Psychology and Aging
1997, Vol. 12, No. 2, 352–361

0882-7974/97/$3.00

An Opposition Procedure for Detecting Age-Related Deficits in Recollection: Telling Effects of Repetition

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In 2 experiments, the advantages of placing automatic and consciously controlled memory processes in opposition to study age-related declines in memory performance were examined. Drawing on the common memory failure of mistakenly repeating oneself, a task was designed in which participants had to rely on conscious memory (recollection) to avoid repetition errors. Recollection proved to be severely affected by aging; older adults showed significantly more repetition errors than did younger adults, even at very short retention intervals. These results contrast sharply with the small age differences found with a standard recognition test. Moreover, L. L. Jacoby's (1991) process-dissociation procedure (Experiment 2) showed that automatic memory processes were unaffected with age and could support recognition performance in older adults. The advantages of the *opposition* procedure for studying memory in older adults relative to other measures are discussed.

"Did I tell you this story before?" As one becomes older, it appears that such questions are asked more frequently, or should be, to avoid the unwanted repetitions that are produced by age-related deficits in memory. Described anecdotally as a common error, there is also empirical evidence indicating that elderly people tend to repeat themselves on memory tests (e.g., Koriat, Ben-Zur, & Sheffer, 1988). These types of errors can be understood by examining the influence of automatic and consciously controlled memory processes. Automatic processing has been described as a fast, unaware process that is under the control of stimuli rather than intention (e.g., Hasher & Zacks, 1979; Posner & Snyder, 1975; Schneider & Shiffrin, 1977), whereas consciously controlled memory is aware and intentional (Jacoby, 1991; Klatzky, 1984; Logan, 1989).

In the case of repetitive story telling, automatic influences from an earlier recounting of a story lead it to come easily to mind, such that it seems appropriate for the particular audience. If these influences of memory are not successfully opposed by conscious recollection that the story was already told, it is repeated. Such errors clearly signify a deficit in recollection, but more important, they indicate the severity of that deficit. For instance, one would be far more concerned about an elderly relative who repeats a story after only 5 min than a relative who repeats his- or herself after 1 week. To measure changes in memory associated with age, we mimicked this storytelling example to determine the length of the interval required to show age differences in repetition errors. The length of this interval provides a measure of the degree of age-related change in recollection; if differences are found when this interval is very short, age-related deficits can be considered severe.

For our procedure, automatic influences of memory were opposed by recollection, as in the case of avoiding repetition. We expected this *opposition* procedure to provide an index of age-related deficits in recollection that would be more sensitive than that afforded by standard tests of memory. Tests of recognition memory, for example, sometimes reveal only small or even nonsignificant age differences in performance (e.g., Craik & McDowd, 1987; Dywan & Jacoby, 1990; Rabinowitz, 1984). Automatic influences of memory, rather than serving as the source of errors seen in the repetition example, can facilitate performance on standard recognition tests—an item can be selected as old either because of automatic influences of memory (familiarity) or on the basis of recollection (e.g., Jacoby & Dallas, 1981; Mandler, 1980). Consequently, correct responding that is due to familiarity may mask a deficit in recollection (e.g., Jacoby, Toth, & Yonelinas, 1993). By placing automatic and consciously controlled processes in opposition, we can examine age-related declines in recollection that are unaided by automatic processing.

The task used in our experiments is a refinement of the opposition procedure used in *false fame* studies to examine age-related differences in memory (Dywan & Jacoby, 1990; Jennings & Jacoby, 1993). In the first phase of those experiments, elderly and young adults read a list of nonfamous names, which were later mixed with famous and new nonfamous names and presented for fame judgments. Participants were correctly informed that all of the names they read in the first list were nonfamous, so if they recognized a name on the fame test as one from the first list, they could be certain that the name was nonfamous. Earlier reading of a nonfamous name was expected to increase its familiarity, making it more likely that the name

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This work was partially supported by Natural Sciences and Engineering Research Council of Canada Grants and by a Canadian Aging Research Network Grant.

We thank Ann Hollingshead and Sharyn Kreuger for their assistance with these experiments.

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would later mistakenly be called *famous*. This automatic influence of memory, however, was opposed by conscious recollection that the name had appeared in the first list (the source of the name's familiarity). Given this arrangement, any increase in the probability of mistakenly calling an old nonfamous name famous must result from an automatic influence of memory for its prior presentation because conscious recollection would produce an opposite effect. Elderly participants showed a deficit in recollection compared with younger participants by being more likely to mistakenly respond famous to old nonfamous names. Younger participants used conscious recollection of the prior presentation to reject old nonfamous names, whereas elderly participants were less able to do so.

The false fame studies are very useful in revealing age differences in conscious memory (recollection). Using a similar rationale, we examined age-related declines in recollection more carefully to determine the severity of such deficits. Our experiments were modeled after the situation of avoiding repeating oneself across increasing delays. Young and elderly adults were asked to study a list of words and were then given a recognition test in which old and new words were presented with each *new* word repeated once, after a certain number of intervening items occurred (e.g., 4, 12, 24, or 48 intervening items). Participants were asked to identify old words; that is, they were to respond yes to earlier studied words but no to the new words regardless of whether it was their first or second presentation in the test list. Further, participants were explicitly warned that new words would be repeated in the test list and were told that if a word occurred earlier in the test list they could be certain that it was not from the study phase and should be rejected. That is, new words were repeated in the test list, but earlier studied words occurred only once.

