03).

After correcting for baseline differences (subtraction of false alarm rates for new items), the hit score (for heard words) was highest for the young adult-long deadline group, followed by the older adult group, which was followed by the young adult-short deadline group. A one-way ANOVA with a follow-up Newman–Keuls test

Table 2
Experiment 2: mean proportion of "old" responses for each group as a function of item type

Age group	Deadline	Hit (heard)	Exclusion errors				
			Read		Conjunction		New
		1P	1P	3P	1P	3P	
Older adult	Long	.54 (.31)	.53 (.30)	.61 (.38)	.37 (.14)	.44 (.21)	.23
Young adult	Short	.57 (.22)	.52 (.17)	.63 (.28)	.47 (.12)	.52 (.17)	.35
Young adult	Long	.65 (.41)	.38 (.14)	.32 (.08)	.41 (.17)	.33 (.09)	.24

Scores with the new word false alarm rate subtracted (i.e., corrected scores) appear in parentheses.
Note: P = study presentation(s).

showed that each of the pair-wise differences was significant ($F(2, 51) = 8.95$, MSE = .02). Thus, both age-related effects and response deadline effects were observed on the hit scores.

The critical data involved the error rates from the visual study conditions. First, all groups produced exclusion errors at rates higher than the baseline condition. Second, a simple comparison of the hits to the exclusion errors for words read once shows that the modality-based exclusion criterion made the task difficult for older adults and young adults with a short deadline. For these groups, the exclusion error rates for words read once were similar to the hit rates. In other words, participants in these groups had difficulty discriminating which words were only heard and which words were read (i.e., seen). In contrast, for the young adults with a long deadline, the hit rate was much higher than the exclusion error rates for words read once, demonstrating an ability to discriminate heard from read words.

Our chief interest was on the ability of the different groups to control the exclusion errors for read and conjunction words. Given that the older adults and young adults with a short deadline had difficulty discriminating words presented auditorily from words presented visually, they should be more vulnerable to the influence of familiarity instantiated from study repetition. This susceptibility can be seen in the increase in exclusion errors with study repetition for both read words and conjunction words. In contrast, the young adults in the long deadline group were able to retrieve modality source information and, hence, to skirt the influence of familiarity. This ability to retrieve source information in order to evade an error is demonstrated by a decrease in exclusion error rates for both read words and conjunction words.

These findings were supported by analyses on the corrected exclusion error scores (e.g., subtraction of the new word false alarm rate). A 2 (Item type: old, conjunction) × 2 (Study repetition) × 3 (Group) mixed ANOVA gave significant effects of Group ($F(2, 51) = 6.68$, MSE = .05) and Item type ($F(1, 51) = 16.39$, MSE = .02) and significant interactions of Group × Item type and Group × Study repetition ($F(2, 51) = 9.41$, MSE = .02, and $F(2, 51) = 9.14$, MSE = .01, respectively). The main effect of Study repetition was not significant ($F(1, 51) = 3.49$, MSE = .01, $p < .07$) but was of little interest relative to the Group × Study repetition interaction.

The interactions were pursued with a 2 (Item type) × 2 (Study repetition) repeated measures ANOVA for each group. The outcomes were similar for the older adult

and young adult-short deadline groups. Both analyses produced significant effects of Item type and Repetition without a significant interaction (older adult, Item type: $F(1,17) = 36.00$, MSE = .01; Study repetition, $F(1,17) = 24.73$, MSE = .004; young adult-short deadline, Item type: $F(1,17) = 8.28$, MSE = .01; Study repetition: $F(1,17) = 6.51$, MSE = .02). In contrast, for the young adult-long deadline group only the effect of study repetition was at the conventional level of significance ($F(1,17) = 4.31$, MSE = .02, $p = .053$).

The findings corroborate those of Jacoby and colleagues (Jacoby, 1999b; Jacoby et al., 1998; McElree et al., 1999) in which study repetition was found to increase familiarity and recollection. In the current experiment, in the absence of recollection for the modality in which words or elements of words were presented, an increase in familiarity led to an increase in exclusion errors for the older adult and the young adult-short deadline groups. In contrast, the young adult-long deadline group was able to use an increase in recollection to counter the increase in familiarity, resulting in fewer exclusion errors for the repeated study conditions. The young adults in the long deadline group showed that modality source information related to a conjunction lure could be retrieved and utilized to circumvent an error. However, this benefit emerged only after the components had been repeated.

