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# Adult Age Differences in Temporal and Item Memory

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Three experiments tested whether the relationship between age differences in temporal and item memory depends on the degree to which the item memory measure relies on memory for context. The authors predicted a stronger relationship of temporal memory to free recall than to recognition memory. Results showed that age differences in temporal memory could be eliminated after controlling for free recall but not recognition memory performance. Under some conditions recognition memory accounted for a significant portion of age-related variance in temporal memory. These results challenge past research that has interpreted age differences in temporal and item memory as independent and suggest that a generalized decline in context memory may underlie reduced performance in older adults on all types of memory tests.

Memory for temporal information has long been considered important to the study of how people learn and retain information. It became a major topic of investigation starting in the 1960s, as researchers looked at the role of order information in free recall and in proactive interference (e.g., Estes, 1972; Underwood, 1969; Wickelgren, 1966). Over time, work by cognitive psychologists and neuropsychologists has led to the view that temporal memory is a distinct variety of memory, separate from memory for item information and similar to other types of context memory such as source memory, reality monitoring, and memory for other peripheral features of the learning episode. In common with other forms of context memory, temporal memory involves the encoding of features other than the central informational content of a learning episode and the associative binding of those contextual features with item information.

In the field of cognitive aging, close to 20 studies of temporal memory have been conducted, showing age differences on tests of relative as well as absolute temporal memory (Cabeza, Anderson, Houle, Mangels, & Nyberg, 2000; Fabiani & Friedman, 1997; Kahana, Howard, & Zaromb, 2002; Kausler, Lichty, & Davis, 1985; Kausler & Phillips, 1989; Kausler, Salthouse, & Saults, 1988; Kausler & Wiley, 1990; McCormack, 1982, 1984; Naveh-Benjamin, 1990; Newman, Allen, & Kaszniak, 2001; Schmitter-Edgecombe & Simpson, 2001; Trott, Friedman, Fabiani, Ritter, & Snodgrass, 1999; Trott, Friedman, Ritter, & Fabiani, 1997; but for exceptions, see McCormack, 1981; Perlmutter, Metzger, Nezworski, & Miller, 1981; Wiley & Kausler, 1993). Effects of age are evident using list discrimination techniques, in which participants indicate to which of two lists studied stimuli belong; recency judgment tests, in which participants must select the most recently presented stimuli in test items constructed from pairs of studied stimuli; and serial order reconstruction tests, which require participants to organize a set of studied stimuli into the order in which they were initially presented. Furthermore, age differences remain stable across manipulations that affect the overall level of performance. For instance, giving intentional rather than incidental memory instructions either has no effect or else improves temporal memory, but the patterns of results are equivalent for old and young (Kausler et al., 1985; Kausler & Phillips, 1989; Schmitter-Edgecombe & Simpson, 2001). Similarly, on recency judgment tasks, performance varies with the temporal distance between items to the same extent for older and younger adults (Fabiani & Friedman, 1997; Masden & Kesner, 1995; Perlmutter et al., 1981). Manipulations of study time and of the delay between study and test also show the same pattern for young and old (Perlmutter et al., 1981). Overall, the existing literature indicates that temporal memory remains qualitatively constant across the life span and that age differences represent a quantitative decrease in temporal memory.

Few studies have focused on information-processing explanations for age differences in temporal memory (but see Maylor, Vousden, & Brown, 1999). Research on other types of context memory, however, has concluded that age differences represent a decrease in the probability of associating items with relevant contextual information. This explanation has been supported with respect to memory for source and for associations between items and features such as color or location (Bayen, Phelps, & Spaniol, 2000; Chalfonte & Johnson, 1996; Glisky, Rubin, & Davidson,

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2001; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000). Naveh-Benjamin (2000) has taken this explanation one step further, suggesting that reduced context memory reflects a generalized decline in associative memory processes, affecting associations between items as well as between items and context.

The goal of the present set of experiments was to test one implication of the hypothesis that age differences in temporal memory stem from an overall reduction in the ability to associate item and contextual information. More specifically, if reduced temporal memory is part of a general decline in context memory, then the relationship between age differences in temporal and item memory should depend on the extent to which the item memory test requires memory for contextual information. Age differences on temporal memory tests should be strongly related to age differences on item memory tests that depend heavily on memory for context and less strongly related to age differences on item memory tests with less reliance on context memory. Consider, for instance, the role of contextual information in free recall and recognition memory tests. On a free recall test, individuals must generate their own cues because no retrieval cues are present. Contextual information, such as associations between items, temporal order, and attributes of the environment, is commonly assumed to be used for this purpose (e.g., Graf & Mandler, 1984). Such contextual information may contribute to recognition memory as well, but a large body of research has demonstrated that unlike free recall, performance also relies on the retrieval of item representations involving minimal contextual elaboration (Jacoby, 1991; Mandler, 1991; Yonelinas, 2002). Thus, contextual memory plays a larger role in free recall than recognition memory, and age-related declines in temporal memory should be more closely related to age differences in the former than the latter, even after accounting for the direct contribution of temporal order information to free recall.

At present there is a dearth of data on the relationship between age differences in temporal and item memory. Nevertheless, generally it has been assumed that the two types of age differences are independent of one another. This assumption has been based in large part on the evidence from neurological patients that temporal and item memory rely on different parts of the brain, with temporal memory dependent on prefrontal cortex and item memory dependent on medial temporal lobe structures (e.g., Jurado, Junque, Vendrell, Treserras, & Grafman, 1998; Mangels, 1997; Marks & Cermak, 1998; Milner, Corsi, & Leonard, 1991; Shimamura, Janowsky, & Squire, 1990). The fact that older adults are believed to show differential loss of function in the frontal lobes (West, 1996) argues for a dissociation between age differences in the two types of memory. There is also evidence that some experimental manipulations have different effects on age differences for item and context memory (Spencer & Raz, 1995).

What evidence there is regarding the relationship of age differences in temporal and item memory rests almost entirely on studies using recognition memory tests to measure item memory. A number of such studies have found age differences in temporal memory when there are no age differences in recognition memory (Cabeza et al., 2000; Parkin, Hunkin, & Walter, 1995) or when temporal memory performance is conditionalized on recognition accuracy (Trott et al., 1997, 1999). Studies covarying recognition memory in statistical analyses of temporal memory similarly have found robust age-related reductions in temporal memory independent of recognition memory ability (Newman et al., 2001). In addition, aging studies examining correlations between temporal and recognition memory have generally failed to find significant associations between them (Fabiani & Friedman, 1997; Parkin et al., 1995; Schmitter-Edgecombe & Simpson, 2001). Taken together, these studies are consistent in their conclusions that age differences in temporal memory occur above and beyond age differences in recognition memory and, more important, are independent of recognition memory.

With respect to the relationship between age differences in free recall and temporal memory, there are unfortunately very few studies. One study has reported reduced temporal memory but intact recall of a series of activities in a group of young–old participants and no correlation between temporal memory and an unrelated word recall test in either young or old participants (Schmitter-Edgecombe & Simpson, 2001). In contrast, an earlier study found a significant correlation between temporal memory and cued recall, as measured by paired associate learning (Kausler et al., 1988). Thus, at present, what little data are available reveal inconsistent findings.