The repeated presentation of new test items served a function similar to that of repeated stories. Recollection of the prior presentation of an item in the test list should allow its rejection, whereas familiarity gained from the prior presentation of the test item would have an opposite effect—leading to mistaken recognition of the repeated test word as earlier studied. We refer to falsely recognizing the second presentation of a new test item as a *repetition error*. We expected repetition errors to increase as the interval between the first presentation of a new test item and its repetition was lengthened. As in the case of inappropriate story repetition, a decrease in the probability of recollection across time was expected to result in more repetition errors.

Our repetition procedure is similar to a task used by Koriat et al. (1988, Experiment 3) to examine output monitoring in older adults. In their study, participants were asked to learn a list of words, then were given a memory test in which they were shown studied and nonstudied words twice, and were asked to classify items as *studied or nonstudied* and *first or second test presentation*. Older adults proved to be poor at distinguishing between the first and second presentation for each item type. That is, their most frequent error was classifying already tested items as newly presented. Our task extends Koriat et al.'s procedure in two important respects. First, by focusing on the tendency to mistake repeated new items as studied, we could examine the influence of automatic and consciously controlled memory on performance, which should clarify the processes underlying misclassifications in Koriat et al.'s task. Second, our lag procedure allows us to examine age-related changes in recollection across different delay intervals.

Unlike the facilitation conditions seen in standard memory tests, in which both automatic and conscious memory produce the same effect on performance, an opposition condition provides a better means of examining automatic and consciously controlled processes by revealing their distinctive influences as they operate concurrently. Results of Experiment 1 showed that our opposition procedure reveals age-related deficits in recollection that were much larger than those detected by a standard recognition test. However, to truly measure recollection, one must separately estimate the contribution of both recollection and automatic influences to performance. In Experiment 2 we replicated the results of Experiment 1 and used a process-dissociation procedure (Jacoby, 1991) to examine separately age-related differences in automatic and consciously controlled memory processes.

Experiments 1A and 1B

In Experiments 1A and 1B, young and elderly adults were asked to read aloud and learn a list of words. They were then given a recognition test in which they were shown old and new words with each new word repeated once, after a varying number of intervening items (lag intervals) occurred. In Experiment 1A, new words were repeated after 4, 12, 24, or 48 intervening items occurred; in Experiment 1B, the lag intervals were 0, 1, 3, and 7 intervening items. For both experiments, participants were asked to identify study words; they were to respond yes to study words but were to respond no to new words and repetitions.

The repetitions are the critical items. The first presentation of these new items should increase their familiarity (Fischler & Juola, 1971; Underwood & Freund, 1970), and participants may misattribute this familiarity to the prior study phase, confuse repetitions with old words, and mistakenly respond yes (a repetition error). However, if participants can recollect the source of a word's initial presentation (study vs. test) or recollect that they have already responded to a word, then any influence of familiarity is opposed, and participants will correctly respond no. Familiarity is an automatic influence of memory—participants reveal memory for the first presentation of repeated new items without conscious intention through their errors (responding yes), whereas recollection can be seen as a controlled, intentional use of memory that prevents errors on this task (responding no).

Telling participants to respond no to repetitions places familiarity and recollection in opposition in a manner similar to the storytelling example and the false fame task described above. This condition can be referred to as an *exclusion* test because recollection serves to exclude repeated words and prevent repetition errors. Failures of recollection can then be inferred from the probability of mistakenly responding yes to repetitions in comparison with the probability of mistakenly responding yes to new items. Responding yes to new items indicates the base-rate level of familiarity associated with words without prior task exposure. If participants respond yes to significantly more repetitions than new items, one can conclude that they were unable to recollect the first presentation of a repeated item but were influenced by an increase in familiarity.

In Experiment 1A, it was expected that recollection should become more difficult with lengthening intervals. Consequently, elderly adults should respond yes to more repetitions than new words as lag intervals increase, and they should answer yes to more repetitions than the young adults at the longer intervals. In Experiment 1B, the same task was used with shorter lag intervals: Zero, one, three, or seven intervening items occurred between the first and second presentation of a repeated item. The Lag 0 condition was included to determine if older participants were capable of following the task instructions. For that condition, a word was repeated immediately after its initial presentation so participants should not fail to recollect the word. If the older participants made many repetition errors in this condition, it suggests that they were unable to comprehend the instructions. However, if repetition errors did not occur until some intervening items were presented, one could be certain that participants understood the task. Ensuring that task instructions are comprehensible is important given that concern has been raised about the difficulty of prior versions of the opposition technique (Graf & Komatsu, 1994). The lag intervals of one, three, and seven items were used to trace changes in performance across short, gradually increasing delays. Because Experiment 1B was designed to test older adults' ability to follow task instructions and trace declines in recollection with delay, there was no need to test young adults.

Method

Participants. Sixteen young adults, ranging in age from 18 to 23 years (M = 19.9), participated in Experiment 1A for credit in an introductory psychology course. They had 14.1 mean years of education and an average score of 73% on the Mill Hill Vocabulary test (Raven, 1965). Two groups of 17 older adults participated in Experiments 1A and 1B. They were McMaster alumni who volunteered their services and were all community-dwelling residents in self-reported good health. Data from 1 elderly participant in Experiment 1A were lost because of computer failure, and data from 1 participant in Experiment 1B were excluded because of the participant's expressed failure to understand instructions. The remaining 16 participants in Experiment 1A ranged in age from 63 to 88 years (M = 72.4). They had an average of 17.4 years of education, which was significantly more than the younger group, $F(1, 30) = 36.46$, $MSE = 2.407$, and an average score of 81% on the Mill Hill Vocabulary test, which was also significantly greater than the young adults, $F(1, 30) = 7.51$, $MSE = 0.007$. The 16 participants in Experiment 1B ranged in age from 60 to 84 years (M = 73.2). They had an average of 17.5 years of education and an average score of 85% on the Mill Hill Vocabulary test.