One novel aspect of the study concerns a comparison of the familiarity engendered by the components of a conjunction lure to that by an exact replica of a test word (i.e., an intact word). For conjunction lures the components are both old, but the word itself is new. For a read word, both components of the word are old and appear in the same context (i.e., the word itself is old). The exclusion criterion requires a "new" response in either of these conditions to be correct. Thus the experiment offers a window into the influence of familiarity for these different cases. The older adult group and young adult-short deadline group committed more errors to read words compared to conjunction lures. This result indicates that read words (i.e., intact words) produced a greater influence on familiarity relative to the components of conjunction lures. The difference in familiarity for read words (exact replicas) and conjunction words probably reflects the reliance on repeated conceptual information for read words but not conjunction lures (cf., Toth, 1996).

A second novel aspect of the study concerns the ability to reject words based on the source modality information. For the young adult-long deadline group, the exclusion error rates for read words and conjunction words were similar. Because the exclusion error rates were higher for read words compared to conjunction words for the older adult and the young adult-short deadline groups, we infer that the similar exclusion error rates for read word and conjunction words for the young adults—long deadline shows a better overall ability to retrieve source modality information for words actually presented in the study phase compared to words with an overlap of morpheme constituents. In other words, greater familiarity from the intact read words compared to that from the components (only) pushed the older adult and young adult-short deadline groups to commit more errors in the absence of recollection, but, by way of inference, relatively strong recollection for the presentation modality of the intact read words allowed the young adult-long deadline group to

overcome that relatively strong influence of familiarity to avoid a similarly high number of errors.

4. General discussion

Experiment 1 showed that feature and conjunction error rates on compound words are similar for young and older adults and that study repetition can increase feature and conjunction error rates across these age groups. These similarities occurred despite age-related or response deadline differences in old–new discrimination. Thus, while recollection for old words was affected by normal aging processes or a deadline manipulation, the familiarity underlying feature and conjunction effects was not affected. Recollection-based rejections of conjunction lures, which have been demonstrated in certain conditions when participants are informed of the presence of feature and conjunction test lures (Jones & Atchley, 2002; Jones & Jacoby, 2001; Lampinen et al., 2004), arguably did not occur in Experiment 1. In fact, to help reach our first aim of the research we purposefully omitted information on feature and conjunction lures from the test instructions to ensure that recollection-based rejections would not be a factor. Elimination of this possibility was meant to provide a relatively clean evaluation of the idea that familiarity effects do not diminish with age. Again, the findings support this idea and extend prior findings with different verbal materials (Kroll et al., 1996; Rubin et al., 1999).

We were specifically interested in whether modality source information could be retrieved despite the difficulty of recollecting a parent word when confronted with a conjunction lure. Although Marsh et al. (2002) suggested that retrieval of source information could promote errors, we reasoned that conditions could be created where retrieval of source information could obviate the need to recollect the actual parent words to prevent an error. The critical condition involved study repetition in a particular modality and instruction to exclude words presented in that modality. For our purposes, the combination of Experiments 1 and 2 demonstrate that, when participants are faced with a feature or conjunction lure but uninformed of the presence of such lures, recollection of a parent word is likely to fail (probably because no attempt to recollect a parent has occurred), but retrieval of relevant modality source information can still occur. The key difference in the test instructions for the two experiments was that modality source information provided a basis for exclusion from "old" judgments on the test in Experiment 2, whereas no such information was given in Experiment 1. Given the results of Experiment 1, it seems quite likely that participants in Experiment 2 would have judged a conjunction lure as "old" on a standard old–new recognition test. However, retrieval of modality source information circumvented a conjunction exclusion error. The ability of young adults to recollect some information in conjunction conditions is revealing. One may recollect or know that one has *seen* something similar to the test word in an earlier study phase without recollecting the studied item(s) itself.

Finally, we suspected that modality source information, which would allow young adults in a long deadline condition to evade an error, would be inaccessible to older

adults and that this relative deficit would leave older adults more susceptible to the effects of familiarity. Both the hit scores and the exclusion scores in Experiment 2 showed that recollection of the presentation modality of studied items was possible for young adults but not older adults. Because of their inability to retrieve modality source information, older adults, as well as young adults under time pressure to respond quickly, were left reliant on familiarity. This reliance on familiarity was manifested in an increase in exclusion errors for read words, and this increase in errors extended to conjunction words. Young adults given time to retrieve source modality information showed a decrease in exclusion errors for both read words and conjunction words. These findings extend prior results on familiarity-based errors (Jacoby, 1999b; Jacoby et al., 1998) to conjunction words and to a new set of materials. For older adults and for young adults with heavy response time pressure, conjunction errors appear to be modality-free.