Despite the paucity of data regarding the relationship of age differences in temporal and item memory, there is substantial evidence from research with younger adults for a closer relationship of temporal memory to free recall than to recognition memory. Thus, there are many studies that show dissociable effects of experimental manipulations on item and temporal memory tests, but these dissociations are generally observed when item memory is measured by recognition memory and not when it is measured by free recall tests (DeLosh & McDaniel, 1996; Lee & Estes, 1977; Mulligan, 2001; Murdock & vom Saal, 1976; Nairne, Riegler, & Serra, 1991; Poirier & Saint-Aubin, 1996; for a review, see Brown, Preece, & Hulme, 2000). For example, generating as compared with reading stimuli at the time of study tends to have opposite effects on recognition memory and temporal memory but similar effects on free recall and temporal memory (Mulligan, 2001; Nairne et al., 1991). In addition, telling study participants to prepare for a free recall test leads to better temporal memory than instructing participants to prepare for a recognition memory test (Leonard & Whitten, 1983). Furthermore, even for recognition memory tests, the relationship to temporal memory differs for stimuli classified as *remembered* rather than *known*, with better temporal memory for the former (Hintzman, 2001). The latter finding is consistent with the notion that the *remember* component of recognition memory involves more knowledge of contextual information than simple familiarity. Overall, the relationship between temporal memory and item memory in younger adults is consistently stronger when measures of item memory require contextual information.

In sum, existing studies indicate that the relationship between temporal and item memory varies as a function of the degree to which the tests of item memory tap contextual knowledge. Free recall tests, which rely heavily on memory for contextual information, show a consistently stronger relationship to temporal memory than do recognition memory tests, which depend to a certain extent on context memory but also rely on item familiarity. This pattern is best demonstrated by studies with younger adults, as there are too few studies of this question in the cognitive aging literature.

The present set of studies was designed to further examine the relationship between age differences in temporal and item memory. We first tested the hypothesis that if older adults experience a generalized decline in context memory, then age differences in free recall and temporal memory will be strongly related. Thus, age effects in temporal memory should be greatly reduced or eliminated after accounting for age differences in free recall. Experiment 1 tested this prediction, using both an experimental condition that equated free recall in young and old as well as statistical methods that examined age differences in temporal memory while controlling for age differences in free recall. We also evaluated the role of temporal order in free recall, to rule out the possibility that relationships between the two measures of memory were due solely to participants' use of temporal information to organize recall.

The second hypothesis we tested was that age differences on temporal memory tests should be only weakly related to recognition memory ability, because the latter is less dependent on context memory. Thus, age differences in temporal memory should occur even after controlling for the impact of recognition memory. Experiments 2 and 3 focused on this prediction, using experimental and statistical control methods to equate recognition memory across younger and older adults.

## Experiment 1

Experiment 1 examined age differences in performance on temporal memory and free recall tests and the relationship between them. Our strategy was to present a series of study lists and have participants complete serial order reconstruction tests on one half of them and free recall tests on the other half. In each case we presented words for study at two different presentation rates (i.e., 1 s per word and 4 s per word). On the basis of previous literature (for a review, see Craik & Jennings, 1992), we expected age differences on both types of tests and for both presentation rates. We tested the prediction that age differences in temporal memory would be reduced after controlling for free recall performance in two ways. First, we compared younger and older adults' temporal memory under conditions producing equivalent free recall, based on pilot work in our laboratory that indicated an absence of age differences in free recall when comparing young adults at the faster study rate and older adults at the slower rate. Second, we used statistical methods to control for free recall while testing for age differences in temporal memory under both slow and fast study rates. Additional analyses sought to determine whether the relationship between age differences in temporal memory and free recall could be attributed to age differences in the use of serial order information during free recall. As a means of further understanding the relationship between temporal memory and free recall, we also examined the correlations between performance on the two types of memory tests, with the expectation of significant correlations for both young and old.

### Method

*Participants.* Participants were 48 younger and 48 older adults (see Table 1). The younger adults were undergraduate students at the University of North Carolina who participated for credit in an introductory psychology course. The older adults were members of the community recruited through notices and advertisements in local newspapers. They were paid $15 for their participation. Older adults were screened to ensure that only healthy individuals were included. All reported themselves to be in good health and to have normal or corrected-to-normal vision. Exclusion criteria included a history of neurological disorders, serious psychiatric illness, or other major illnesses that could affect cognitive functioning (e.g., heart attacks, diabetes, and lung disease); current consumption of four or more alcoholic drinks a day; and current use of psychoactive medications (e.g., antidepressant and antianxiety medications). Older adults were also screened for dementia by means of the Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) and were required to attain a minimum score of 27 out of 30. All of the participants also completed the Shipley–Hartford Vocabulary test (Shipley, 1940). Older adults performed better than younger adults (see Table 1), $t(94) = 9.4$, $\eta^2 = .48$.

*Design and materials.* Twenty-four study lists were constructed for the memory tests, each consisting of nine words. The words were of medium frequency of occurrence ($M = 32.7$, $SD = 30.1$, range = 6–100 times per million words; Francis & Kučera, 1982) and between four and seven letters in length. They had concreteness values higher than 5 on a scale of 1–7, with 7 being the most concrete ($M = 6.0$, $SD = 0.6$; Paivio, Yuille, & Madigan, 1968; Toglia & Battig, 1978). Care was taken to ensure that words were from different semantic categories and were not meaningfully

Table 1
*Characteristics of Older and Younger Adults*

| | Age | | Shipley–Hartford Vocabulary Test (max = 40) | | Mini-Mental State Exam (max = 30) | |
|---|---|---|---|---|---|---|
| Group | *M* (*SD*) | Range | *M* (*SD*) | Range | *M* (*SD*) | Range |
| Experiment 1 | | | | | | |
| Older adults | 72.7 (5.1) | 62–84 | 37.4 (2.3) | 30–40 | 29.1 (1.1) | 27–30 |
| Younger adults | 19.8 (2.0) | 18–30 | 32.1 (3.1) | 25–39 | | |
| Experiment 2 | | | | | | |
| Older adults | 69.7 (5.2) | 62–80 | 37.3 (1.7)[a] | 33–40 | 29.5 (0.9) | 27–30 |
| Younger adults | 19.5 (1.2) | 18–23 | — | | | |
| Experiment 3 | | | | | | |
| Older adults | 70.5 (7.2) | 60–87 | 36.5 (2.8) | 29–40 | 29.2 (0.8) | 27–30 |
| Younger adults | 18.8 (1.2) | 18–23 | 31.3 (3.6) | 23–36 | | |

*Note.* The dash indicates that vocabulary scores were unavailable for younger adults. max = maximum.
[a] Vocabulary scores were missing for 3 older adults.

associated. Word lists were counterbalanced such that each list appeared equally often at each presentation rate and in each type of memory test.

*Procedure.* Participants were tested individually. Older adults were administered the MMSE (Folstein et al., 1975) at the beginning of the session. After this, there were no differences in the procedure for younger and older adults. All memory tests were presented on computer monitors, and responses were made in booklets that had a separate page for each list. Participants were instructed to study each list of words for a specified type of memory test, and detailed instructions were provided. For the serial order reconstruction test, participants were given a sample list and three practice lists. In the free recall condition, participants were shown one sample and completed one practice list. All of the participants completed six of each type of test at both the slow and fast presentation rates. The type of memory test and presentation rate were both blocked, and the order of testing was counterbalanced across participants.[1]

In all of the conditions, each list began with an auditory signal and a 2-s "Get Ready" prompt on the computer screen. Words then appeared on the screen one at a time, for either 1 or 4 s.[2] A 500-ms blank was inserted between each word. After the ninth and final word in each list, participants were given a 20-s distraction task during which a three-digit number appeared in the middle of the computer screen every 2 s. The participant's task was to add 1 to each number and say the answer out loud. Following the distraction task, participants completed a memory test. If participants were being tested on the serial order reconstruction test, the nine studied words were re-presented in a different pseudo random order on the computer screen. Participants were asked to write the words on a piece of paper in the order that they were originally presented. If participants were being tested with a free recall test, the screen was cleared and they were told to write down as many words as they remembered, in any order.

Rest breaks were given after every third list and additionally as needed. At the end of the session, participants completed the Shipley–Hartford Vocabulary Test (Shipley, 1940).

## Results

In all of the analyses that follow, the alpha level for rejection of the null hypothesis was set at .05.