Materials. The stimuli consisted of 120 concrete nouns, ranging from four to eight letters in length, which were obtained from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982). Sixty words were presented at study and comprised the old items for the recognition test. The remaining 60 words were only presented at test and served as new items. Two study formats were devised so that words presented at study in one condition occurred only at test in the second condition. In addition, the 60 new words were divided into four subgroups of 15 items. These 15-item groups of words were designed to have equal distributions of frequency of occurrence in the language, imagibility ratings, concreteness ratings, number of letters per word, and number of words beginning with a given letter.

Each group of 15 test words was used for a different lag condition. In Experiment 1A, words in one group were presented then repeated after 4 intervening words had occurred; the second group of words was repeated after 12 intervening words and so on. Four test formats were developed by rotating these groups through each lag condition so that every group of words was tested as a repetition after 4, 12, 24, and 48 intervening items across the experiment. In short, eight formats of the experiment were devised so that each word was presented as an old or new item, and every new item was repeated at each lag interval. The study and test list orders were random, with the restriction that no more than 3 items of a given type (study word or test item type) could occur consecutively. The same procedure for counterbalancing was applied to Experiment 1B with the shorter lag intervals.

Procedure. An Apple IIE computer was interfaced with a monochrome green monitor to present the stimuli. The character size of the stimuli was approximately 5.7 × 6.6 mm. Words were presented in lowercase letters in the center of the screen. In the study phase each word was presented for 2 s, and participants were told to read each word aloud and try to remember it for the recognition test that would follow.

Immediately after the study phase, participants were given the exclusion test. In Experiment 1A, words were repeated after 4, 12, 24, or 48 intervening items had occurred between the first and second presentation of the word and after 0, 1, 3, or 7 intervening items in Experiment 1B. Words were shown one at a time, and participants had to decide if a word was one they had read aloud. They were to respond yes if a word was one they had read aloud and no if a word was new or repeated. They were informed that study words would not be repeated, and if they recognized a word as one they had already seen in the test list then they should respond no. Participants responded by pressing one of two keys.

The significance level for all statistical tests was set at $p < .05$. Tests revealing significant main effects are not reported when variables producing those main effects entered into significant interactions.

Results and Discussion

In Experiment 1A, a 2 (group: young vs. elderly) × 2 (item type: old vs. new) analysis of variance (ANOVA) revealed no significant main effect of age on the probability of correctly recognizing old words or the first presentation of new words (Table 1), $F(1, 30) = 1.29$, $MSE = 0.017$, nor a significant

Table 1
Observed Probabilities of Responding Yes to Old, New, and Repetition Items at Each Lag Interval in Experiment 1

Group	Old	New	Lag intervals			
			Experiment 1A			
			4	12	24	48
Younger						
M	.63	.08	.05	.06	.06	.13
SD	.19	.08	.08	.07	.06	.08
Older						
M	.54	.09	.23	.25	.27	.25
SD	.11	.09	.15	.16	.19	.14
			Experiment 1B			
			0	1	3	7
Older						
M	.60	.11	.004	.07	.17	.27
SD	.23	.15	.02	.11	.15	.21

Age × Item interaction, $F(1, 30) = 2.38$, $MSE = 0.015$. The elderly and young adults did not differ significantly in their ability to recognize words that they had read aloud, although the young adults did tend to recognize slightly more words.[1] More important, the two groups were equally capable of identifying new words they had not seen at study. Both groups made few yes responses to those items. The older adults in Experiment 1B (Table 1) showed a similar level of performance as those tested in Experiment 1A.

As mentioned earlier, the probability of responding yes to new items is important because it is a measure of the base-rate familiarity for items that have not been shown during the experiment. Therefore, any increase in the probability of responding yes to repeated items from their first (new item) to second presentation (repetition) can be taken as evidence for an increase in familiarity because of prior presentation. Moreover, finding no age difference in the probability of responding yes to new items shows that there is no age difference in bias or willingness to accept familiar words as old.

The more important effect involves comparing performance between new items and repetitions for young and elderly adults. Mistakenly responding yes to more repetitions than new items shows that participants failed to recollect the first presentation of those items yet they found the items familiar, and repetition errors provide evidence for an age-related decline in recollection. A 2 (group: young vs. elderly) × 5 (item type: new vs. Lag 4 vs. Lag 12 vs. Lag 24 vs. Lag 48) ANOVA examining the probability of responding yes to new items versus repetitions at each lag revealed a significant interaction of Age × Item, $F(4, 120) = 5.90$, $MSE = 0.009$. A post hoc Newman–Keuls test exploring this interaction showed that young adults were equally likely to respond yes to new items and repetitions at each of the four lag conditions (Table 1). That is, the young made few repetition errors regardless of the number of intervening items between the first and second presentation of an item, although errors did rise slightly at Lag 48. In contrast, the elderly adults responded yes to significantly more repetitions than new items at all four lags. Although they were as capable as the young adults in discriminating new from old words, they were less able to discern repetitions from old words. They responded yes to far more repetitions than the young adults at all four lags, suggesting poorer recollection for the initial presentation of repeated items. Furthermore, their recollection was equally weak across all four lag conditions. The ability of the older adults to recollect repetitions seemed to have reached its maximum decline after only four intervening words.

A difference between the age groups after four intervening items was unexpected because it was thought that age differences would gradually increase as lags increased. Instead, there was a large discrepancy found in performance between the two groups at a very short interval, which did not change. One potential explanation for these results is that the older adults may have misunderstood or had difficulty complying with the task instructions. However, the results of Experiment 1B suggest that this possibility is unlikely.