The results from the present experiments are consistent with other research on aging where study repetition has increased the likelihood of a memory error for older, but not younger, adults (Bartlett, Strater, & Fulton, 1991; Light, Patterson, Chung, & Healy, in press; Schacter, Koutstaal, Johnson, Gross, & Angell, 1997; for other related results, see Jennings & Jacoby, 1997; Kensinger & Schacter, 1999) and support the idea that older adults exhibit a normal, age-related decline in controlled, but not automatic, memory processes (e.g., Jacoby, 1999a, 1999b; Jennings & Jacoby, 1997; Light et al., in press). The results also parallel those where remember judgments (Gardiner, 1988; Tulving, 1985) have been taken as a measure of recollection. During retrieval, older adults have fewer recollective experiences for details of study episodes compared to younger adults (for discussions of this literature, see Light, Prull, La Voie, & Healy, 2000; Yonelinas, 2002). In the current instances, recollection for both actual item information and modality source information was shown to be relatively poor in older adults. The results on the hit scores for both experiments show that the older adults suffered a relative inability to use recollection for the recognition of actual items. The exclusion results in Experiment 2 show how this deficit includes modality source information.

The conjunction paradigm bears a resemblance to work where pairs of unrelated words (*shoe–paper*, *town–cloud*) are studied but sometimes rearranged (*shoe–cloud*) on the test (e.g., Clark & Gronlund, 1996). A distinction between items and associations has been the focus of the work with word pairs, but this particular distinction does not appear to be applied easily to compound word or syllable conjunctions because there is no clear associative information in the conjunction paradigm (Jones & Jacoby, 2001). Instead, the rearrangements in the conjunction word paradigm are more at the item level, though the source of familiarity underlying the conjunction errors remains unspecified (Jones et al., 2001).

However, memory for associative information is thought to rely more on recollection than is memory for item information (Hockley & Consoli, 1999; Yonelinas, 1997, 2002). A recent study by Light et al. (in press) manipulated study repetition for unrelated word pairs. Similar to our present findings in the conjunction paradigm, older adults and young adults with a short response deadline showed an

increase in rearrangement errors (also see Jones, in press; Jones & Jacoby, 2001), indicating that study repetition increases familiarity. Study repetition has not produced a consistent net decrease in conjunction (Jones, in press; Jones & Jacoby, 2001) or rearrangement errors (Kelley & Wixted, 2001; Light et al., in press, Experiment 2) for young adults who have been given a relatively long time to respond on the test (for an exception see Light et al., in press, Experiment 1). Thus, in both paradigms, recollection-based rejection appears to occur but not be strong. One important goal for future research is to determine how memory performance, and hence underlying processes, for conjunctions and word pair rearrangements might differ.

4.1. Alternative theories

4.1.1. Feature-based theories

One proposal is that representations of the elements (features) of a stimulus are formed during encoding. These feature representations are either miscombined during encoding (Kroll et al., 1996) or retrieval (Reinitz et al., 1992, 1996) to produce conjunction errors. These feature-based approaches currently do not account for feature errors above chance (Jones & Jacoby, 2001; Rubin et al., 1999) and appear limited to individuals with hippocampal damage when the to-be-conjoined components of study words appear close together in time (Kroll et al., 1996) or to normal individuals when the to-be-conjoined components occur simultaneously or in alternation in the same study trial (a feature bundling account; Reinitz & Hannigan, 2001, 2004; though see Underwood et al., 1976, for an alternative explanation for compound word lures). None of the conditions that have supported the feature bundling account were included in the current experiments, and our results do not offer clear support for any of the feature-based approaches. In addition, we note that proponents of one feature-based approach, which is now described as a feature bundling account, have conceded that familiarity provides a basis for conjunction effects (Reinitz & Hannigan, 2001, 2004). Areas in need of attention to advance the feature-based approach include a clear definition of features (i.e., what constitutes a feature or feature representation) and a fuller description of feature bundle characteristics.

