Source Memory in Older Adults: An Encoding or Retrieval Problem?

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Source memory has been found to be more affected by aging than item memory, possibly because of declining frontal function among older adults. In 4 experiments, the authors explored the role of the frontal lobes (FLs) in source memory, the extent to which they may be involved in the encoding and/or retrieval of source or context, and the conditions under which the source memory deficit in older people may be reduced or eliminated. Results indicated that only a subset of older adults show deficits in source memory, namely those with below average frontal function, and these deficits can be eliminated by requiring people at study to consider the relation between an item and its context. These results provide convincing evidence of the importance of frontal function during the encoding of source and suggest that older adults with reduced FL function fail to initiate the processes required to integrate contextual information with focal content during study.

As people age, their memories for recent events tend to become less precise, less well specified. Although they may know that a particular event occurred or have knowledge of a particular fact, they may be less likely to recollect where or when the event took place or how they acquired their knowledge of it. This latter kind of memory, which seems to be especially susceptible to the deleterious effects of aging, has been referred to as source memory. Although source memory has sometimes been narrowly defined as "the episodic source from which a specific item was acquired (e.g., from a person, a book, or television)" (Schacter, Kasziak, Kihlstrom, & Valdiserri, 1991, p. 559), it can also be more broadly construed to include any aspects of context—perceptual, spatiotemporal, affective, social—that are present when an event occurred (Johnson, Hashtroudi, & Lindsay, 1993). As such, it is often contrasted with item or fact memory or with memory for the content of an experience. Such a broad definition of source, however, raises the further question of exactly how context should be distinguished from content (for discussion of this issue, see Van Petten et al., 2000). In a general sense, context is what is perceived as focal, either as a result of experience or as a result of specific instructions. Context is what is perceived as nonfocal. In most experimental studies of source memory, the item–source relation is determined by the many-to-few mapping of items to sources: many words are spoken in one of two voices, are printed in one of two fonts, or are either perceived or imagined. In the present article, we adopt the broad definition of source and operationally define it in terms of the many-to-few mapping.

A number of studies have shown that source memory is generally affected by aging more than fact or item memory (Brown, Jones, & Davis, 1995; Ferguson, Hashtroudi, & Johnson, 1992; Henkel, Johnson, & DeLeonardis, 1998; McIntyre & Craik, 1987; Schacter et al., 1991; Spencer & Raz, 1995; Trott, Friedman, Ritter, & Fabiani, 1997; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999), but the reasons for the differential effects are unclear. One hypothesis is that source memory relies to a greater extent on the integrity of the frontal lobes (FLs), and the FLs are particularly likely to be affected by aging (Coffey et al., 1992; Raz, 2000; Raz et al., 1997). This hypothesis has been supported by findings in patients with focal frontal lesions (Janowsky, Shimamura, & Squire, 1989; Johnson, O'Connor, & Cantor, 1997), who were found to make more source memory errors than normal control participants concerning the place and time that facts were acquired, despite their equivalent memory for the facts themselves. Also, studies of source memory in amnesic patients have demonstrated that those patients who show deficits on tests of FL function are more likely to exhibit impaired source memory performance (Schacter, Harbluk, & McLachlan, 1984; Shimamura & Squire, 1987), whereas those without frontal impairment perform normally on source tasks, despite their severe impairment on tests of fact memory. Recent studies measuring event-related potentials in source memory tasks with normal individuals have also supported a special role for the FLs in source memory relative to item memory (Johnson, Kounios, & Nolde, 1997; Senkfor & Van Petten, 1998; Trott et al., 1997; Trott et al., 1999; Van Petten et al., 2000; Wilding & Rugg, 1996), as have studies using event-related functional magnetic resonance imaging (Nolde, Johnson, & D'Esposito, 1998). There are, however, contrary findings. For example, Kopelman (1989) noted in a list discrimination task with amnesic Korsakoff patients that the probability of correct list identification was unrelated to the amount of FL atrophy or to performance on tests of frontal function, but it was related to...
performance on standard tests of item memory. Similarly, Shoaeri and Mayes (1991; also Mayes, Meudell, & MacDonald, 1991) found no correlation between memory for spatial location and performance on FL tasks in amnesic patients but instead found an association between spatial location memory and item memory (see also Kopelman, Sunhope, & Kingsley, 1997).

Studies of healthy older adults have also produced conflicting findings. Several investigators have reported that the performance of older individuals on source memory tasks is correlated with their performance on tests of FL function and is uncorrelated with their performance on tests of fact or item memory (Craik, Morris, Morris, & Loewen, 1990; Glisky, Polster, & Routhieaux, 1995; Parkin, Walter, & Hunkin, 1995). Other researchers, however, have not obtained this relation. For example, Spencer and Raz (1994) found that some kinds of source memory were not predicted by FL tests (see also Degl’Innocenti & Bäckman, 1996; Johnson, DeLeonardis, Hashtroudi, & Ferguson, 1995) but were correlated with fact recall. Recently, Henkel et al. (1998) reported in a source monitoring experiment that source accuracy, although correlated with performance on frontal tasks under some conditions, was also correlated with performance on tasks usually associated with functions of the medial temporal lobes (MTLs)—standard tests of item memory—under other conditions. They suggested that explanations that assigned source memory processes solely to the FLs were too simplistic and that source memory tasks may share processes or features with item memory tasks in some circumstances (see also Johnson et al., 1993). Nevertheless, as noted above, disproportionate source memory deficits have generally not been found in patients with damage confined to MTL structures (Milner, Corsi, & Leonard, 1991; Schacter et al., 1984).

Reasons for the somewhat variable results with respect to the brain regions implicated in source memory may stem from materials used, task demands, and individual differences among participants. So, for example, studies grouped under the rubric of source memory have required people to make a range of judgments about the context in which an event occurred, including when and where it happened, whether it was heard or seen, perceived or imagined, in what voice it was spoken or font it was written, and numerous other questions about the contextual features of a particular episode (for reviews, see Johnson et al., 1993; Kausler, 1994; Spencer & Raz, 1995). Encoding instructions have also varied, as have the formats of the memory tests used, and in many cases frontal function has been assessed on the basis of just one or two “frontal” tasks. Participants in the studies have often been brain-injured and older individuals, who are notably variable in behavior and neuropsychology. It is therefore not surprising that different outcomes have been obtained across experiments. Yet, despite this variability there is now considerable consensus that the FLs are in some way involved in source memory.

The interesting questions now concern the processes involved in memory for source or context, the extent to which these are qualitatively or quantitatively different from those required for item or fact memory, and the exact role that the FLs play in these processes. More generally, interest focuses on how multiple attributes of an event are encoded, linked together, stored, and later retrieved, and which brain regions are involved in these different aspects of memorial processing.

Source memory tasks are virtually always more difficult than item memory tasks, requiring the retrieval of additional detail and the use of more complex decision processes. So, for example, if one heard a sentence spoken in a particular voice, memory for the sentence might be achieved without knowledge of the voice, and recognition might be accomplished on the basis of a simple familiarity judgment. However, memory for which voice spoke that particular sentence would require retrieval of the sentence, of the voice, and of information linking the two in a particular spatio-temporal context. Although a source recognition decision might still be made on the basis of familiarity, the judgment is almost certainly more difficult than item recognition, requiring an evaluation of the familiarity of an item–source pair rather than of the item alone. In many source recognition tasks, this judgment requires discrimination among highly confusable alternatives, each with high and equivalent levels of familiarity (i.e., alternative sources have been presented equally often during the experiment), making the task particularly difficult. Such difficult decision processes may require the FLs.