In Experiment 1B, a one-way ANOVA comparing the probability of mistakenly responding yes to new items versus repetitions at Lags 0, 1, 3, and 7 revealed a significant effect of lag for older adults, $F(4, 60) = 15.75$, $MSE = 0.010$. A post hoc Newman–Keuls test indicated that the older adults responded yes to significantly fewer repetitions than new items at Lag 0. They were also inclined to respond yes to fewer repetitions than new items at Lag 1, although this difference was not significant. However, more repetitions than new words invoked a yes response at Lags 3 and 7. This difference was only significant at Lag 7 (Table 1), although there was a significant drop in performance between Lags 1 and 3.

These findings suggest that the age-related decline in recollection seen in Experiment 1A cannot be attributed to a failure to understand the task. The elderly adults chose fewer repetitions at Lag 0 than new items, showing that they were able to follow instructions. Recollection appears to begin showing an age-related decline when one to four items intervene between presentation of a new word and its repetition. In addition, these declines seem to asymptote after four intervening items have occurred, remaining constant for up to at least 48 intervening words.

For older adults, the ability to recollect repetition items declined rapidly after only a few items intervened between their first and second presentation. This finding presents a striking contrast to the results obtained with the old and new items. Asking participants to respond yes to the study items and no to the new items incorporates a standard recognition test into the opposition task. In our experiment, the standard recognition test revealed a small but nonsignificant age difference in performance. It is possible that this difference may have proved significant with a more powerful design, but even so, if we had drawn conclusions about the memory ability of older participants from this measure of memory, we would have concluded that age deficits were small (less than 10%). However, an examination of our opposition condition (exclusion) indicates that the age-related decline in recollection was far more pronounced.

In Experiments 1A and 1B, deficits in recollection were measured with the opposition condition; however, this approach rests on a hidden assumption that automatic memory influences were unaffected by age. Suppose we had found that elderly participants were no more likely to make repetition errors than they were to falsely recognize new words. One possible explanation for this finding would be that their ability to avoid repetition errors reflects accurate recollection of repeated test words. A second possibility, though, would be that repeated test words were no more familiar than new test words. That is, a deficit in automatic influences of memory (familiarity) would also prevent repetition errors. An increased tendency to produce repetition errors on our task suggests that automatic influences of memory are somewhat preserved with age and that elderly participants did suffer a deficit in recollection relative to young adults. However, to measure accurately the decline in recollection, we must also measure automatic influences of memory. Age-related differences in repetition errors could underestimate deficits in recollection unless automatic influences are invariant with age.

In Experiment 2, we adopted Jacoby's (1991) process-disso-

[1] It is possible that the power of our analysis was not strong enough to detect a significant age difference in standard recognition performance. Nonetheless, the magnitude of this difference is small and does not hint at the large memory impairment seen in recollection with the opposition procedure. The same point holds true for Experiment 2.

ciation procedure to estimate separately the contributions of recollection and automatic memory processing (familiarity) to performance in our repetition–lag paradigm. The process-dissociation procedure requires two test conditions: an opposition condition, such as our exclusion test, in which automatic and conscious processes have opposite influences on performance, and a facilitation condition, in which automatic and consciously controlled processes produce the same effect on performance. By combining these conditions it is possible to tease apart the contribution of each process (Jacoby, 1991).

Experiment 2

For the repetition–lag version of the process-dissociation procedure, young and older adults were again asked to study a list of words but were then given two recognition tests. Both tests consisted of old and new words with each new word repeated once, after 0, 3, or 12 intervening items occurred. The exclusion test was the same as that used in Experiment 1. Participants were asked to identify study words; they were to respond yes to old words but no to new items and repetitions. Again, telling participants to respond no to repetitions places familiarity and recollection in opposition. For the exclusion test (Exc), a repeated word will be mistaken for old only if it is sufficiently familiar (F) and not recollected (1 − R) as presented earlier at test. The probability of responding yes to a repetition on the exclusion task can be represented as $\text{Exc} = F(1 - R)$.

In contrast, for the facilitation recognition test (inclusion), we told participants to respond yes to any words that they had seen before in the experiment (words they had read aloud and repetitions of new test words). In this case, both recollection and familiarity would lead to correctly responding yes to repetitions. For an inclusion test (Inc), participants could respond yes to a repetition either because it was recollected as being presented earlier on the test list (R) or, because, although recollection failed, the word was sufficiently familiar ($F[1 - R]$). The probability of responding yes to a repetition on the inclusion test can be represented as $\text{Inc} = R + F(1 - R)$.

Combining results from the inclusion and exclusion test conditions allows one to estimate separately the effects of consciously controlled and automatic processes for each lag condition. Subtracting the probability of responding yes to a repetition on the exclusion test from that probability on the inclusion test provides an estimate of the probability of recollection: $R = \text{Inc} - \text{Exc}$. Given an estimate of recollection, an estimate of familiarity can be computed by simple algebra, dividing the probability of responding yes to a repetition in the exclusion condition (Exc) by the estimated probability of a failure in recollection $(1 - R)$: $F = \text{Exc}/(1 - R)$.

One cannot separate the contributions of automatic and conscious processing without making an assumption about the relationship between the two types of processes. One of the strongest assumptions underlying the process-dissociation procedure is that automatic and consciously controlled uses of memory act independently. To justify that assumption, Jacoby and colleagues have shown dissociations between the two processes, finding factors that affect one process while leaving the other process unchanged (e.g., Jacoby, 1991; Jacoby, Yonelinas, & Jennings, 1997; Jennings & Jacoby, 1993).