4.1.2. Fuzzy trace theory

Memory errors are accounted for in the fuzzy trace theory by a reliance on gist information or traces, which follow a probe-to-trace feature overlap rule (Brainerd et al., 1995). Errors can be avoided through the retrieval of a verbatim trace, which follows a probe-to-trace identity rule (Brainerd et al., 1995; though see Wallace et al., 2000). Gist traces typically have been described with an emphasis on conceptual (semantic) information, whereas verbatim traces have been described as containing exact perceptual information (Brainerd, Reyna, & Mojardin, 1999). In contrast, feature and conjunction effects have been obtained with a wide variety of materials, including nonverbal materials (Kroll et al., 1996; Reinitz, Morrisey, & Demb, 1994; Searcy, Bartlett, & Memon, 1999), and there is only one instance where feature

and conjunction errors have been shown to be influenced by conceptual information (Ghatala et al., 1978). Thus, a stringent adherence to gist information as conceptual would limit fuzzy trace theory to errors that are committed outside of the feature-conjunction paradigm. A broader definition of gist information could allow fuzzy trace theory to account for feature and conjunction errors, but it would make the theory less amenable to testing and more difficult to distinguish from other dual-process theories.

4.1.3. Source monitoring framework

In the source monitoring framework, an emphasis is placed on the difference between accuracy for old–new and explicit source judgments (Johnson, Hashtroudi, & Lindsay, 1993). Direct questions of source are meant to push participants to monitor the aspects or details of an earlier experience. Older adults have often (though not always) exhibited a relative decrement in source identification (e.g., Hashtroudi, Johnson, & Chrosniak, 1989; Johnson, De Leonardis, Hashtroudi, & Ferguson, 1995), and the direct solicitation of source judgments has been found to reduce errors relative to an exclusion paradigm (e.g., Multhaup, 1995, with the false fame paradigm). Marsh et al. (2002) attempted to reduce conjunction error rates by querying young participants directly on source information. However, the solicitation of source judgments did not reduce conjunction errors, and the authors concluded that retrieval of source information could fuel the errors.

Retrieval of source modality information and familiarity were placed in opposition in our second experiment to emphasize the utilization of source modality. Retrieval failures for source modality information revealed familiarity-based errors but retrieval successes resulted in evasion of those errors. For young adults with relatively little time pressure to respond quickly, retrieval of source modality information served to reduce, instead of compound, conjunction errors. If we had used the typical source judgment procedure in that experiment, then it is possible that the conjunction error rates might not have been affected (e.g., Marsh et al., 2002), leaving us to wonder whether young adults could put any advantage in modality source identification to use. Of course, this suggestion should be treated with caution because our experiment included repeated study words to make modality information more retrievable, whereas Marsh and colleagues' did not. Study repetition was a critical factor in our experiment, and the use of study repetition in combination with direct source modality judgments could produce similar results. Future work on the conjunction paradigm that directly compares the two methods would make a valuable contribution to the understanding of how participants utilize study modality information in different circumstances. Another method that could prove helpful is one that solicits remember (recollection)/know judgments for items judged as "new" (Jones, in press). In this new procedure, participants indicate whether they just know that an item was not presented in the study phase or recollect that a similar but different word appeared in the study phase. Thus, the procedure offers the opportunity to understand more directly why participants make correct rejections.

5. Conclusion

The hit scores and the two effects of repetition on exclusion error rates in the current studies provide evidence for recollection failures due to normal aging. However, it is important to note that an agreement between hits and exclusion errors may not always be the case. Sometimes recognition tests show unimpaired performance by older adults compared to their young counterparts (e.g., Craik & McDowd, 1987; Dywan & Jacoby, 1990; Rabinowitz, 1984). One possible reason for such results is that young and older adults may rely on familiarity (or an accessibility bias) and recollection differentially. For older adults, a reliance on familiarity may sometimes mask failures in recollection. As has been emphasized by Jacoby and his colleagues (Jacoby, 1999a, 1999b; Jennings & Jacoby, 1997), the importance of an exclusion task is that it creates an opportunity to reveal a deficit in recollection that might not be observed on a standard recognition memory test. The value of the exclusion task in Experiment 2 was that it showed young adults could recollect source modality information connected to the components of the conjunction lures, but normal older adults could not. Thus, the results provide evidence that conjunction errors are modality-free errors for older adults.

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