It may also be the case that the FLs are not just involved in source memory per se but are recruited for any difficult or novel memory tasks that cannot be easily handled by well-worn routines (Shallice, 1982). Considerable evidence implicates the FLs in recall tasks (for a review, see Wheeler, Suss, & Tulving, 1995), which are typically more difficult than recognition tasks and usually require a search process not always necessary for recognition. Similarly, remembering aspects of experience, such as new voices or fonts, may be more difficult than remembering the meaning of words and sentences and thus may require more controlled processing. Even in recognition tasks, retrieval of context may be needed if familiarity assessments fail to yield an unambiguous result. When memory retrieval is not simple or effortless, as in many free recall and source memory tasks and also in difficult recognition tasks, the FLs may be required to formulate and initiate search strategies and engage in complex decision processes concerning the outcome of the search (Moscovitch, 1994).

Although the FLs may have a special role to play during memory retrieval, they may also be involved at encoding, particularly for the encoding of nonfocal information like source or context (Craik & Jennings, 1992). Central aspects of an episode, such as the meaning of a sentence, may be processed rather automatically, limiting the need for frontal involvement. Peripheral information, however, may require more controlled frontal processing to ensure that it is attended, adequately encoded, and represented in memory. In many source memory experiments, participants’ attention is directed toward the primary content information. Contextual features may therefore be ignored. There is some evidence to suggest that source memory deficits may be eliminated in older adults when attention is directed specifically to the source (Naveh-Benjamin & Craik, 1995), but failure to reduce such deficits through attentional manipulations has also been reported (Schacter, Osowiecki, Kasznia, Kihlstrom, & Valdiserri, 1994). It may be, as suggested by Naveh-Benjamin and Craik (1996), that older adults exhibit a trade-off between memory for item and source such that they process one at the expense of the other. Failure to take account of more than one aspect of a stimulus may be particularly likely in older adults with frontal dysfunction.
Finally, for source memory tasks, it is not sufficient to encode an item and its context independently; the two must be linked. The source memory question is not, “Did you hear this voice in the experiment?” but rather, “Which of the voices that you heard in the experiment spoke this particular sentence?” To answer the latter question, content and context (i.e., sentence and voice) must be integrated at encoding, and information about their co-occurrence must be stored in memory. Integrative encoding processes may depend on the FLs (Stuss & Benson, 1986; Wheeler, Stuss, & Tulving, 1997). Alternatively, the binding of multiple components of a stimulus event into an integrated trace may be a function of the MTLs (Chálon & Johnson, 1996; Cohen & Eichenbaum, 1993; Cohen, Poldrack, & Eichenbaum, 1997; Henkel et al., 1998; Kroll, Knight, Metcalfe, Wolf, & Tulving, 1996). Further, it may be that both brain regions are needed for successful coding and storage of an entire event: The FLs are needed to initiate and carry out the control processes to ensure that all aspects of an experience are encoded; the MTLs are needed to ensure that these various attributes are bound together and coregistered in the memory storage system.

The present series of experiments was designed to investigate the nature of the role of the FLs in source memory, specifically the extent to which the FLs are implicated in the encoding and/or retrieval of source or context information. In a previous source memory experiment with older adults (Gisky et al., 1995), we found a double dissociation between item and source memory such that older adults with below average frontal function showed an impairment in memory for the voice that spoke a sentence (i.e., source memory) relative to adults with above average frontal function, but they showed no impairment in memory for the sentence itself (i.e., item memory). However, those adults with below average performance on MTL tests showed a relative impairment of item memory but not of source memory. Although these findings were suggestive of a special role for the FLs in source memory, the nature of that role was not explored.

The present experiments examined that role more fully by including comparisons with young adults, by extending the findings to different domains of item and source information, and by manipulating the focus of attention during encoding. We also increased the size of the normative group on which neuropsychological functioning of the older adults was based to ensure greater reliability of our FL and MTL measures. Still, our measures of FL and MTL function are based, at this point, solely on neuropsychological, not neuroanatomical, evidence, and so they provide only indirect indication of the involvement of specific brain regions. We note that, although the tests that generate the composite scores have been found to be sensitive to dysfunction of the FLs and the MTLs, most of them require several cognitive processes and may rely on multiple brain structures. Nevertheless, factor analyses suggest that the tests contributing to each factor share a common variance that is not shared by the tests in the other factor. Our composite measures may therefore be more stable than the individual test measures that have often been reported in the literature and may be more likely to reflect two independent processes. We also do not mean to imply that these factors represent the only functions subserved by these brain regions, but rather that they reflect one of many functions that may involve these brain areas.

In the following experiments, we focus particularly on the role that the FLs play in memory for the context of an event.

Experiment 1

Source memory judgments are virtually always more difficult than item memory judgments, and for this reason it is possible that the involvement of the FLs in source memory tasks reflects their difficulty rather than any specific memory processing component. In our earlier experiment (Gisky et al., 1995), the source task required memory for an unfamiliar voice—a relatively difficult memory task. If the FLs are involved when memory encoding and retrieval processes are nonroutine (Shallice, 1982), then they may be required for remembering novel voices whether these constitute source information or represent the primary focal content of an experience. In the present experiment, the stimuli for the item memory task were unfamiliar voices, each speaking one of two sentences. If the FLs are involved in all difficult memory tasks, then we would expect that our low-frontal older adults would be at a particular disadvantage on the difficult item task. However, if there is something special about source memory that requires frontal involvement, then we would expect that our low-frontal performers would be impaired, as they were previously, on the source or context memory task, which in the present study required memory for the particular sentence that each voice spoke.

Method

Participants. The participants in all of the experiments reported in this article were selected from a larger pool of healthy, community-dwelling adults over the age of 65, who had been characterized on the basis of their neuropsychological test performance within 2 years of experimental testing. Each individual in the pool has been assigned two scores, one representing relative performance on a group of tests associated with FL function and the other representing relative performance on a group of tests thought to represent MTL function. The tests contributing to the FL factor include: number of categories achieved on the modified Wisconsin Card Sorting Test (Hart, Kwentus, Wade, & Taylor, 1988), the total number of words generated in a word fluency test, using initial letters F, A, and S (Spreen & Benton, 1977), Mental Arithmetic from the Wechsler Adult Intelligence Scale—Revised (WAIS-R; Wechsler, 1981), Mental Control from the Wechsler Memory Scale—Revised (WMS-R; Wechsler, 1987), and Backward Digit Span from the WMS-R (all from the Wechsler Memory Scale—Revised). The tests contributing to the MTL factor include Logical Memory I, Verbal Paired Associates I, and Visual Paired Associates II (all from the WMS-R) and the Long-Delay Cued Recall measure from the California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987). These tests were grouped according to the results of two factor analyses: (a) an exploratory principal factors analysis of data from 48 older adults, which was reported in Gisky et al. (1995), and (b) a confirmatory factor analysis of data from a separate group of 100 older adults. (Variance attributable to age was removed from test scores prior to the factor analyses.) Both analyses produced two uncorrelated factors and the same factor structure. The composite scores for each individual represent average z scores for those tests loading on each factor, relative to either the 48- or 100-member normative groups (depending on when the experiment was conducted). Scores in the 100-member normative group are distributed such that 34 are above the mean on both factors, 26 are below the mean on both factors, 18 are above the mean on the FL factor and below the mean on the MTL factor, and 22 are above the mean on the MTL factor and below the mean on the FL factor (see Gisky et al., 1995, for information about the 48-member group). Factor scores for participants
for Experiment 1 were based on the 48-member group, and for all other experiments were based on the 100-member group. In all of the experiments reported in this article, the high- and low-FL groups differed significantly on their composite FL scores but not on their MTL scores, whereas the high- and low-FL groups differed on MTL scores but not on FL scores.