Because the process-dissociation procedure allows separate estimation of the contributions of automatic (familiarity) and consciously controlled (recollection) processes, the influence of age on each process can be examined separately to see if one or both processes are affected. Estimates for each process can be calculated for both age groups at each lag condition, allowing one to determine how rapidly the recollective process declines across test intervals with age. In addition, one can establish whether familiarity changes as test intervals increase. Previous research examining the effects of age on automatic memory processing with the process-dissociation procedure has shown that automatic influences of memory are invariant across age (Jacoby, Jennings, & Hay, 1996; Jennings & Jacoby, 1993). Given that familiarity remains impervious to age while the ability to recollect deteriorates, familiarity also may not decline across lags as rapidly as recollection.

Method

Participants. Twenty-five younger adults and 30 older adults participated in the experiment. The young participants were enrolled in an introductory psychology course and took part for course credit. The elderly adults were McMaster alumni who volunteered their services. They were all community-dwelling residents with self-reported good health. Data from 1 young adult and 5 elderly adults were discarded because these participants were unable to follow task instructions, as evidenced by their own admission or their performance in the Lag 0 condition. In addition, data from 1 elderly adult were lost because of computer failure. The remaining 24 young adults ranged in age from 18 to 21 years ($M = 19.1$). They had 13.3 mean years of education and an average score of 69% on the Mill Hill Vocabulary test. The remaining 24 older adults ranged in age from 63 to 80 years ($M = 71.5$). They had an average of 17.0 years of education, which was significantly more than the younger group, $F(1, 46) = 105.46$, $MSE = 1.512$, and an average score of 87% on the Mill Hill Vocabulary test, which was also significantly greater than the young adults, $F(1, 46) = 52.55$, $MSE = 0.007$.

Materials. The stimuli were 180 concrete nouns ranging from four to eight letters in length, which were obtained from the Toronto Word Pool (Friendly et al., 1982). Ninety words were shown at study and comprised the old items for the two recognition tests. The remaining 90 words were only presented at test and served as new items. Two study formats were devised by rotating the old and new items so that words presented at study in one condition occurred only at test in the second condition.

Two recognition test lists were constructed (inclusion and exclusion). Each list consisted of 45 old and 45 new items. In addition, the new words were divided into three groups of 15 items. These 15-item groups of words were designed to have equal distributions of frequency of occurrence in the language, imagibility ratings, concreteness ratings, number of letters per word, and number of words beginning with a particular first letter.

Each group of 15 words was tested in a different lag condition. One group was presented and repeated after zero intervening items; the second group was presented after three intervening items and so on. Three test formats were developed by rotating every group through each lag condition so that items repeated after zero intervening items in one format were repeated after three intervening items in a second format and so forth. In addition, these lists were rotated so that each item was tested in both the inclusion and exclusion conditions across the experiment. In brief, 12 formats of the experiment were devised so that each word was presented as an old or new item, every new item was repeated at each test lag interval, and all items occurred in both the inclusion and exclusion tests. Each test list order was random with the restriction that no more than three items of a given type (study word or test item type) could occur consecutively.

Procedure. An Apple IIE computer was interfaced with a monochrome green monitor to present the stimuli. The character size of the stimuli was approximately 5.7 × 6.6 mm. Words were presented in lowercase letters in the center of the screen. For the study phase, each word was presented for 2 s, and participants were asked to read the words aloud and remember them for a recognition memory test.

Immediately after the study presentation, participants were given the inclusion and exclusion tests. Testing order was counterbalanced across the experiment. Each test consisted of 45 old words from study and 45 new words. In addition, the new words were repeated at one of three different lags. Words were repeated after 0, 3, or 12 intervening items had occurred between the first and second presentation of the repetition word. For the inclusion test, participants were to respond yes to any word they had seen before (from study or test) and no if a word was a new word they had not yet viewed. For the exclusion test, participants were again to respond yes if a word was one they had read aloud and no if a word was new or a repetition. Participants responded by pressing one of two keys.

The significance level for all statistical tests was set at $p < .05$. Tests revealing significant main effects are not reported when variables producing those main effects entered into significant interactions.

Results and Discussion

As in Experiment 1, a 2 (group: young vs. elderly) × 2 (item type: old vs. new) × 2 (test condition: inclusion vs. exclusion) ANOVA showed that there was no effect of age on the probability of correctly recognizing old and new words (Table 2), $F(1, 46) = 1.16$, $MSE = 0.050$, no significant Age × Item interaction, $F(1, 46) = 1.81$, $MSE = 0.017$, nor a significant Age × Test × Item interaction, $F(1, 46) = 1.60$, $MSE = 0.011$. Elderly and young adults did not differ significantly in the ability to recognize words they had read aloud or to identify new words, although older adults were inclined to mistakenly respond yes to slightly more new words than the young. Because of this tendency, we reexamined the probability of correctly recognizing old items when false alarms were taken into account by subtracting false alarms from hits. A 2 (group: young vs. elderly) × 2 (test: inclusion vs. exclusion) ANOVA revealed no significant effect of age, $F(1, 46) = 1.76$, $MSE = 0.034$, nor a significant Age × Test interaction, $F(1, 46) = 1.58$, $MSE = 0.023$, confirming that any age differences in recognition were statistically nonsignificant. In addition, because group differences in the tendency to respond yes to new items can signify a difference in bias or willingness to accept familiar words as old, base-rate responding was taken into account when interpreting the familiarity estimates obtained from the process-dissociation procedure (see Yonelinas, Regehr, & Jacoby, 1995). However, there was no concern about bias differences across the two test conditions because the probability of responding yes to new items remained equivalent across the inclusion and exclusion tests within each group.