*Temporal memory.* To fully explore temporal memory performance on the serial order reconstruction test, we used three measures of temporal memory. One was the proportion of words correctly placed in the original serial position. This score is a measure of absolute temporal memory ability and shows how accurately participants reproduced the order of the original list. Two measures of relative temporal memory abilities were also included. The first was the Asch–Ebenholtz (Asch & Ebenholtz, 1962) index of input–output (I-O) correspondence. It consists of the proportion of pairs of adjacent items placed in the correct relative order. The second comprised the correlation between the serial position of the words at study and a participant's reconstructed list. If a participant had some knowledge of where an item occurred on a list but could not remember its exact position, the I-O index and the correlation of scores should be more sensitive to this knowledge than simply measuring the proportion correct. Performance based on each of these scores is presented in Table 2; however, because statistical analyses of the relative order scores produced the same pattern of results as the absolute order scores, we report only the results of the latter.

Performance on the serial order reconstruction test was analyzed by means of a 2 (age group) × 2 (presentation rate: 1 s vs. 4 s) mixed-factorial analysis of variance (ANOVA), with the latter factor as a within-subjects variable. The ANOVA revealed two significant effects. First, there was a main effect of age group, which indicated that younger adults performed better than older adults, $F(1, 94) = 67.74$, $MSE = 0.05$, $\eta^2 = .42$. Second, there was a main effect of presentation rate, with better performance at the 4-s than the 1-s presentation rate, $F(1, 94) = 186.84$, $MSE = 0.01$, $\eta^2 = .67$. The interaction between age and presentation rate did not approach significance.[3]

*Item memory.* The next analysis examined performance on the free recall tests. The dependent measure was the proportion of

Table 2
*Performance (Proportions Correct) on Temporal and Item Memory Tests in Experiment 1*

| Variable | Older adults *M* (*SD*) | Younger adults *M* (*SD*) |
|---|---|---|
| Temporal memory | | |
| Proportion correct | | |
| 1 s | .32 (.15) | .57 (.19) |
| 4 s | .55 (.20) | .82 (.17) |
| Input–output correspondence | | |
| 1 s | .61 (.09) | .77 (.11) |
| 4 s | .74 (.12) | .90 (.11) |
| Correlation of scores | | |
| 1 s | .50 (.19) | .75 (.19) |
| 4 s | .70 (.19) | .90 (.14) |
| Free recall | | |
| Proportion correct | | |
| 1 s | .24 (.10) | .45 (.14) |
| 4 s | .44 (.15) | .69 (.18) |
| Input–output correspondence | | |
| 1 s | .60 (.30) | .66 (.18) |
| 4 s | .71 (.17) | .71 (.17) |

[1] An additional factor involving the method of presenting stimulus lists was also included to test for effects of breaking up the list into smaller sections. One half of the participants studied the lists in the standard fashion; for the other half, pauses called *temporal markers* divided the study lists into thirds. We hypothesized that the insertion of the temporal markers into the study lists would improve performance for both age groups. This manipulation had no effect on temporal memory performance for either age group, however, and results concerning this variable are not discussed.

[2] Although on average each word was presented for either 1 s or 4 s, the inclusion of the temporal marker factor (see Footnote 1) required some adjustments in the procedure. In the temporal marker condition, 1,500-ms pauses were inserted into each study list after the third, sixth, and ninth words, during which time a blue screen was presented. Because the temporal markers would have increased the total study time of each list by 4,500 ms, the presentation times for each word were adjusted to equate the total study time for the temporal marker and no-temporal marker conditions. Thus, words were presented for 250 ms less in the temporal marker condition (e.g., 750 ms instead of 1 s and 3,750 ms instead of 4 s). Similarly, in the no-temporal marker condition, presentation rates were lengthened by 250 ms (e.g., 1,250 ms instead of 1 s and 4,250 ms instead of 4 s).

[3] Performance was also examined across lists on the serial order reconstruction test to see if the reduced performance of older adults was due to increased proactive interference. An ANOVA that included list number as a variable indicated that neither old nor young showed any change in performance across lists. Thus, there was no proactive interference for either age group.

words correctly recalled (see Table 2). A 2 (age group) × 2 (presentation rate) mixed-factorial ANOVA revealed significant main effects but no interaction. There was a main effect of group, $F(1, 94) = 69.15$, $MSE = 0.04$, $\eta^2 = .42$, with younger adults recalling more words than older adults. There was also a main effect of presentation rate, $F(1, 94) = 347.89$, $MSE = 0.01$, $\eta^2 = .79$, with better recall for the 4-s than the 1-s condition.[4]

*Relationship between temporal and item memory.* The first analyses focused on the pattern of Pearson product–moment correlations between temporal memory and free recall. As expected, these analyses revealed significant correlations for young and old that were moderate in size for both the 1-s and 4-s presentation times conditions (see Table 3).

We used two methods of examining the relationship between age differences in the two types of memory. First, we identified conditions that produced equivalent free recall for older and younger adults. As expected based on pilot data, this occurred when older adults studied the words for 4 s each and younger adults studied the words for 1 s each. A *t* test comparing free recall in these conditions confirmed the absence of age differences between the groups, $t(94) = 0.12$, $p > .10$ (44%–45% correct for each group; see Table 2). Temporal memory performance was then compared using data from these two conditions. The resulting *t* test showed no age differences, $t(94) = 0.69$, $p > .10$ (57% correct for the younger adults vs. 55% correct for the older adults; see Table 2).

A second method involved the use of statistical methods to control for free recall while testing for age differences in temporal memory. The logic of these hierarchical regression analyses was that by controlling the variance shared between item memory and temporal memory, we could then examine any variance remaining that was shared between temporal memory and age. First, a simple regression analysis was computed to show the relationship between temporal memory performance and age group. This analysis revealed that age group alone accounted for 37% of the variance in temporal memory in the 1-s condition and 35% in the 4-s condition. Next, two hierarchical regression models were examined, one for each presentation rate, with temporal memory accuracy as the dependent variable in each (see Table 4). These analyses included free recall performance as a predictor in the first step of each model; this measure of item memory performance accounted for 49% and 51% of the variance in temporal memory for the 1-s and 4-s presentation times, respectively. In the final step, age group was added into each model after free recall. In both of these analyses, age accounted for only 4% of the variance after item memory performance was controlled; this effect, although small, was still significant. Thus, after free recall memory was controlled, the age-related variance in temporal memory was reduced by approximately 89% (i.e., from 37% and 35% to 4%). These results mirror the findings using experimental control of free recall and support the hypothesis of a shared basis for age differences in temporal memory and free recall.

Because memory for temporal information may contribute directly to free recall, it is possible that the association between age differences in temporal memory and free recall can be attributed to age differences in the explicit use of order information during free recall. To test whether this was the case, we calculated the I-O correspondence index of serial order (Asch & Ebenholtz, 1962) for each free recall trial in which at least two words were recalled. These scores were then averaged separately for each study time (see Table 2) and analyzed by means of a 2 (age group) × 2 (presentation time: 1 s vs. 4 s) mixed-factorial ANOVA, with the latter factor as a within-subjects variable. The only significant effect was an effect of presentation time, $F(1, 93) = 8.88$, $MSE = 0.04$, $\eta^2 = .09$, which indicated that participants were more likely to recall words in order in the 4-s presentation rate

Table 4
*Hierarchical Regression Analysis for Variables Predicting Performance on the Serial Order Reconstruction Test in Experiment 1*

| Variable | *B* | *SE B* | $\beta$ |
|---|---|---|---|
| 1-s presentation | | | |
| Step 1 | | | |
| Free recall | .91 | .10 | .70* |
| Step 2 | | | |
| Free recall | .69 | .12 | .53* |
| Age group | .11 | .04 | .26* |
| 4-s presentation | | | |
| Step 1 | | | |
| Free recall | .80 | .09 | .72* |
| Step 2 | | | |
| Free recall | .63 | .10 | .56* |
| Age group | .12 | .04 | .26* |

*Note.* For the 1-s model, for Step 1, $R^2 = .49$; for Step 2, $\Delta R^2 = .04$ ($ps < .05$). For the 4-s model, for Step 1, $R^2 = .51$; for Step 2, $\Delta R^2 = .04$ ($ps < .05$).
* $p < .05$.