For the present study, 32 older adults were selected from the pool, 8 from each of the four neuropsychological groups. They received monetary compensation for their participation. Characteristics of each group are presented in Table 1. Separate one-way between-subjects analyses of variance (ANOVA) indicated that there were no differences in age, education, or scores on the Mini-Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975) as a function of neuropsychological group (all Fs < 2.5). The probability of a Type I error was set at .05 for all statistical comparisons. There were also no significant differences in scaled scores from either the Vocabulary subset of the WAIS-R, F(3, 28) = 2.15, MSE = 5.15, or the Similarities subset of the WAIS-R, F(3, 28) = 2.50, MSE = 3.10. Twenty-four young adult undergraduates (age range = 18–40, M = 19.9, SD = 4.5) at the University of Arizona volunteered to participate to fulfill a course requirement. The scaled score on the Vocabulary subset was significantly lower in young adults (M = 9.0, SD = 1.7) than in older adults (M = 13.4, SD = 2.6), F(1, 53) = 56.60, MSE = 4.60.

Materials. A large number of voices, both female and male, were recorded speaking two sentences that were equated for speaking time: “Clouds are expected to move in from the west later this afternoon, increasing the likelihood of rain overnight,” and “Stock prices fell sharply in heavy trading today, reflecting the uncertainty in the trade function.” Voices were selected to be as distinctive as possible and included both young and old voices and voices with accents. Recording was done using Soundedit software (Parallon Computing Inc., Berkeley, CA) and a Macintosh IIx computer. Voices were rated for distinctiveness by an independent group of 12 undergraduates, and three sets of 12 voices—half female and half male—were constructed such that all three sets had relatively high and equivalent ratings of distinctiveness. Two 12-item lists served as study lists, and a third 12-item list was the source-context memory test (i.e., memory for the particular sentence that was spoken by the voice). Pilot data indicated no differences as a result of test order or whether the memory test was incidental or intentional as long as an orienting task was used. In the first study session, participants listened to one 12-item list of voices that was presented three times in a different random order. After they heard each voice, participants made a judgment on a 4-point scale, ranging from 1 (very unlikely) to 4 (very likely), concerning how likely it was that each voice would be heard on the radio. No mention was made of a subsequent memory test. Following a 2-min interval in which people were engaged in conversation while the test program was being loaded on the computer, a two-alternative forced-choice (2AFC) recognition memory test for the voices was given. Each of the 12 target voices was presented, speaking either the same sentence as at study or the other sentence. The distractor voice was a novel voice of the other gender, which spoke the other sentence. The interstimulus interval was 500 ms.

Voices were presented at test in a different random order for each participant, and the order in which target and distractor voices were heard was counterbalanced across items. Participants were asked to press the appropriate key (1 or 2) to indicate whether they had heard the first or the second voice at study, without regard to the particular sentence that was spoken. They had unlimited time to respond. Following a 15-min break, during which participants engaged in an unrelated task, a second study session was administered, which was identical to the first except it had a new list of 12 voices. The recognition memory test in this case was a 2AFC test for the sentence that each voice spoke. Each of the 12 voices that had been heard during study was re-presented at test, speaking each of the two sentences in a 2AFC format. The participants' task was to indicate, by pressing a key on the computer keyboard, which sentence the voice had spoken in the study phase. Voices were presented in a different random order for each individual, and the order in which the two sentences were heard was counterbalanced across items.

Finally, all participants were given a voice discrimination test to ensure that their sensory and perceptual abilities were adequate to detect similarities and differences in voices. Each individual heard 16 pairs of novel

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>High FL function</th>
<th>Low FL function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Age (years)</td>
<td>71.8</td>
<td>4.4</td>
</tr>
<tr>
<td>Education (years)</td>
<td>14.5</td>
<td>2.1</td>
</tr>
<tr>
<td>MMSE</td>
<td>29.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>14.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Similarities</td>
<td>11.3</td>
<td>1.5</td>
</tr>
<tr>
<td>FL score</td>
<td>.56</td>
<td>.55</td>
</tr>
<tr>
<td>MTL score</td>
<td>.49</td>
<td>.33</td>
</tr>
</tbody>
</table>

Note. FL = frontal lobe; MTL = medial temporal lobe; MMSE = Mini-Mental Status Examination. * Scaled scores from the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981). t z scores (see text).
voices speaking one of two sentences. The voices and sentences were
different. For half of the pairs, the same voice spoke both sentences; for the
other half of the pairs, a different voice spoke each sentence. The two
sentences were always different.

Results

On the discrimination task, all participants obtained a score of at
least 12 out of 16, with a mean score of 15.1 for young adults
and 14.2 for older adults. This difference was significant,
(54) = 3.29, SE = 0.28, but both groups were close to the ceiling.
There were no significant differences among the four groups of
older adults.

Table 2 presents the proportion of items correctly identified in
the two memory tests as a function of age. Older adults were
impaired relative to young adults in both item memory (i.e.,
memory for voice) and source memory (i.e., memory for the
sentence), and both age groups scored higher on the item memory
test than on the source memory test. A 2 X 2 mixed ANOVA of
the number of items correctly recognized, with age as the between-
subjects factor and type of memory test as the within-subject
variable (see data in Table 4) showed that all groups
of older adults demonstrated an equivalent advantage for voices
that spoke the same sentence at study and at test, F(1, 28) = 3.82,
MSE = 1.33. The same–different variable did not interact with
group.

The bottom half of Table 3 shows results from the source memory
task (i.e., memory for the sentence that each voice spoke)
as a function of neuropsychological group. As supported by a
2 X 2 between-subjects ANOVA, high-frontal older adults out-
performed low-frontal adults, F(1, 28) = 8.88, MSE = 1.86. In
fact, the low-FL group did not perform significantly above chance
(i.e., .50), t(15) = 1.24, SE = 0.35. There were no differences in
performance as a function of MTL function, and the two factors
did not interact (both Fs <1). An additional analysis compared the
high-FL group with the young group and found a nonsignificant
subsequent analysis that added the same–different factor as a
within-subject variable (see data in Table 4) showed that all groups
of older adults demonstrated an equivalent advantage for voices
that spoke the same sentence at study and at test, F(1, 28) = 3.82,
MSE = 1.33. The same–different variable did not interact with
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performance as a function of MTL function, and the two factors
did not interact (both Fs <1). An additional analysis compared the
high-FL group with the young group and found a nonsignificant
Table 2
Proportion of Items Correctly Identified in Each Two-
Alternative Forced-Choice Recognition Memory Task as a
Function of Age in Experiment 1

<table>
<thead>
<tr>
<th>Memory</th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Voice (item)</td>
<td>.83</td>
<td>.17</td>
</tr>
<tr>
<td>Same</td>
<td>.93</td>
<td>.14</td>
</tr>
<tr>
<td>Different</td>
<td>.73</td>
<td>.23</td>
</tr>
<tr>
<td>Sentence (source)</td>
<td>.74</td>
<td>.15</td>
</tr>
</tbody>
</table>

Table 3
Proportion of Items Correctly Identified in the Item Memory
Task and Source Memory Task as a Function of
Neuropsychological Group in Experiment 1

<table>
<thead>
<tr>
<th>MTL function</th>
<th>FL function</th>
<th>High</th>
<th>Low</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source memory task</td>
<td>High</td>
<td>.75</td>
<td>.66</td>
<td>.70</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>.68</td>
<td>.73</td>
<td>.70</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>.71</td>
<td>.69</td>
<td>.70</td>
</tr>
<tr>
<td>Item memory task</td>
<td>High</td>
<td>.58</td>
<td>.55</td>
<td>.59</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>.66</td>
<td>.54</td>
<td>.61</td>
</tr>
</tbody>
</table>

Note. FL = frontal lobe; MTL = medial temporal lobe.