Table 2
Observed Probabilities of Responding Yes to Old, New, and Repetition Items at Each Lag Interval for Both Test Conditions in Experiment 2

			Lag intervals		
Group/Test	Old	New	0	3	12
Younger					
Inc					
M	.63	.09	.98	.96	.94
SD	.21	.08	.04	.06	.09
Exc					
M	.63	.10	.02	.06	.12
SD	.13	.10	.03	.06	.09
Older					
Inc					
M	.61	.17	.96	.91	.88
SD	.22	.16	.05	.08	.11
Exc					
M	.66	.15	.02	.21	.36
SD	.16	.11	.04	.16	.23

Note. Inc = inclusion; Exc = exclusion.

The probability of correctly identifying new items versus repetitions was examined with a 2 (group: young vs. elderly) × 2 (test condition: inclusion vs. exclusion) × 4 (item type: new vs. Lag 0 vs. Lag 3 vs. Lag 12) ANOVA. This analysis revealed a significant Age × Test × Item interaction, $F(3, 138) = 19.47$, $MSE = 0.008$, which was interpreted through the use of a post hoc Newman–Keuls test. We found that the interaction between age and lag interval differed across the two test conditions (see Table 2). For the exclusion test, both groups responded yes to fewer repetitions than new items in the Lag 0 condition, indicating that both groups were following instructions. In addition, there was no significant difference in the probability of responding yes to new items versus repetitions at Lag 3 for either group. However, there was a significant age difference in the probability of saying yes at Lag 3. The elderly adults responded yes to slightly more repetitions than new items, whereas the young responded yes to slightly fewer repetitions than new items. This discrepancy between the groups increased at Lag 12. The young adults continued to answer yes to a comparable number of new items and repetitions, but the elderly adults said yes to significantly more repetitions than new items and significantly more repetitions than the young adults.

Given failures in recollection are manifest in the probability of responding yes to repetitions, the above-mentioned pattern of results shows that younger adults demonstrated better recollection than the older adults at Lags 3 and 12. Similar to Experiment 1A, this result is particularly striking when contrasted with the pattern of performance for old and new words. When we consider this standard recognition component of our task, we only see evidence for a small age discrepancy in memory, despite the large deficit in recollection found when only three items intervened between the first and second presentation of a repeated word.

The results of the inclusion task were similar to the standard recognition findings. The post hoc Newman–Keuls test of the Age × Test × Item interaction showed that the young adults were proficient at correctly answering yes to repetitions on the inclusion test, an ability that did not diminish significantly across the three lags. The elderly adults were also as capable as the young at including repetitions at Lags 0 and 3. However, the older adults' performance declined slightly from Lag 3 to

Lag 12, producing a small but significant group difference at Lag 12.

Considering only the results of the inclusion task or the standard recognition test could suggest that memory is slightly deficient in older adults; however, the results of the exclusion test revealed a strong age-related impairment. This latter interpretation is supported by estimates of recollection calculated from the previously described equations. The probability of recollection (Table 3) was estimated as the difference between the probability of responding yes to repetitions in the inclusion and exclusion test conditions. A two-way ANOVA testing the influence of Age (young vs. elderly) × Lag (0 vs. 3 vs. 12) on the recollection estimates revealed a significant interaction, $F(2, 92) = 13.5$, $MSE = 0.016$. Examination of this interaction in which a post hoc Newman–Keuls test was used revealed no significant age difference in the probability of basing a decision on recollection at Lag 0, but it did reveal significant age differences in recollection at Lags 3 and 12. Moreover, the older adults showed a significant decrease in recollection across each of the three lags. Performance for the young, however, only differed significantly between Lag 0 and Lag 12.

The probability of responding on the basis of familiarity (automatic influences) was calculated for the longer lags (Table 3). Estimates at Lag 0 could not be calculated because most participants showed a probability of correctly responding yes in inclusion of one and a probability of mistakenly responding yes in exclusion of zero. This makes recollection equal to one, which makes the estimate of familiarity undefined. Even for the longer lags, scores for 2 elderly participants and 6 young adults could not be analyzed for the same reason. Those 8 participants all had at least one familiarity estimate at Lag 3 or Lag 12 that was undefined. A 2 (group: young vs. elderly) × 2 (lag: 3 vs. 12) ANOVA on familiarity estimates revealed no significant effect of age, lag, or a significant Age × Lag interaction (all $Fs < 1$). The estimated probability of responding yes to repetitions because of added familiarity (Table 3) was significantly higher than the probability of responding yes to new words (baseline familiarity; see Table 2) for young adults at Lags 3 and 12, $t(17) = 5.74$ and $t(17) = 6.76$, respectively. The elderly adults showed the same effect, $t(21) = 9.24$ and $t(21) = 12.36$, for Lags 3 and 12, respectively.

Table 3
Estimated Probabilities of Basing a Decision on Recollection and Familiarity at Each Lag Interval in Experiment 2

	Lag intervals					
	Recollection			Familiarity		
Group	0	3	12	0	3	12
Younger						
M	.96	.90	.83	—	.64	.66
SD	.04	.07	.13	—	.44	.39
Older						
M	.94	.71	.51	—	.67	.74
SD	.06	.18	.28	—	.29	.23

Note. Dashes indicate that estimates of familiarity at Lag 0 could not be calculated because most participants showed a probability of correctly responding yes in inclusion of one and a probability of mistakenly responding yes in exclusion of zero. Recollection is thus equal to one, which makes familiarity undefined.

Age differences in responding on the basis of familiarity can also be examined by removing the baseline probability of responding yes to new words from the familiarity estimates. The simplest method of doing so involves averaging the baseline probability across the two test conditions and then subtracting that baseline from each estimate of familiarity. After calculating these new values for each group, the means for the younger and older adults at Lag 3 (.55 and .51, respectively) and at Lag 12 (.56 and .58, respectively) are even more similar than when the familiarity values (Table 3) are examined. This change stems from the tendency for young participants to respond yes to fewer new words on the basis of familiarity than the older participants.