Table 3
*Correlations Between Serial Order Reconstruction and Item Memory Tests in Experiments 1, 2, and 3*

| Test of item memory | Older adults | Younger adults |
|---|---|---|
| Experiment 1 | | |
| Free recall, 1 s | .50* | .52* |
| Free recall, 4 s | .51* | .62* |
| Experiment 2 | | |
| Short-list recognition memory | .27 | .15 |
| Long-list recognition memory | .12 | .51* |
| Experiment 3 | | |
| Short-list recognition memory | .43* | .21 |
| Long-list recognition memory | .48* | .03 |

* $p < .05$.

[4] Performance was also examined across lists on the free recall test for evidence of proactive interference with an additional ANOVA that included list number as a factor. Results showed a main effect of list number and a significant three-way interaction between list number, age, and study time. Follow-up tests indicated a performance decline across lists, but the decline was significant only for the 4-s study time condition, and the effect was larger for younger than older adults. Thus, older adults' reduced performance cannot be attributed to increased proactive interference.

condition.[5] Thus, age differences on free recall cannot be attributed to less use of order information by older adults. Similarly, the strong relationship between free recall and serial order reconstruction is not based on overlap in the use of temporal order in the two types of tests.

In sum, Experiment 1 showed significant age differences in temporal memory, with similar patterns of age effects for both absolute and relative measures of temporal memory. Older adults also recalled fewer studied items, as measured by free recall tests. In fact, the size of age effects were similar for item and temporal memory tests ($\eta^2 = .42$, for both). In addition, the two types of memory were significantly related, and age differences in them were not independent. Under conditions in which free recall was equivalent for the age groups, there were no age differences in temporal memory. Thus, after experimentally equating the two groups of participants on free recall, age differences in temporal memory were eliminated. Similarly, when statistical control methods were used, the effects of age on temporal memory were greatly diminished. After accounting for the observed age differences in free recall, the amount of age-related variance in temporal memory performance was reduced by 89%. Additional analyses indicated that the role of order information in free recall could not explain the association between age differences in free recall and temporal memory, as older and younger adults used serial order information to a similar degree on the free recall tests.

The results of this experiment confirmed one of our major predictions, namely that age differences in temporal memory and free recall would show a strong relationship. Given that context memory plays an important role in both types of memory tests, the findings support the hypothesis that age differences in temporal memory may reflect a generalized decline in context memory. Although Experiment 1 did not directly examine the nature of the context memory deficit, the results indicated that giving older adults additional study time enabled them to bring their performance to the level of younger adults receiving less study time. Of particular note was that older adults needed quite a large amount of extra time—several seconds per word—to achieve this result, suggesting that the difficulty is not at the level of perception. A more plausible explanation and one consistent with other studies of age differences in context memory (Bayen et al., 2000; Chalfonte & Johnson, 1996; Glisky et al., 2001; Mitchell et al., 2000) is that older adults used the extra time for binding context to item information. Although increased study times may have also boosted memory for item information, an interpretation in terms of contextual processing seems more compelling, given the importance of context for the temporal memory test and given that participants always knew what type of test to expect.[6]

## Experiment 2

Experiment 2 examined temporal and item memory using recognition memory tests as the measure of the item memory. We predicted age differences in temporal memory, as observed in Experiment 1. Unlike the results for free recall in Experiment 1, however, age effects on recognition memory were expected to be minimal, because recognition memory tends to show relatively small declines with age (Spencer & Raz, 1995). Furthermore, we expected that the amount of variance in temporal memory performance accounted for by age would not be substantially reduced after statistically controlling for recognition memory test performance. Overall, the correlations between temporal memory and recognition memory accuracy were expected to be small and nonsignificant as well.

This experiment included the same serial order reconstruction task as Experiment 1 and added two forced-choice recognition memory conditions. The first of these, referred to as the *short-list recognition memory* condition, tested memory after each 9-word list, as with the temporal memory task. One concern, however, was that performance might be near ceiling for both younger and older adults in recognition memory. Although this would permit us to determine whether a failure to recognize the words could directly explain poor temporal memory performance, we also wished to examine the relationship between temporal and recognition memory in a more general sense, under conditions free of ceiling effects. For this reason, a *long-list recognition memory* condition was included as well. This second recognition memory condition also consisted of a forced-choice recognition test but was administered following the presentation of a list of 54 rather than 9 study words and after a 10-min delay period.

### Method

*Participants.* Participants were 36 younger and 36 older adults (see Table 1). Methods of recruiting and inclusion–exclusion criteria were the same as in Experiment 1. Older adults were paid $10 for their participation. None of the younger or older adults had participated in Experiment 1, but they were similar in terms of demographic variables, including age and health status.

*Design and materials.* This experiment consisted of three types of memory tests (serial order reconstruction, short-list recognition memory, and long-list recognition memory), each of which was administered to all participants.

Eighteen study lists of 9 words each were constructed using criteria very similar to those in Experiment 1. Eighty of the 166 words were the same as those in the previous experiment. All stimuli were nouns of medium frequency of occurrence ($M = 36.2$, $SD = 27.9$, range = 6–150 times per million words; Francis & Kučera, 1982) and between four and seven letters in length. Words had concreteness values higher than 4.4 out of 7 ($M = 6.0$, $SD = 0.5$; Friendly, Franklin, Hoffman, & Rubin, 1982; Gilhooly & Hay, 1977; Gilhooly & Logie, 1980a, 1980b; Paivio et al., 1968; Spreen & Schultz, 1966; Toglia & Battig, 1978). For the recognition

[5] The degrees of freedom reflect that the I-O score could not be calculated for 1 older participant who recalled fewer than two words on all 1-s study time trials. Because I-O scores can only be calculated when at least two words from a list are recalled, we also conducted an ANOVA to test for possible age differences in the number of lists that met this criterion. Results showed fewer such lists for older than younger adults ($M = 4.8$, $SD = 1.1$, vs. $M = 5.7$, $SD = .44$), $F(1, 94) = 29.08$, $MSE = 1.36$, $\eta^2 = .24$, particularly at the 1-s presentation time, $F(1, 94) = 11.66$, $MSE = 0.82$, $\eta^2 = .11$. Thus, the seriation scores were based on fewer data points for older than younger adults and raise the possibility that order information is used less frequently by older adults. Nevertheless, there were no age differences in the number of lists used to calculate the I-O scores for the two conditions that produced equivalent recall, older adults 4-s ($M = 5.5$, $SD = 1.0$) versus younger adults 1-s ($M = 5.4$, $SD = 0.8$), which mitigates against this concern.

[6] Although the ideal situation would be to have an encoding manipulation that selectively increases context memory, most instructional manipulations such as generate–read and levels of processing are likely to affect both context and item memory.

memory tests, a semantically associated foil was selected for each study word (e.g., for the study word *bread*, the foil was *roll*). This was done to increase the difficulty of the recognition test and prevent ceiling effects. Foils were chosen from the Nelson, McEvoy, and Schreiber (1998) norms and were matched for word frequency, concreteness rating, and word length with the studied items.

In the serial order reconstruction and short-list recognition memory test conditions, participants completed six 9-word test lists. For the long-list recognition memory condition, a longer study list was created by combining six of the 9-word lists into a single list of 54 words. The type of memory test was blocked so that participants completed each kind of test before moving onto the next. The order of the tests and the lists was counterbalanced. A rest break occurred after every three lists of the serial order reconstruction test and the short-list recognition memory test conditions.