Table 4
Proportion of Voices Correctly Identified as a Function of
Whether the Voice Spoke the Same or a Different Sentence at
Study and at Test in Experiment 1

<table>
<thead>
<tr>
<th>MTL function</th>
<th>FL function</th>
<th>High</th>
<th>Low</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>High</td>
<td>.77</td>
<td>.73</td>
<td>.75</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>.73</td>
<td>.58</td>
<td>.66</td>
</tr>
<tr>
<td>Different</td>
<td>High</td>
<td>.63</td>
<td>.69</td>
<td>.66</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>.75</td>
<td>.75</td>
<td>.75</td>
</tr>
</tbody>
</table>

Note. FL = frontal lobe; MTL = medial temporal lobe.
reduced FL function may engage in less elaborate or less thorough retrieval. Those people with diminished FL function may not have had average FL function were impaired relative to those with high FL function. It is therefore not the case that the FLs are involved in all difficult or nonroutine memory tasks. Instead, once again, the results implicated the FLs in memory tasks that require the encoding and retrieval of source or context information. Thus, there seems to be something qualitatively different about the kinds of processes required for source memory relative to item memory—at least in the experimental paradigm used here. This conclusion was further supported by the lack of correlation between performance on the two kinds of memory tasks. It should also be noted that the frontal effect is unlikely to be attributable to IQ differences. The groups were equivalent in Vocabulary and Similarities scores from the WAIS–R.

A hint concerning what component of memory processing may be particularly dependent on FL function comes from results of the same–different manipulation. In Table 4, it can be seen that the older adults with low FL function showed a same–different effect that was roughly equivalent to that of the high-FL group. When the voice spoke the same sentence at test as at study, both frontal groups benefited equally. This finding suggests that information about the conjunction of the voice and sentence was encoded during study by both groups. Those in the low-FL group, however, were unable to make use of that information. When asked explicitly to discriminate between two possible conjunctions, the low-FL participants' recognition of the correct sentence was at chance. Two possible explanations of these findings may be considered. First, it may be that both groups encoded the conjunction equally well, but the low-FL group had a problem at retrieval. The two sentences that were presented in the 2AFC memory test were very familiar, both having been presented many times during the experiment. Thus, a recognition decision could not be made on the basis of familiarity of the sentence alone. Instead recognition would likely require retrieval of the specific voice–sentence pairing. Those people with diminished FL function may not have initiated a search for the conjunction information and may therefore have had little relevant data on which to base their decision. Second, the problem may lie in the decision process itself such that individuals with low FL function may have difficulty evaluating retrieved information, particularly when it requires discrimination among highly confusable alternatives.

Although the finding of a same–different effect in the low-FL group seems to implicate a retrieval problem in source memory, it does not entirely rule out an encoding difficulty. People with reduced FL function may engage in less elaborate or less thorough encoding processes, focusing on central information to the detriment of the peripheral or contextual detail. Nevertheless, they may encode some of the context, perhaps enough to make the target voice more familiar, particularly when re-presented in the same context, yet not enough to support the kind of explicit retrieval required by the source memory task (cf. Naveh-Benjamin & Craik, 1995).

Overall, older adults showed a much smaller benefit of the repeated context than young adults, a 9% advantage compared with a 20% advantage, respectively (see Table 2), and this finding extended across all neuropsychological groupings of older people. Young people appeared able to take advantage of the repeated context to benefit item recognition in a way that older adults could not. We suspect that with repeated presentations of a voice speaking the same sentence, components of the voice that are involved in that specific voice–sentence pairing may be strengthened. This may serve to enhance memory for the voice when it is heard again at test speaking the same sentence. Evidence from pilot testing is consistent with this interpretation. When 16 voices were presented only once, young people showed only a 9% advantage for the same compared with the different condition. It was only with repetition that the enhanced same–different advantage emerged. Also, in the present study, the item memory performance of younger adults was superior to that of older adults only in the same condition. Two possible explanations for this age-related same advantage come to mind. First, with repetition, younger adults may have developed a strategy that focused on specific voice–sentence features. Older adults may not have used this strategy, although to the extent that such strategies are dependent on frontal function, we might have expected the high-FL group to engage a similar strategy. Perhaps with more repetitions they would have. Alternatively, the failure to benefit from repetition may reflect poorer voice discrimination abilities among older adults. Although voice discrimination was high in all participants, there was a small but significant advantage for young adults, which may have been sufficient to allow them but not older adults to detect voice features that were specific to a particular sentence. A correlation between discrimination and the size of the same–different effect was not significant, however ($r = .21$). In addition, a reanalysis of the data including only those participants who scored at least 15 out of a possible 16 on the discrimination task (16 older adults and 20 young adults) showed exactly the same pattern of effects. Nevertheless, a more sophisticated analysis of auditory discrimination abilities might have revealed deficits among the older adults that were not detectable in the current study.

One puzzling aspect of the findings in this study was the complete absence of an effect of MTL function in the item memory task. In a previous study (Glisky et al., 1995) in which sentences were the focal targets, we found a significant effect of MTL function on item memory. There was no hint of such an effect in the present study. Although we postulated that our MTL factor reflected some basic memory process that would span materials, three of the four tests that contribute to the factor are verbal. It is possible therefore that the composite score reflects primarily verbal memory and not a more global measure of memory functioning, or that memory for novel voices relies on different processes than those needed on standard neuropsychological tests of memory (cf. Winograd, Kerr, & Spence, 1984).
In summary, the principal findings of this first experiment discount the possibility that the FLs are involved in all memory tasks that are novel and difficult. Instead, it appears that there is something special about source memory tasks that requires the input of the FLs. The question of interest, then, is whether the source memory problem experienced by older adults with compromised FL function lies at encoding, retrieval, or both. Before pursuing this question, we decided first to test the generality of our findings with a different set of materials.

Most source memory studies have focused on memory for perceptual features of linguistic stimuli, such as the voice, the font, or the modality in which words or sentences are presented. Few studies have examined nonlinguistic, visuospatial materials, and the findings from those studies have been conflicting. Spatial memory has usually been associated with MTL rather than FL function. For example, Kopelman et al. (1997) reported that memory for spatial context may rely on different processes than perceptual or linguistic context. We proposed to create a visuospatial analogue of our voice-sentence experiments in order to test whether the effects that we have observed reflect general memory principles applicable across stimulus domains or whether they are specific to the verbal domain.