It should be noted that subtracting baseline responding from a familiarity estimate is a relatively unsophisticated correction procedure that does not reflect the nonlinear relationship between the two measures. A more precise method for correction entails applying a signal-detection procedure to the familiarity estimates to take baseline responding into account (Yonelinas et al., 1995). Doing so showed that familiarity, as measured by d', did not differ significantly between the young (2.65) and elderly adults (1.98) at Lag 3, $F(1, 38) = 2.12$, $MSE = 2.070$, nor did it differ significantly between the younger (2.60) and older group (2.04) at Lag 12, $F(1, 38) = 2.06$, $MSE = 1.516$.[2]

Our results replicate previous work showing that automatic influences of memory do not decrease with age (Jennings & Jacoby, 1993). The ability of elderly adults to use familiarity also remained constant across test intervals, suggesting that familiarity is robust to both age and interference. In contrast, elderly adults showed a sharp decline in recollection when only a few intervening items occurred between the first and second presentation of a repeated item, whereas younger adults did not show a significant change.

General Discussion

Our repetition–lag paradigm provides a useful means of assessing the severity of deficits in recollection, showing that age-

[2] Because participants were given two test conditions there is always the concern that order effects may influence estimates of recollection and familiarity, although testing order was counterbalanced within each group. To examine order effects, we carried out a 2 (group: young vs. elderly) × 2 (order: exclusion tested first vs. exclusion tested second) × 2 (test: inclusion vs. exclusion) × 4 (item type: new vs. Lag 0 vs. Lag 3 vs. Lag 12) ANOVA. We found a significant Age × Order × Test × Item interaction. A post hoc Newman–Keuls test of this interaction revealed that the older adults in the exclusion-tested-first group showed significantly worse exclusion performance at Lags 3 and 12 than their older exclusion-tested-second counterparts. This result does not seem to be an effect of test order per se, because the exclusion-first group should be comparable to the older adults from Experiments 1A and 1B, when, in fact, the exclusion-first group performed more poorly. The older adults in the exclusion-first group seem to have worse recollection. To ensure that this group difference was not unduly influencing our results, we reanalyzed our recollection and familiarity data as a function of order. We found that both groups of older adults showed poorer recollection than the younger adults but preserved familiarity, confirming our original analyses.

related declines in conscious memory were surprisingly pronounced. Older adults revealed significantly worse recollection than younger adults when only three items intervened between the first presentation of a test word and its repetition. Moreover, the elderly adults' performance seemed to decline across one to four intervening items and then remain constant for at least 48 intervening words.

This opposition technique provides a more precise measure of memory than a standard recognition test. The large deficit in recollection revealed by repetition errors contrasted strongly with our finding that age-related differences in recognition memory performance were small. For a standard test of recognition memory, automatic influences of memory (familiarity) facilitate performance by serving as an alternative basis to recollection for correctly accepting an item as old. Similarly, for the inclusion test used in Experiment 2, participants could correctly respond yes on the basis of either familiarity or recollection. The recognition data for study items and inclusion task performance revealed only small age-related differences. Evaluating those results as a measure of recollection could lead one to believe that consciously controlled processing remains relatively intact with age. In contrast, the opposition condition offered far more information about age effects than these facilitation tasks, in which reliance on familiarity masked a true age-related change in recollection.

Use of an opposition procedure can produce unambiguous evidence for a deficit in recollection. However, to measure accurately the magnitude of such impairments, one must have a means of separately examining the contributions of recollection and automatic influences of memory. The deficit in recollection measured by repetition errors would be underestimated if older adults also suffered a decline in automatic influences of memory. However, results from the process-dissociation procedure (Experiment 2) agreed with those from earlier experiments (e.g., Jacoby et al., 1996; Jennings & Jacoby, 1993), showing that despite deficits in recollection, automatic influences were invariant across age. The lack of an age effect on familiarity-based responding is consistent with the results of indirect tests that reveal nonsignificant age differences in performance (Light & Albertson, 1989; Light & Singh, 1987; Mitchell, 1989). Moreover, our earlier findings (Jennings & Jacoby, 1993), and those obtained here, suggest that indirect tests showing age deficits (Chiarello & Hoyer, 1988; Davis et al., 1990; Howard, Shaw, & Heisy, 1986; Rose, Yesavage, Hill, & Bower, 1986) likely reflect contamination by conscious memory. As suggested by LaVoie and Light (1994), indirect tests that require the production of a response such as category exemplar generation or word stem completion may be more prone to this type of influence.

Problems With the Process-Dissociation Procedure?

The utility of the process-dissociation procedure has been controversial (e.g., Curran & Hintzman, 1995; Graf & Komatsu, 1994), and criticisms against it are discussed thoroughly elsewhere (Jacoby, Begg, & Toth, 1997; Yonelinas & Jacoby, 1996). Particularly contentious has been the assumption that recollection and automatic influences of memory serve as independent bases for responding. However, evidence for that assumption has been strong. Jacoby, Yonelinas, et al. (1997) reviewed the results of 20 studies in which the process-dissociation procedure had been used and found that variables traditionally associated with reduced cognitive control, such as dividing attention at study, each decreased estimates of consciously controlled processes but left automatic influences unchanged. Similarly, manipulations that influence automatic processing in a different manner than that shown with consciously controlled processing have also been discovered (Hay & Jacoby, 1996; Jacoby et al., 1993).