*Procedure.* The presentation of words for study was for the most part similar to Experiment 1 for the serial order reconstruction and the short-list recognition memory conditions. Unlike Experiment 1, however, presentation rate was not varied, and words were always presented for study at a rate of 2 s per word. Participants were instructed to read each word aloud as it appeared. The study portion of the long-list recognition memory condition was different from the others in that 54 words appeared for study before the memory test was administered. The 20-s distraction task used in Experiment 1 followed presentation of the final study word in all three conditions.

The test portion of the procedure for the serial order reconstruction condition was identical to Experiment 1. For the short-list recognition memory condition, participants completed a forced-choice recognition test after each list. It consisted of nine test trials. On each, two words appeared simultaneously on the computer screen: a studied word and its semantically related foil. Participants had to decide which word they had studied previously. They signaled their response by pressing a key on the keyboard that corresponded to the side of the screen on which the word appeared. For both of these memory tests, participants were shown one sample trial and given three practice trials.

In the long-list recognition memory condition, memory was tested after a filled retention interval lasting approximately 10 min. During this time, several unrelated tasks that did not involve words were administered. At the end of the retention interval, a 54-item forced-choice recognition memory test was given using the same format as in the short-list recognition memory condition.

## Results

*Temporal memory.* As in Experiment 1, three measures of serial order reconstruction performance were calculated for the temporal memory tests: proportion correct, I-O correspondence, and the correlation of scores (see Table 5). As before, the pattern of results was identical for the three measures. Consequently, we report only the analyses of the measure of proportion correct. A *t* test examining age differences on the serial reconstruction test showed that older adults performed significantly worse than younger adults, $t(70) = 4.45$, $\eta^2 = .22$.

*Item memory.* The proportion of words correctly recognized was calculated for both the short-list and long-list recognition memory conditions (see Table 5). The *t* tests showed no age differences on either of the two recognition tests: for the long-list recognition test, $t(70) = 1.57$, $p > .10$, and for the short-list recognition test, $t(70) = 1.38$, $p > .10$. Because accuracy was above 90% in the short-list condition, raising concerns about ceiling effects, we reanalyzed the data after excluding individuals who made fewer than two errors. With the remaining sample (27 young and 31 old), there were again no age differences in accuracy, $t(56) = 0.80$, $p > .10$. A similar reanalysis of the long-list condition, with 32 younger and 35 older adults, also showed no effect of age, $t(65) = 0.96$, $p > .10$. Thus, older and younger adults' item memory performance was equivalent on the recognition memory tests, but age differences were nevertheless observed on the temporal memory test.

Table 5
*Performance (Proportions Correct) on Temporal and Item Memory Tests in Experiments 2 and 3*

| Type of memory test and variable | Older adults *M* (*SD*) | Younger adults *M* (*SD*) |
|---|---|---|
| Experiment 2 | | |
| Temporal memory | | |
| Proportion correct | .36 (.16) | .57 (.23) |
| Input–output correspondence | .65 (.10) | .79 (.12) |
| Correlation of scores | .55 (.22) | .79 (.19) |
| Item memory | | |
| Short-list recognition | .91 (.06) | .93 (.05) |
| Long-list recognition | .81 (.09) | .84 (.09) |
| Experiment 3 | | |
| Temporal memory | | |
| Proportion correct | .28 (.11) | .49 (.16) |
| Input–output correspondence | .60 (.08) | .74 (.08) |
| Correlation of scores | .42 (.20) | .70 (.17) |
| Recency judgment | .52 (.06) | .62 (.11) |
| Item memory | | |
| Short-list recognition | .84 (.07) | .92 (.05) |
| Long-list recognition | .69 (.12) | .79 (.09) |

*Relationship between temporal and item memory.* We examined the relationship between these two types of memory by calculating Pearson product–moment correlation coefficients for each age group (see Table 3). Results indicated nonsignificant correlations in all cases, with the exception of the relationship between temporal memory and long-list recognition memory for younger adults ($r = .51$). None of the other correlations even approached significance ($p$s $> .10$). The pattern remained unchanged when participants who made fewer than two errors were removed from the data analyses.

We examined the relationship between age differences in temporal and item memory by using hierarchical regression analyses to control for the relationship between item and temporal memory. First, a simple regression analysis showed that age group alone accounted for 22% of the variance in temporal memory. Next, two hierarchical regression models were examined, each using temporal memory accuracy as the dependent variable and varying only in the measure of recognition memory—the short-list or long-list condition (see Table 6). In these analyses, the short-list and long-list recognition memory measures were included as predictors in the first step in each model. Results showed that recognition memory accounted for 6% and 15% of the variance in temporal memory performance in each model, respectively. When age group was added into the model after short-list recognition memory performance, the variance accounted for by age was 19%. Age group was still a significant predictor, and the age-related variance in temporal memory was reduced by only 14%, from 22% to 19%,

Table 6
*Hierarchical Regression Analysis for Variables Predicting Performance on the Serial Order Reconstruction Test in Experiment 2*

| Variable | *B* | *SE B* | $\beta$ |
|---|---|---|---|
| Short-list recognition | | | |
| Step 1 | | | |
| Recognition | .98 | .46 | .25* |
| Step 2 | | | |
| Recognition | .70 | .42 | .18 |
| Age group | .20 | .05 | .44* |
| Long-list recognition | | | |
| Step 1 | | | |
| Recognition | .96 | .27 | .39* |
| Step 2 | | | |
| Recognition | .77 | .25 | .31* |
| Age group | .18 | .05 | .41* |

*Note.* For the short-list recognition model, for Step 1, $R^2 = .06$; for Step 2, $\Delta R^2 = .19$ ($ps < .05$). For the long-list recognition model, for Step 1, $R^2 = .15$; for Step 2, $\Delta R^2 = .16$ ($ps < .05$).
* $p < .05$.

after item memory was controlled. Similarly, the variance in temporal memory accounted for by age after controlling for long-list recognition memory performance was 16%, reflecting a reduction of only 27% (i.e., from 22% to 16%). Thus, when recognition memory tests were used as the measure of item memory, age differences in temporal memory appeared largely independent of item memory.

In sum, Experiment 2 showed significant age differences in temporal memory for both absolute and relative measures of performance. There were no differences between young and old in item memory as measured by recognition tests, even when data analyses corrected for possible ceiling effects. Furthermore, the size of the age effect was greater for temporal than recognition memory ($\eta^2 = .22$ vs. $\eta^2 = .03$). Thus, conditions that produced equivalent performance for young and old on recognition memory tests did not eliminate age differences in temporal memory, and reduced temporal memory in older adults could not be attributed directly to an inability to recognize the test stimuli as having been previously studied. Confirmation of this result came from a series of regression analyses showing that controlling for recognition memory performance only had a small effect on the relationship of age to temporal memory. These findings contrast with those from Experiment 1, in which equating younger and older adults on free recall led to the disappearance of almost all age differences in temporal memory.

A secondary finding of Experiment 2 concerned the overall relationship between temporal and item memory. In contrast to Experiment 1, in which there was a significant and moderate-sized correlation between temporal memory and free recall, the correlations involving recognition memory were all small and nonsignificant except for the correlation involving the long-list condition for younger adults. Regression analyses, however, indicated an overall small but significant association between recognition and temporal memory, with 6%–15% of their variance shared. The reason for the single significant correlation in this experiment is not obvious; however, given the results of the regression analyses, conclusions about the lack of significant correlations in the other conditions should be considered only preliminary, because of the possibility that restricted range of recognition memory performance or unreliability of test scores may have precluded detection of relationships between the two types of tests. In addition, the use of semantic foils in the recognition memory test may have reduced the strength of the correlations, if they boosted reliance on semantic knowledge on this test in relation to the temporal memory test. Thus, the present results raise the possibility of an inconsistent, small, but perhaps meaningful relationship between the two types of memory. We take up this issue further in Experiment 3 and the General Discussion.