Experiment 2

In this experiment, the materials consisted of a series of photographs portraying different chairs located in one of two rooms. The item memory task required memory for visual objects (i.e., the chairs), whereas the source memory task required memory for the location of the objects. If source memory effects are independent of the materials used but instead depend on the nature of the memory task (i.e., source memory as opposed to item memory), we should once again find that older adults with reduced FL function are impaired relative to the high-FL group on memory for the location of the chairs, despite equivalent memory for the chairs themselves.

Method

Participants. Twenty-four older adults were selected from the pool, 6 from each of the four neuropsychological groups created by combining high and low FL and MTL function. They each received monetary compensation for their participation. Characteristics of each group are presented in Table 5. The groups did not differ in age or education (Fs < 1). There was a significant difference between groups in MMSE, F(3, 20) = 3.84, MSE = 0.91. Newman–Keuls tests indicated that the group with high performance on both factors scored significantly higher than the low-FL/high-MTL group, but as can be seen in Table 5, all groups were near the ceiling and there was little variance in performance. The IQ measures in this study were obtained from different versions of the WAIS across individuals. We report mean scaled scores for the Vocabulary and Similarities subtests, derived from the performance of 21 of the 24 participants on the WAIS–R or the WAIS–III (Wechsler, 1997). Two other participants had scores from the WASI (Wechsler Abbreviated Scale of Intelligence, 1999), but we could not convert those to the same scale.

Table 5

<table>
<thead>
<tr>
<th>Variable</th>
<th>High FL function</th>
<th>Low FL function</th>
</tr>
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<tbody>
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<td></td>
<td>High MTL function</td>
<td>Low MTL function</td>
</tr>
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<td></td>
<td>M</td>
<td>SD</td>
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<tr>
<td>MTL score*</td>
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<td>.39</td>
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</tbody>
</table>

Note. FL = frontal lobe; MTL = medial temporal lobe; MMSE = Mini–Mental Status Examination.

* Scaled scores from the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981) and the Wechsler Adult Intelligence Scale—III (Wechsler, 1997). b z scores (see text).
used during the study phase and 16 served as distractors during the recognition test. These two 16-item sets appeared equally often as targets and distractors across participants. A different set of 12 chairs, half in each of the two locations, served as targets for the source memory test. There were two versions of each of the three lists such that the chairs that appeared in one room in one version appeared in the other room in the alternate version, and these were counterbalanced across participants in groups. An additional two chairs occurred at the start of each study list to absorb primacy effects and at the start of each test list to serve as practice items. All study and test materials were presented by a Macintosh Quadra 610 using SuperLab (Cedrus Corporation, San Pedro, CA).

Procedure. Two study-test sessions were conducted. The first was always the item memory test (i.e., memory for the chair) and the second was the source-context memory test (i.e., memory for the room in which the chair appeared); pilot data indicated no differences as a result of test order. In the first study session, participants viewed one set of 16 chairs, which were presented one at a time for 3 s each. Participants were asked to make a judgment on a 4-point scale, ranging from 1 (very uncomfortable) to 4 (very comfortable), concerning how comfortable each chair was likely to be. They had unlimited time to respond. No mention was made of a subsequent memory test. Following a 2-min interval in which people were engaged in conversation while the test program was being loaded, a 2AFC recognition memory test for the chairs was given. Each of the 16 target chairs was pictured at test either in the same room as at study or in the other room. The distractor chair was a novel chair that had been photographed in the other location. The two choices were presented sequentially (to maintain equivalence to the voice study); each remained on the screen for 3 s, with a 500-ms interstimulus interval, and participants were required to press key 1 or 2 to indicate whether they had seen the first or the second chair at study, without regard to its studied location. Chairs were presented at test in a different random order for each participant, and the order in which target and distractor chairs were seen was counterbalanced across items.

Following a short break, a second study session was administered, which was identical to the first except with the 12-item list of chairs. The recognition memory test in this case was a 2AFC test for the location in which the chair had initially appeared. Each of the 12 chairs that had been seen during study was shown at test in each of the two rooms in a 2AFC format. The two choices were presented sequentially for 3 s each, and the participants’ task was to indicate, by pressing a key on the computer keyboard, in which room the chair had appeared in the study phase. Chairs were presented in a different random order for each individual, and the order in which the two locations appeared was counterbalanced across items.

Results

Table 6 presents the proportion of items correctly identified in the two memory tests as a function of age. Older adults were impaired relative to young adults in both item memory (i.e., memory for chair) and source memory (i.e., memory for the room in which the chair appeared), and both age groups scored higher on the item memory test than on the source memory test. A 2 x 2 mixed ANOVA of proportion correct, with age as the between-subjects factor and type of memory test as the within-subject factor, confirmed a main effect of age, F(1, 46) = 12.60, MSE = 0.02; a main effect of type of memory, F(1, 46) = 20.8, MSE = 0.02; and no interaction. There was no same–different effect (F < 1); chairs were equally well remembered whether they were re-presented in the same room as at study or in a different room.

The top half of Table 6 presents the proportion of chairs recognized correctly in the item memory task as a function of neuropsychological group. There were no significant differences among groups. A 2 x 2 between-subjects ANOVA indicated no main effect of the FL factor (F < 1); no significant effect of the MTL factor, F(1, 20) = 2.96, MSE = 0.02; and no interaction (F < 1). A subsequent analysis that added the same–different factor as a within-subject variable showed no main effect and no interactions associated with this variable (Fs < 1).

The bottom half of Table 6 shows results from the source memory task (i.e., memory for the room in which each chair was located) as a function of neuropsychological group. The data indicate that high-frontal older adults outperformed low-frontal older adults on this task, but this difference was not reliable, F(1, 20) = 1.38, MSE = 0.02. There was also no effect of the MTL factor (F < 1) and no significant interaction, F(1, 20) = 1.36, MSE = 0.02. However, the high-FL group was the only group that performed significantly above chance, t(11) = 2.11, SE = 0.04. The high-FL group also did not differ significantly from the young group, F(1, 34) = 1.50, MSE = 0.02, whereas the low-FL group did, F(1, 34) = 5.53, MSE = 0.03. Finally, there was no correlation between performance on the item memory and source memory tasks among older adults (r = -.02) or younger adults (r = .01).

Discussion

The pattern of results in the present experiment was roughly consistent with previous findings, although the frontal effect on the source memory task was not significant in this study. Nevertheless, the effect was in the predicted direction, with the high-FL group performing at a higher level than the low-FL group. The overall levels of performance on the source memory task were rather low, however, and so the failure to find a significant difference between the two frontal groups may be attributable to a floor effect. As in the previous study, the low-FL group failed to perform better than chance on the source task and was impaired relative to young adults, whereas the high-FL group performed at above chance levels and was equivalent to young adults.

On the item memory task, there were no differences between the high and low groups in either neuropsychological category. Although the lack of a frontal effect on item recognition is not surprising—we have not found such an effect in any of our studies—the failure to see an effect of MTL function on item memory was unexpected, even though we failed to obtain that effect in Experiment 1. We speculated that our MTL composite
source memory task in Experiment 1. Thus, the retrieval explanation, which seemed the most likely interpretation of the source memory deficit in Experiment 1, could not be supported. It may be that voice and sentence information are well integrated at the level of the stimulus, whereas object and location information are more likely to be separate (Troyer, Woc- ocur, Craik, & Moscovitch, 1999). Thus, in the case of chairs in rooms, the background spatial context may have been only weakly encoded, if at all, and not well linked with the target item, particularly in the low-FL group. The poor source memory performance of that group may therefore be attributable to an encoding problem.