Another criticism against the process-dissociation procedure, as mentioned earlier, has involved task instructions, particularly when used with memory-impaired populations. The idea is that these instructions are too difficult, and process estimates may be confounded by a participant's inability to perform the inclusion–exclusion tasks. However, as was shown here by use of the Lag 0 condition, it is possible to ascertain comprehension of instructions separately from memory performance.

These various complexities and criticisms can largely be avoided if one's goal is to show the existence of a deficit in recollection, rather than measuring its actual probability with the process-dissociation procedure. By setting automatic and conscious processing in opposition for the exclusion task, we clearly showed pronounced differences in conscious processing with age. That result was in clear contrast with the inclusion test (Experiment 2) in which participants did not need to rely on conscious memory.

Memory for Source Information

Age-related differences in our exclusion task agree with findings obtained by Koriat et al. (1988). As described earlier, Koriat et al. asked participants to classify test items as old or new and first or second test presentation. They found that older participants had greater difficulty distinguishing between first and second presentations than between old and new items, a result that corresponds to our data. Age-related impairments in recollection should make it difficult to decide whether a test item has already occurred (first or second presentation), whereas familiarity would help in old–new classifications. Further, if one looks specifically at the tendency of Koriat et al.'s participants to classify repeated new items as old (when recollection and familiarity are opposed), one can see results identical to ours; the older adults made more of these errors than the younger adults.

Finding age-related differences in repetition errors is closely related to evidence of age deficits in source or context memory (for review, see Spencer & Raz, 1995). A repetition error, as defined here, can reflect a failure of source memory; if participants recollect that a repeated item was first presented at test rather than at study, then recollection will oppose any feeling of familiarity, and participants will respond correctly on the exclusion task. Given the source nature of our measure of recollection, one could argue that the difference between repetition errors as a memory measure and standard recognition tests is merely the difference between source and item memory. However, examining repetition errors differs significantly from the form of tests traditionally used to measure memory for source. Standard tests of source memory explicitly instruct participants to report the source of information, rather than examining the monitoring of source as part of some ongoing task. Yet monitoring of source while engaging in other activities is critical for guiding everyday behavior (Dywan & Jacoby, 1990). For example, consider the discrepancy between the task of avoiding repeatedly telling a story while engaging in conversation and the task of listing all the people to whom one has told the story. This difference and its importance are illustrated by results from a study by Multhaup (1995).

Multhaup (1995) failed to find a false fame effect with older adults when participants were explicitly asked whether a test name was one they had read earlier, one that was actually famous, or one that was new. The technique of directly questioning source contrasts with the procedure used in the false fame studies described in the introduction. For those studies, participants judged names as famous, monitoring source spontaneously as they performed the task. Multhaup's results suggest that increasing the structure or support of a task by directly asking participants about source can benefit older adults' performance, but doing so might also underestimate their memory impairment. Experiments designed to look for memory deficits with older adults in which they are explicitly asked to make source judgments may lead one to overlook the most critical aspect of their problem—an inability to monitor in unstructured situations.

Retention Interval

The repetition–lag paradigm further extends traditional tests of source memory by examining recollection across a variety of test intervals and showing that recollection can be impaired with age at a very short delay. These data are consistent with other continuous recognition paradigms that include lag manipulations. For example, Lehman and Mellinger (1986) found that performance on a continuous recognition test in which participants were asked to remember presentation modality showed a significant age difference when the retention interval was only five items. Similarly, Le Breck and Baron (1987) found that older adults showed impairments on a continuous recognition test for four-character letter number combinations (i.e., A24G) when four items intervened between study and test. In keeping with our results, these studies suggest that elderly adults show pronounced memory deficits at short study–test intervals when they cannot use automatic processes to make a correct decision. For Le Breck and Baron's task, it seems likely that after several trials with the four-character letter–number stimuli, most combinations will appear similar, such that familiarity will not aid memory performance. Likewise, automatic influences probably do not play a strong role in Lehman and Mellinger's modality task. In short, age deficits at brief intervals seem to arise when participants need to rely on consciously controlled memory, regardless of whether they must recollect item or source information.

Future Directions

In summary, Experiments 1 and 2 suggest that aging impairs consciously controlled memory processing but leaves automatic memory processes intact. Moreover, age-related deficits in conscious processing are quite severe. Older adults are impaired relative to younger adults when only three words have occurred between the first and second presentation of a test item. The pattern of dissociations found here has also been obtained with a group of moderate-to-severe closed-head injured patients by using a similar technique. They, too, show deficits in recollection but preserved automatic processing (Ste-Marie, Jennings, & Finlayson, 1996). More important, the pattern of recollection found with the closed-head injured group is identical to that found with older adults, revealing a deficit when only three items have intervened between presentation and test. Finding that head trauma produces a similar degree of impairment as aging makes the decline in recollection seen here even more striking. Moreover, it suggests that the repetition–lag paradigm may be a sensitive index of memory deficits that can be used to examine a variety of memory disorders.

Studying other memory-impaired populations with this opposition procedure may help shed light on the mechanisms underlying age-related deficits in recollection. Consider again the similarity between our repetition paradigm and tests of source memory. Impairments of source memory have been related to frontal lobe deficits in patient populations (e.g., Schacter, 1987; Schacter, Harbluk, & McLachlan, 1984; Shimamura & Squire, 1987) and older adults (e.g., Craik, Morris, Morris, & Loewen, 1990; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991). If impaired frontal functioning is associated with poor source memory, it may also underlie age-related differences in recollection. Investigating the relationship between our measure of recollection and frontal functioning may help to better characterize memory deficits in older adults.

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Received June 3, 1996
Revision received December 12, 1996
Accepted December 12, 1996 ■