## Experiment 3

The goal of Experiment 3 was to again examine the relationship between temporal and item memory, using recognition memory tests as the measure of the latter. This experiment sought to replicate and extend Experiment 2, with two changes in methodology. The first change was aimed at increasing the difficulty of the recognition memory test, by creating a measure with a lower mean and larger range of scores. This was done by reducing the presentation rate at the time of study from 2 s to 1 s per word and increasing the delay between study and test in the long-list recognition condition from 10 to 30 min. The second change was to include a recency judgment task as an additional measure of temporal memory to examine the generality of our previous results regarding the relationship between temporal and item memory. In a recency judgment task, each test item is constructed from two previously studied stimuli, and the participant must judge which of the pair was studied more recently. In comparison with the serial order reconstruction test, the decision-making processes involved in responding are less complex than for the serial order reconstruction tests, and the format for testing is more similar to the recognition memory test. Because both types of temporal memory tests require memory for context, however, we predicted similar findings for both temporal memory tests. Thus, we predicted age differences in temporal memory on both the serial order reconstruction and recency judgment tests, and we expected that if age differences in recognition memory were obtained, they would not completely account for these differences.

### Method

*Participants.* Participants were 36 younger and 36 older adults (see Table 1). Methods of recruiting and inclusion–exclusion criteria were the same as in Experiments 1 and 2. Older adults were paid $15 for their participation. None of the participants in Experiment 3 were included in Experiment 1 or 2, but they were similar in terms of demographic variables, including age and health status. Older adults performed better than younger adults on the Shipley–Hartford Vocabulary test, $t(70) = 6.81$, $\eta^2 = .40$.

*Design and materials.* This experiment included four types of memory tests (serial order reconstruction, recency judgment, short-list recognition memory, and long-list recognition memory), each of which was administered to all participants.

The same 18 lists used in Experiment 2 were used in Experiment 3 for the serial order reconstruction and recognition memory tasks, and the lists were counterbalanced across these tasks. As before, participants completed six 9-word test lists in the serial order reconstruction and short-list recognition memory conditions. Fifty-four words were studied in the long-list recognition memory task. Semantically related foils were used again in the recognition memory tests. Ten new lists of nine words each were created for the recency judgment test. These words were similar in linguistic frequency, concreteness, and word length to the words selected for Experiment 2 (frequency: $M = 33.1$, $SD = 30.0$; concreteness: $M = 6.0$, $SD = 0.6$).

The administration of the four types of memory test was blocked so that participants completed each kind of test before moving onto the next, and the order of these tests was counterbalanced. A rest break occurred after every three lists of the serial order reconstruction test and the short-list recognition memory test conditions and after five lists in the recency judgment task.

*Procedure.* Words were presented for study at the rate of 1 s per word in all tests. The procedure for the serial order reconstruction test and short-list recognition memory test was the same as in Experiment 2. The procedure for the long-list recognition test was similar, except that the retention interval was lengthened to approximately 30 min. During this time, participants performed a task that was unrelated to the present experiment and did not involve words.

In the recency judgment test, the procedure for presenting words for study was the same as in the other conditions. Memory for each list was tested with four pairs of words presented one at a time in the center of the monitor. Participants were required to press a button on the keyboard corresponding to the side of the screen on which the word seen most recently was located. The word pairs presented at test were always selected from adjacent items in the study portion of the task. Thus, test pairs for a given list were constructed from one of two possible sets of pairs: either items from Serial Positions 1 and 2, 3 and 4, 5 and 6, and 7 and 8, or else from Serial Positions 2 and 3, 4 and 5, 6 and 7, and 8 and 9. The selection of pairs of words tested from each list and the order in which word pairs appeared during the test were counterbalanced across lists. The position on the computer screen of the more recent word within each pair was also counterbalanced. Participants were shown one sample trial and performed one practice trial to become familiar with the procedure.

## Results

*Temporal memory.* As in Experiments 1 and 2, three measures of serial order reconstruction performance were calculated: proportion correct, I-O correspondence, and the correlation of scores (see Table 5). As in the previous experiments, the pattern of findings was identical for the three measures, and again we report just the statistical results for the measure of proportion correct. A *t* test examining age differences in reconstruction performance showed that older adults performed worse than younger adults, $t(70) = 6.62$, $\eta^2 = .39$.

The dependent measure for the recency judgment task was the proportion correct. On this test of temporal memory, there were again age differences, such that older adults performed worse than younger adults, $t(70) = 4.82$, $\eta^2 = .25$. However, older adults did not perform significantly above chance. Consequently, we did not conduct any further analyses with this test.

*Item memory.* The proportion of words correctly recognized was calculated for both the short-list and long-list forced-choice recognition memory conditions (see Table 5). Older adults performed worse than younger adults on both: short-list condition, $t(70) = 5.20$, $\eta^2 = .28$; long-list condition, $t(70) = 3.98$, $\eta^2 = .18$. It appeared that our goal of creating a recognition memory test that was more difficult also resulted in a test sensitive to the effects of age. Thus, in Experiment 3 there were age differences in both temporal and item memory.

*Relationship between temporal and item memory.* Pearson product–moment correlations between serial order reconstruction performance and each measure of recognition memory were calculated for each age group. Results indicated nonsignificant correlations for younger adults ($ps > .10$) but significant correlations for older adults (for the short-list recognition test, $r = .43$, and for the long-list recognition test, $r = .48$; see Table 3). These results were unchanged when we reanalyzed the data from the short-list recognition condition after excluding participants who made fewer than two errors ($n = 31$ younger and 35 older adults for this analysis). (For the long-list recognition condition, all participants made at least two errors.)

To test whether age differences in temporal memory would remain after item memory performance was statistically controlled, we used two hierarchical regression analyses, one for each recognition memory measure. First, a preliminary simple regression analysis showed that age group alone accounted for 39% of the variance in temporal memory. Next, the two hierarchical regression models were examined, each using temporal memory accuracy as the dependent variable and varying only in the measure of recognition memory—the short-list or long-list condition (see Table 7). The short-list and long-list recognition memory measures were entered as predictors in the first step of each model. The results showed that recognition memory accounted for 24% and 23% of the variance in temporal memory performance in each model, respectively. In the next step, age group was entered into the model after recognition memory performance. In the analysis with short-list recognition memory, age group accounted for an additional 18% of the variance after item memory performance was controlled ($p < .05$). This reflects a reduction of 54%, from 39% to 18%, in the amount of variance in temporal memory accounted for by age alone. Similarly, the model using the long-list recognition memory measure showed that age accounted for an additional 21% of the variance in temporal memory after controlling for item memory ($p < .05$), indicating a reduction of 46%, from 39% to 21%, in the age-related variance in temporal memory. Thus, when recognition memory tests were used as the measure of item memory, substantial age differences remained in temporal memory, even when older and younger adults differed in their

Table 7
*Hierarchical Regression Analysis for Variables Predicting Performance on the Serial Order Reconstruction Test in Experiment 3*

| Variable | *B* | *SE B* | $\beta$ |
|---|---|---|---|
| Short-list recognition | | | |
| Step 1 | | | |
| Recognition | 1.18 | .26 | .49* |
| Step 2 | | | |
| Recognition | .53 | .26 | .22* |
| Age group | .18 | .04 | .51* |
| Long-list recognition | | | |
| Step 1 | | | |
| Recognition | .73 | .16 | .48* |
| Step 2 | | | |
| Recognition | .40 | .15 | .26* |
| Age group | .18 | .04 | .51* |

*Note.* For the short-list recognition model, for Step 1, $R^2 = .24$; for Step 2, $\Delta R^2 = .18$ ($ps < .05$). For the long-list recognition model, for Step 1, $R^2 = .23$; for Step 2, $\Delta R^2 = .21$ ($ps < .05$).
* $p < .05$.

levels of recognition memory performance. Nevertheless, about one half of the age-related variance in temporal memory was accounted for by recognition memory ability.