To rule out the possibility that people were failing to take account of the source information at study, we decided to conduct another experiment using an orienting question that focused attention on the relevant information during encoding. When the memory test was to be an item test, participants were oriented to the item, but when the test was a test of source, people were oriented to the relation between the item and its context. Thus for both the item and the source task, the orienting question was task relevant.

### Experiment 3

**Method.**

Participants. Twenty-four older adults, 6 from each of the four neuropsychological groups created by combining high and low FL and MTL function, were selected to participate in this experiment. They each received monetary compensation for their participation. Characteristics of each group are presented in Table 8. There were no significant differences among groups in age, $F(3, 20) = 2.25, \text{MSE} = 22.0$, or MMSE, $F(3, 20) = 2.37, \text{MSE} = 1.62$. There were, however, differences in education, $F(3, 20) = 5.38, \text{MSE} = 6.31$, and in the scaled scores from the Vocabulary and Similarities subtests of the WAIS–R, $F(3, 19) = 8.50, \text{MSE} = 4.68$, and $F(3, 19) = 3.98, \text{MSE} = 3.76$, respectively. Post hoc comparisons using Newman–Keuls tests indicated that older adults who were low on both FL and MTL factors had significantly less education than both high-FL groups. On the Vocabulary subtest, the group that was high on both factors scored significantly higher than all other groups; on the Similarities subtest, the high–high group scored significantly higher than the low–low group. Twenty-four young adult undergraduates (age range = 17–23, $M = 19.5, SD = 1.9$) at the University of Arizona volunteered to participate to fulfill a course requirement. The scaled score of the young adults on the Vocabulary subtest ($M = 8.8, SD = 1.7$) was significantly lower than that of the older adults ($M = 12.6, SD = 3.1$), $F(1, 45) = 27.40, \text{MSE} = 6.10$.

### Table 8

<table>
<thead>
<tr>
<th>Variable</th>
<th>High FL function</th>
<th>Low FL function</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>High MTL function</td>
<td>Low MTL function</td>
</tr>
<tr>
<td></td>
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<td>$SD$</td>
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<td>Education (years)</td>
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<td>MMSE</td>
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<td>Vocabulary*</td>
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</tr>
<tr>
<td>Similarities*</td>
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<td>2.2</td>
</tr>
<tr>
<td>FL scoreb</td>
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<td>.45</td>
</tr>
<tr>
<td>MTL scoreb</td>
<td>.54</td>
<td>.35</td>
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</table>

**Note.** FL = frontal lobe; MTL = medial temporal lobe; MMSE = Mini–Mental Status Examination.

* Scaled scores from the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981). b $z$ scores (see text).
Materials and procedure. The same materials and procedure were used in Experiment 3 as in Experiment 2, except for the orienting questions during study. In the first study session, participants were asked to make a judgment on a 4-point scale concerning how comfortable each chair was likely to be. Their attention was thus focused on item information, as in the previous studies. The memory test that followed was a 2AFC recognition memory test for the chairs.

During the second study session, participants were asked to make a judgment concerning how well each chair fit in the room. This question was designed to encourage integration of the chair and the room, ensuring that the participants encoded the particular conjunction that they would have to recognize at retrieval. The recognition memory test that followed was a 2AFC test for the location in which the chair had initially appeared.

Results

Table 9 presents the mean proportion of items correctly identified in the two memory tests as a function of age. Older adults, although still impaired relative to young adults in item memory, were no longer impaired in source memory. Both age groups scored higher on the item memory test than on the source memory test. A 2 × 2 mixed ANOVA, with age as the between-subjects factor and type of memory test as the within-subject factor, confirmed a main effect of age, F(1, 46) = 7.02, MSE = 0.02; a main effect of type of memory, F(1, 46) = 17.50, MSE = 0.02; and a significant interaction, F(1, 46) = 6.87, MSE = 0.02. There was a marginal same–different effect, F(1, 46) = 2.75, MSE = 0.02, p = .10; chairs were somewhat better remembered when they were re-presented in the same room at test as at study.

The bottom half of Table 10 shows the mean proportion of chairs recognized correctly in the item memory task as a function of neuropsychological group. There were no differences among groups. A 2 × 2 between-subjects ANOVA indicated no main effect of the FL factor, F(1, 20) = 1.67, MSE = 0.02, no main effect of the MTL factor, and no interaction (Fs < 1). A subsequent analysis that added the same–different factor as a within-subject variable again showed a marginal effect, F(1, 20) = 2.83, MSE = 0.03, p = .10, but did not show any interactions associated with this variable (Fs < 1.5).

The bottom half of Table 10 shows results from the source memory task (i.e., memory for the room) as a function of neuropsychological group. The difference between high- and low-frontal older adults that was present in Experiment 2 is no longer evident in Experiment 3. In fact, there was a significant reversal of the previous effect with the low-FL group now performing at a higher level in source memory than the high-FL group, F(1, 20) = 5.73, MSE = 0.01. There was also no effect of the MTL factor and no significant interaction (Fs < 1). Neither the low- nor the high-FL groups differed significantly from young adults (Fs < 1.7), and all groups performed significantly above chance. Finally, there was no correlation between performance on the item memory and source memory tasks among older adults (r = −.09), but there was a significant correlation among younger adults (r = .45).

Discussion

The source memory deficit that was present in the low-FL group in Experiment 2 was completely eliminated in Experiment 3. The change in the encoding question, which required participants to attend to the relation between the chair and its visuospatial context rather than just to the chair alone, benefited the low-FL group selectively. The performance of the young adults and the older adults with high-FL functioning was unaffected by this manipulation. This finding suggests that young people and older people with high-FL functioning engaged these integrative encoding processes spontaneously, whereas those in the low-FL group did not. Nevertheless, the older adults with reduced FL functioning were able to encode the chair–room conjunction when instructed to do so, and their source memory performance benefited accordingly. This interpretation of the source memory deficit places the locus of the deficit at encoding rather than at retrieval. It appears that without instruction, older adults with below average FL functioning do not initiate the appropriate processes to ensure that the relation between an object and its spatial location is encoded (cf. Craik & Jennings, 1992). When the encoding processes are supported by an appropriate orienting question, however, they appear able to achieve a well-integrated encoding that can be readily discriminated from similar alternatives at retrieval.

This encoding explanation appears at odds with the retrieval explanation suggested by Experiment 1. However, there may be trade-offs between encoding and retrieval. So, for example, when encodings are poor, as might be the case in people with low-FL
functioning in the absence of appropriate orienting tasks, frontal control processes at retrieval might be relatively more important. However, when encodings are task relevant, as in the source memory condition of Experiment 3, frontal retrieval processes might be relatively less important.

Alternatively, the effectiveness of the integrative orienting task may depend on materials. The encoding of words spoken by a voice may be more automatic than the encoding of the location of an object. Thus, an integrative encoding question that ensures that the relation between an item and its context is processed may be more important with visuospatial materials than with auditory-verbal materials. In Experiment 3, therefore, we tested the generality of the encoding effect with auditory-verbal stimuli.

In Experiment 3, as in the other experiments, we failed to find any effect of the MTL factor on memory for items. Again, we have no explanation for this result except to suggest that forced-choice recognition tasks may rely on different processes than those tapped by our factor scores. In this experiment, there is clearly an age-related deficit in recognition of visual stimuli that is unaccounted for by either of our neuropsychological composites.

An unexpected finding in Experiment 3 was the significant correlation between item and source memory among young adults but not among old adults. In Experiments 1 and 2, item and source memory were uncorrelated in both age groups, consistent with the view that the two memory tasks rely on different processes. It is possible, however, that the integrative orienting question, designed to link item and context, enabled or encouraged young adults to use similar mechanisms or processes for both tasks. Older adults, however, may have continued to rely on different processes for the two tasks. In Experiment 4 we attempted to replicate the findings of Experiment 3, using the auditory-verbal stimuli from Experiment 1.

**Experiment 4**

Experiment 3 suggested that at least part of the problem in source memory for older adults with reduced FL function is a failure to encode the relation between an item and its spatiotemporal context. To test the generality of this effect with auditory-verbal materials, we repeated Experiment 1, changing the orienting question so that it focused people’s attention on the aspects of the stimuli that were relevant to the following memory test. When the memory test was for the voice (i.e., the item in this experiment), participants were oriented to the item; when the memory test was for the sentence the voice spoke, participants were oriented to the conjunction between the voice and the sentence. We know from the results of Experiment 1 that all groups encoded the relation between the voice and the sentence. It is possible, however, that such encoding was relatively weak, sufficient to support the same-different decision but not sufficient to enable the low-FL group to retrieve the context at test. Given the results of Experiment 3, we predicted that the addition of the relevant encoding task would strengthen the encoding with respect to the item-source relation and again eliminate the source memory deficit in the low-FL group.

**Method**

**Participants.** Thirty-two older adults were randomly selected from the pool, 8 from each of the four neuropsychological groups. They each received monetary compensation for their participation. Characteristics of each group are presented in Table 11. There were no differences among groups in age (F(3, 28) = 1.32, MSE = 1.72). The differences in education, F(3, 28) = 4.61, MSE = 5.63, was accounted for entirely by the high-FL/low-MTL group, which had significantly more education than all of the others. In this experiment, IQ scores were obtained from the Vocabulary and Similarities subtests of the WAIS-R or the WAIS-III, derived from the performance of 23 of the 32 participants. Seven other participants had scores on the WASI that could not be converted to the same scale. There were no significant differences in Vocabulary, F(3, 19) = 1.90, MSE = 6.65, or Similarities (F < 1). Twenty-four young adult undergraduates (age range = 18–28, M = 20.0, SD = 2.4) at the University of Arizona volunteered to participate to fulfill a course requirement. The scaled score on the Vocabulary subtest was significantly lower in young adults (M = 8.0, SD = 2.2) than in older adults (M = 11.9, SD = 2.8), F(1, 44) = 27.80, MSE = 6.20.

**Materials and procedure.** The same materials and procedure were used in Experiment 4 as in Experiment 1, except for the orienting questions during study. In the first study session, participants were asked to make a judgment on a 4-point scale concerning how likely it was that each voice...
would be heard on the radio. Their attention was thus focused on the item information. The memory test that followed was a 2AFC recognition memory test for the voices.

During the second study session, participants were asked to make a judgment concerning how likely it was that each voice would have spoken that particular sentence. This question ensured that the participants encoded the specific relation between voice and sentence that they would later have to recognize at retrieval. The recognition memory test that followed was a 2AFC test for the sentence that the voice spoke.

**Results**

Table 12 presents the mean proportion of items correctly identified in the two memory tests as a function of age. As in Experiment 3, older adults were no longer impaired in source recognition, given the integrative orienting question. In this study, they were also not different from young adults in item recognition. Both age groups scored higher on the item memory test than on the source memory test. A $2 \times 2$ mixed ANOVA of number of items correctly recognized, with age as the between-subjects factor and type of memory test as the within-subject factor, indicated a marginal effect of type of memory, $F(1, 54) = 3.43, MSE = 3.33, p = .07$, and no other effects. An analysis of the same–different effect indicated that both young and old individuals were more likely to identify voices when they spoke the same sentence at test as at study, $F(1, 54) = 41.50, MSE = 0.80$.

The top half of Table 13 shows the mean proportion of voices recognized correctly in the item memory task as a function of neuropsychological group. Once again, there were no differences as a function of neuropsychological group. For the main effects, $Fs < 1$, and for the interaction, $F(1, 28) = 2.28, MSE = 3.96$. A subsequent analysis that added the same–different factor as a within-subject variable showed all groups were more likely to identify voices when they spoke the same sentence at test as at study, $F(1, 28) = 24.20, MSE = 0.70$. This same–different effect, however, was enhanced in the high-FL group, as indicated by an interaction between the same–different variable and the FL factor, $F(1, 28) = 6.42, MSE = 0.70$. This interaction is illustrated in Table 14. There were no other significant effects (all $Fs < 1$).

The bottom half of Table 13 shows results from the source memory task (i.e., memory for the sentence that each voice spoke) as a function of neuropsychological group. The difference between high- and low-frontal older adults that was observed in Experiment 1 is no longer present ($F < 1$). There was also no effect of the MTL factor and no significant interaction ($Fs < 1$). Neither the low- nor the high-FL groups differed significantly from young adults ($Fs < 1$), and all groups performed significantly above chance. Finally, there was no correlation between performance on the item memory and source memory tasks among older adults ($r = .0009$), but as in Experiment 3, there was a significant correlation among younger adults ($r = .40$).

**Discussion**

The results of this experiment replicate the findings of Experiment 3, showing that the source memory deficit associated with reduced FL function in older adults is eliminated by the presentation of a task-relevant orienting question for auditory-verbal materials as well as visuospatial materials. As in Experiment 3, the change in the orienting task benefited the low-FL group selectively, providing no improvement in source memory for the young or the high-FL group. Presumably, those with high FL functioning spontaneously engaged such integrative encoding processes and so gained no further advantage from the orienting task. The source memory problem experienced by those with relatively lower FL function thus appears to be an encoding problem—a failure to initiate the appropriate processes required to encode the relation.

**Table 12**

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<td>.79</td>
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<td>Different</td>
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<td>Sentence (source)</td>
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<td>.64</td>
<td>.14</td>
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</table>

**Table 13**

Proportion of Items Correctly Identified in Each Two-Alternative Forced-Choice Recognition Memory Test as a Function of Age in Experiment 4

<table>
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<th>MTL function</th>
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<th>Low</th>
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<td>Item memory task</td>
<td>.73</td>
<td>.19</td>
<td>.63</td>
<td>.19</td>
</tr>
<tr>
<td>Source memory task</td>
<td>.70</td>
<td>.12</td>
<td>.77</td>
<td>.15</td>
</tr>
</tbody>
</table>

Note. FL = frontal lobe; MTL = medial temporal lobe.

**Table 14**

Proportion of Items Correctly Identified When the Voice Spoke the Same Versus a Different Sentence at Study and at Test as a Function of Frontal Lobe (FL) Group in Experiment 4

<table>
<thead>
<tr>
<th>FL function</th>
<th>High</th>
<th></th>
<th>Low</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Study/test context</td>
<td>.84</td>
<td>.11</td>
<td>.74</td>
<td>.19</td>
</tr>
<tr>
<td>Same</td>
<td>.58</td>
<td>.24</td>
<td>.66</td>
<td>.11</td>
</tr>
<tr>
<td>Different</td>
<td>.71</td>
<td>.16</td>
<td>.70</td>
<td>.18</td>
</tr>
</tbody>
</table>

Note. FL = frontal lobe; MTL = medial temporal lobe.
between an item and its context. Although the present experiment provides no evidence for a retrieval deficit, as was suggested in Experiment 1, it does not rule out the possibility that the FLs play a role at retrieval under some circumstances, particularly when source information is weakly encoded.