In sum, Experiment 3 both corroborated some of our earlier findings and produced some novel results. Similar to the previous experiments, older adults had reduced performance on the serial order reconstruction test of temporal memory. Results from the recency judgment test showed the generality of age differences in temporal memory across methods of assessment. Interestingly, although recency judgment tests are generally considered easier than serial order reconstruction tests, this is clearly not always the case, and older adults in the present experiment performed at chance levels. One reason for the difficulty of our version of the test may be that the test items were created from pairs of words presented at adjacent serial positions at the time of study, thus requiring fine-grained knowledge of temporal memory. Others, however, have also reported floor effects in older adults using recency tests that were not constructed in this way (Fabiani & Friedman, 1997). Furthermore, recency tests may seem easier than they are because their format has the appearance of a recognition test rather than a recall test. Nevertheless, there are no temporal cues at the time of testing; therefore, order information must be actively recalled.

With regard to the relationship between temporal and item memory, Experiment 3 replicated the previous experiment in showing that age differences in temporal memory remained significant even after controlling for recognition memory performance. In addition, age effects tended to be larger for temporal than recognition memory. This was particularly true for the serial order reconstruction test ($\eta^2 = .39$ vs. $\eta^2$s $= .28$ and .25), but the smaller effect size for recency memory ($\eta^2 = .25$) probably occurred because of overall low levels of performance on this test. There were a number of differences from Experiment 2, however. One was that older adults performed more poorly than younger adults on the recognition memory tests. This finding was not specifically predicted, although the literature on cognitive aging indicates significant, albeit small age differences in this form of memory (Spencer & Raz, 1995). A short study time would seem to account for this result, because age effects occurred in both the short-list and long-list conditions.

A number of other differences from Experiment 2 indicated a stronger than expected relationship between recognition and temporal memory. For instance, age differences in temporal memory were explained to a significant extent by corresponding differences in recognition memory, with about half of the variance in temporal memory accounted for by the relationship between the two types of tests. In addition, temporal and recognition memory performance were correlated, at least in older adults, and recognition and temporal memory tests overall shared 23%–24% of their variance, up from 6%–15% in Experiment 2. Taken together, these findings suggest a significant overlap in the cognitive processes underlying age differences in recognition and temporal memory, with some evidence for a more global relationship between the two types of tests. We discuss these issues further in the General Discussion. At this point, we wish to reemphasize, however, that the primary prediction of the experiment was supported, namely that age differences in temporal memory were not eliminated after accounting for age differences in recognition memory ability. This finding is consistent with results of Experiment 2 and contrasts with the conclusions about free recall tests in Experiment 1.

## General Discussion

The present study takes as its starting point a challenge to the assumption in past research that age differences in temporal and item memory are independent. We hypothesized instead that age-related declines in temporal memory reflect a generalized decrease in context memory, which affects both temporal and item memory tests. The set of experiments presented here tested one implication of this hypothesis, namely that the relationship between age differences in temporal and item memory should vary as a function of the degree to which the measure of item memory relies on contextual information. The primary prediction of the study was that age-related declines in temporal memory would be more closely related to declines in free recall than recognition memory.

The predictions about free recall were strongly supported. Thus, in Experiment 1, older adults had reduced temporal memory and free recall, but when their recall was equated experimentally with that of younger adults through the manipulation of study presentation rates, age differences in temporal memory disappeared. Statistical control methods showed a similar result: When free recall performance was taken into account, the effect of age was reduced by 89%. Furthermore, the relationship between these tests could not be attributed to differential use of serial order information on the free recall test by older and younger adults.

The results for the free recall test are consistent with the hypothesis that age differences in free recall and temporal memory may result from a shared reduction in context memory, although they conflict with the findings of Schmitter-Edgecombe and Simpson (2001). In the latter study, a group of young–old adults showed age differences in temporal memory but not free recall, and there was no correlation between temporal memory and an unrelated word list recall test. Unlike the present study that used verbal stimuli, however, their stimuli comprised a set of activities that each lasted several minutes. Differences between temporal memory for activities versus words have been reported in the neuropsychological literature with frontal lobe patients (Butters, Kaszniak, Glisky, Eslinger, & Schacter, 1994; McAndrews & Milner, 1991) and may occur for healthy older adults as well.

The results involving recognition memory were also generally consistent with the study hypotheses. In both Experiments 2 and 3, older adults showed reduced temporal memory that could not be accounted for by recognition memory ability alone. In Experiment 2, old and young adults showed equivalent performance on the recognition memory tests, thus indicating that failures to identify the words as previously studied stimuli did not directly cause poor temporal memory. In Experiment 3, which included a more difficult recognition memory test, age differences in recognition memory were observed, but statistical control of recognition memory performance left a substantial amount of the age-related variance in temporal memory unaccounted for. Thus, age differences in temporal memory were less strongly related to declines in recognition memory than free recall. The results, nevertheless, revealed only partial independence between the effects of age on temporal and recognition memory, in that recognition memory test performance accounted for as much as a quarter of the age-related variance in temporal memory in Experiment 2 and for about half of it in Experiment 3. Although not as close as the relationship between free recall and temporal memory, our findings nevertheless showed a somewhat greater association between age differences in recognition and temporal memory than expected.

Additional evidence that age differences in temporal memory are more similar to age effects in free recall than recognition memory comes from a comparison of the size of age effects. Effect sizes involving age were similar for temporal memory and free recall but were generally greater for temporal than recognition memory. The pattern is precisely what would be expected if context memory were a more prominent component of temporal memory and free recall than of recognition memory and if age differences reflect primarily a reduction in memory for contextual information. Our findings are also consistent with a meta-analysis showing similar-sized effects of age for free recall and an aggregate of context memory measures, with smaller effects for recognition memory (Spencer & Raz, 1995).

Further validation of the context memory hypothesis comes from the more general relationship observed between performance on temporal and item memory tests. If age differences in memory reflect the degree to which the tests rely on context memory, then the pattern of age effects should be mirrored by a pattern of stronger correlations of temporal memory to free recall than to recognition memory. With respect to free recall, correlations between the two types of tests were consistently significant and moderate in size. For recognition memory, the correlations varied in size, but only three of the eight coefficients were statistically significant (i.e., in the long-list recognition condition for younger adults in Experiment 2, and in both recognition conditions for older adults in Experiment 3). Whereas these findings indeed suggest a stronger and more consistent relationship between temporal memory and free recall, the reasons for the variable correlations involving recognition memory are not obvious. One possibility may be the relatively small sample size in these experiments, leading to unreliable results. For the short-list recognition conditions, it is also possible that a restricted range of scores led to nonsignificant results. It is also conceivable that the semantic foils in the recognition memory test limited its relationship with the temporal memory task. This could have occurred if semantic knowledge was more important in the recognition memory test than the temporal memory test. Restricted range may also explain the different correlational pattern for younger adults in Experiments 2 and 3, in that performance on the serial order reconstruction test showed a smaller range of scores in the latter, in which the correlation with recognition memory was not significant. Given the uncertain interpretation of the correlational results, we felt it best not to overinterpret the inconsistencies among them. Nevertheless, a direct comparison of the two sets of correlations showed a significantly higher correlation with free recall than recognition memory (Mann–Whitney $U = 1.50$, $p < .01$), a pattern consistent with the hypothesis of a greater degree of reliance on context in temporal memory and free recall than recognition memory.

Despite the weak relationship between temporal and recognition memory, our results nevertheless suggest there is a real relationship between them. The presence of significant correlations between temporal and recognition memory in some conditions cannot be completely dismissed. Further evidence of a relationship comes from the regression analyses, which show that between 6% and 24% of the variance in these two types of tests was shared, a statistically significant result in all cases. These findings may on the surface run contrary to previous studies (Fabiani & Friedman, 1997; Parkin et al., 1995; Schmitter-Edgecombe & Simpson, 2001), but the apparent inconsistency may be explained by differences among the studies. For instance, although Parkin et al. (1995) found no correlation between recognition and temporal memory, there were also no age differences in recognition memory in their study, so that in fact their results are identical to ours in Experiment 2. Furthermore, the absence of a correlation in Fabiani and Friedman's (1997) study may have been due to the low level of performance for older adults on their measure of temporal memory. Performance was at chance when stimuli consisted of pictures, and significantly above chance but still poor for words. With respect to Schmitter-Edgecombe and Simpson's (2001) study, differences may result from their focus on temporal memory for activities that, as noted above, appears to produce a different pattern of age differences from temporal memory for verbal stimuli. All in all, the relationship between temporal and recognition memory may be best observed when, as in the present Experiment 3, memory tests produce mean performance levels that are not too close to either the maximum or the minimum. In addition, this relationship may not generalize across all types of study materials.

In addition to the patterns of correlations, our results provide an additional demonstration of the parallels between the association of temporal and item memory tests and the association of age effects on these tests. If one examines the amount of shared variance between item and temporal memory across the three experiments, they may be seen as falling on a continuum in which the free recall test in Experiment 1 explained the most variance in temporal memory (49%–51%), and the recognition memory test in Experiment 2 explained the least (6%–15%), with the recognition memory test in Experiment 3 falling somewhere in between (23%–24%). The degree of overlap between age differences on these tests constitutes a parallel set of relationships.[7] Thus, free recall explained the most age-related variance in temporal memory, the recognition memory tests in Experiment 2 explained the least, with the recognition memory tests in Experiment 3 falling in the middle. The more an item memory test had in common with a test of temporal memory, the greater the overlap in age effects for the two types of tests. Interpreted in the framework of context memory, the more an item memory test relied on context, the greater its relationship to age differences in temporal memory. The differences between Experiments 2 and 3 show that even recognition memory tests can differ in the contribution of context. In Experiment 3, when participants had less study time and thus less opportunity for contextual processing than in Experiment 2, good performance on recognition memory may have been particularly dependent on the ability to engage in such processing quickly and efficiently.[8] This

[7] We wish to thank an anonymous reviewer for pointing this out.

[8] Another possible reason for differences in the patterns of results for Experiments 2 and 3 is that fact that the size of the age effect for temporal memory was smaller in Experiment 2. The reason for this finding is not obvious, as the stimuli were identical in the two experiments and Experiment 1 showed an effect of age comparable with Experiment 3 even with a long study time of 4 s per word. Although it is possible that the smaller age effect in Experiment 2 could have contributed to the differences in the results of regression analyses, the lack of age effects for recognition memory appears to be the core reason why recognition memory did not explain a significant amount of age-related variance in temporal memory.

would account for the greater age differences in recognition memory and the stronger relationship to age differences in temporal memory. It was in this experiment that recognition memory accounted for one half of the age-related variance in temporal memory.

Findings of a relationship between temporal and recognition memory and a corresponding relationship between age differences in the two forms of memory suggest a sharing of underlying memory processes. As Jacoby (1991) pointed out more than a decade ago, no memory test is a pure measure of a single process. We can now add to this statement that no memory test is a pure measure of a particular type of information, be it item or context. In fact, recognition memory tests are frequently understood to rely in part on a recollective component (Gardiner, 1988; Jacoby, 1991; Mandler, 1980; Yonelinas, 2001, 2002). To the extent that recollection involves retrieval of contextual information about a study event, one would expect a relationship between recognition memory and temporal memory.

Although we have framed our results in terms of age differences in context memory, we now consider a number of alternative explanations. One such explanation is that the pattern of findings reflects age differences in retrieval ability, independent of the type of test. From this perspective, the stronger relationship of temporal memory and free recall could be due to the greater retrieval demands on the serial order reconstruction and free recall tests compared with tests of recognition memory. This is a reasonable hypothesis, yet cannot account for all the results. For instance, the retrieval hypothesis would also predict greater age differences on the serial order reconstruction test when scoring was based on measures of absolute rather than relative temporal memory. This was not observed, however. Similarly, a retrieval explanation cannot easily explain differences between Experiments 2 and 3 in the relationship of temporal and recognition memory, because the two studies used identical methods of assessment. In addition, earlier studies have found no differences in the effects of age on context memory as a function of retrieval effort (Spencer & Raz, 1995). Despite these arguments against a pure retrieval explanation, however, it is important to add that the effects of age may have occurred at both retrieval and encoding.

Another possible explanation of the relationship between age differences in temporal and item memory is that there are parallel declines in elaborative intraitem memory (sometimes called *item processing*; e.g., Einstein & Hunt, 1980) and context memory. This *extended-processing* interpretation is consistent with results across the three experiments. For instance, the close relationship between age differences in free recall and temporal memory could result from a global decrease in all types of processing beyond what is needed to create a very basic memory representation, whether this additional processing involves accessing associated semantic knowledge or relating the stimuli to information about the experimental context. Similarly, the more distant relationship between recognition and temporal memory could occur because recognition memory is less dependent on elaborative intraitem and contextual processing.

The extended-processing interpretation would bring our results in line with several other perspectives in the literature. It is consistent, for instance, with the hypothesis that older adults engage in less self-initiated processing than younger adults (Craik, 1986). This hypothesis suggests that, because of a reduced pool of attentional resources, older adults are less likely than younger adults to initiate processing not directly supported by the structure of the task. Thus, it would predict reduced processing of both contextual and elaborative item information. The extended-processing interpretation also supports the view that age-related declines in memory are due primarily to reduced recollective processes (for a review, see Light, Prull, La Voie, & Healy, 2000). Recollection involves processing of both elaborative item and context information (Jacoby, 1991; Mandler, 1991) and is more important on free recall than recognition memory tests, and even recognition memory tests can vary in their degree of reliance on recollection (see Yonelinas, 2002, for a review).

Although our data are entirely congruent with the self-initiated processing and recollective hypotheses of age differences in memory, at present we prefer an explanation in terms of contextual memory as the more parsimonious account of our results. We believe as well that it may ultimately prove useful to separate the notion of elaborative item processing from extraitem contextual processing. Conceptually they represent different processes, and the process of elaborating on the meaning of an item would seem to be less complex than integrating item information with information that is not intrinsic to the identity of the item. The large literature studying temporal memory and other types of context memory as processes distinct from item memory reinforces this view.

## Conclusions and Future Directions

This study is the first to systematically examine the relationship between age differences in temporal memory and two types of item memory—free recall and recognition memory. Although the study hypotheses concerning the relationships between them were supported, it is important to acknowledge that the use of free recall tests and recognition memory tests to study differences in the impact of context memory on age differences is a crude method for examining this issue. Although it proved useful for establishing a difference in the relationship of item to temporal memory as a function of the type of item memory test, this methodology did not permit us to establish precisely the contributions of item and context information to test performance. Overall, these experiments simply make the point that age differences in temporal and item memory are not independent and that their relationship may be due to their shared dependence on context memory. It may be useful in future studies to develop other methodologies, perhaps focusing on a single measure of item memory and then varying the degree to which it depends on contextual information.

Another direction for future work is to determine whether the relationship of temporal and item memory generalizes to all types of context memory and whether reduced context memory is itself an indicator of age-related declines in all types of associative memory. The meta-analysis of Spencer and Raz (1995) has demonstrated smaller age differences in memory for contextual information used in identifying stimuli than for temporal–spatial context, and the work of Chalfonte and Johnson (1996) shows differences in the pattern of age differences for context memory involving color versus location. On the other hand, Naveh-Benjamin (2000) has argued for a global reduction in associative memory that affects both context memory and memory for associations between items. It is our hope that further work in this area will pursue these ideas.

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