In the present study, there was no age difference in item memory as there was in Experiment 1, and there were no effects of neuropsychological group. All groups showed a same–different effect, exhibiting higher levels of recognition when the voice was re-presented speaking the same sentence at test. In this study, unlike Experiment 1, the high-FL group showed a greater advantage of the re-presentation of context than the low-FL group, suggesting perhaps that, like the young, they developed a strategy of focusing on specific voice–sentence features. Given that Experiments 1 and 4 were identical with respect to the item memory task, however, this performance difference across experiments may reflect individual differences or chance variation.

Of interest, in this experiment as in Experiment 3, performance on the item memory and source memory tasks was correlated in the young people but not in the older adults. This finding suggests that despite the fact that there were no age-related differences in either item or source memory in Experiment 4, the older adults may have performed the tasks differently than the young adults.

General Discussion

The results of Experiments 1 and 2, which used auditory–verbal stimuli (i.e., many voices speaking one of two sentences) and visuospatial materials (i.e., many chairs in one of two rooms), respectively, expand the domain of source memory studies and provide further support for the hypothesis that source memory is particularly dependent on functions associated with the FLs. In addition, they suggest that the age-related deficits often observed in source memory tasks are a result not of age per se but of reduced FL functioning, which occurs in a subset of older adults.

The primary focus of the present article, however, is on the nature of the frontal involvement in source memory, specifically whether the FLs played a relatively more important role at encoding or retrieval. Although the answer to this question is not straightforward, the findings of Experiments 3 and 4 provide convincing evidence of the importance of the FLs for the encoding of source. When people are given specific instructions to process the relation between an item and its source or context, age differences in source memory are eliminated as are differences between the high- and low-FL groups. The performance of the impaired low-FL group improves, whereas the performance of the normally performing high-FL group and the young group is unaffected. This finding suggests that young people and the high-functioning older adults spontaneously encode the relation between an item and its context and thus do not obtain any added benefit from the integrative orienting question. However, those with poorer FL function appear not to process that relation unless explicitly instructed to do so, although they are capable of such processing. The FLs thus seem necessary to initiate the processes required to encode contextual information and integrate it with focal content. These processes may be partly attentional, ensuring an attentional focus that is broad enough to include the contextual information, and they may be partly integrative, ensuring not only that context is encoded but that it is linked with content. In the present set of studies, we cannot separate the attentional and integrative aspects of frontal control. The orienting question that we provided both focused attention on the source and required people to consider it in relation to the item. In other studies, however, when attention was focused on the source without any instruction for people to relate it to the item (Schacter et al., 1994), source memory deficits in older adults were not eliminated. Thus, it appears that attending to contextual information is not sufficient to remediate source memory deficits. The FLs must also initiate processes to integrate the item with its context.

The idea that older adults may be deficient at initiating appropriate encoding processes is not new. Craik (1986; 1994) proposed that failure of self-initiated processing is the principal cause of reduced memory performance in aging. The present study further suggests that these self-initiating processes are frontally controlled and are deficient only in a subset of older adults. Craik (1986; 1994) also suggested that the provision of environmental support in the form of encoding and retrieval cues should reduce or eliminate the age-related memory deficit. The integrative orienting questions in Experiments 3 and 4 clearly played such a supportive role for adults with reduced frontal function, enabling them to encode the relation between item and source and thereby perform normally on the source memory task. The use of recognition tests may also have provided retrieval support, reducing the need for search processes at test.

It appears not to be the case, however, that the FLs are necessary for all difficult encoding tasks. In both Experiments 1 and 2, the item memory tasks were difficult and performance was impaired in older adults relative to young. Yet there was no hint that this impairment was related to low-FL functioning: The high- and low-FL groups performed equivalently on the item recognition tasks. Rather, the low-FL group seemed not to initiate encoding activities beyond the processing of the focal stimulus and were therefore impaired on the task requiring memory for nonfocal information—the source memory task. By this account, the FLs are important for initiating processing that is not clearly task driven or experimenter driven. This characterization of the FLs’ role may also account for the association between source memory performance and our frontal composite score. Although none of the tasks comprising the frontal factor are memory tasks, they all require some degree of nonautomatic, self-initiated processing.

Although the findings from the present experiments strongly implicate encoding as the locus of the source memory deficit in people with low FL functioning, they do not rule out the possibility that the FLs may also play a role at retrieval. In Experiment 1, the low- and high-FL groups showed an equivalent tendency toward better item memory performance when the encoding context was repeated at test. These findings suggest that both groups encoded the relation between item and context but that the low-FL group was unable to make use of that information at retrieval. Retrieval problems of this sort may arise when encoded information is weak or not relevant to the particular memory task at hand. Under these circumstances, the FLs may be required to guide a search for source information at retrieval or to engage decision processes to evaluate an item–source pairing in the presence of confusable alternatives. When two sources are both highly familiar, as in the present experiments and in most studies of source memory, pro-
cesses that reduce interference from the incorrect alternative may also be involved. These search, evaluation, and inhibitory processes may break down as the FLs deteriorate with age.

These ideas about the role of the FLs in the retrieval of source are clearly speculative and are not directly addressed by the present experiments. Nevertheless, other evidence has suggested a role for the FLs at retrieval (e.g., Senkfor & Van Petten, 1998; Van Petten et al., 2000). We suspect that there may be trade-offs between encoding and retrieval in the extent to which the FLs are implicated in source memory. When an encoded trace is well specified with respect to source information, either because of self-initiated frontal processes or the support of appropriate orienting questions, the FLs may be relatively unimportant at retrieval. However, if the memory trace is poorly specified, as might be the case for people with reduced FL function and no encoding support, the FLs may be critical at retrieval. In the present experiments, we have found that we can eliminate the source memory deficit in older adults with low FL function by using an appropriate orienting task. We are now beginning further experiments to determine how we might eliminate the deficit by affecting processing at retrieval.

Although our primary interest in this series of experiments was in the effect of the FLs on source memory, we also characterized our older participants in terms of their MTL function. We were interested in MTL function for two reasons. First, in a previous experiment (Glisky et al., 1995), we found MTL function to be predictive of item memory, and so we were interested in replicating that finding with different materials. In the earlier study, the stimuli for the item memory task were verbal, namely sentences. In the present experiments, the stimuli for the item recognition tests were nonverbal, namely voices and chairs. Our failure to find an effect of MTL function on item memory in the present set of experiments may reflect the largely verbal nature of our MTL factor—three of the four tests are verbal. It is possible that some memory processes are material specific, and that those processes important for good verbal memory performance are not the same as those needed for good memory in nonverbal domains. Memory processes may also be task specific. All of the tests in the composite MTL factor are recall tasks, which may differ in some fundamental ways from the 2AFC tasks used in the present experiments. Nevertheless, in the earlier sentence–voice experiment, we did obtain a relation between the MTL factor and 2AFC recognition memory for sentences, and so the factor does seem sensitive to differences in recognition memory. In three of the four experiments reported here, older adults were impaired in item recognition, an impairment not accounted for by our composites. Thus it seems likely that our MTL factor score is not an accurate reflection of global memory function. To explore whether such a global measure is possible or whether different composite measures may be needed to account for both verbal and nonverbal memory, we are currently expanding our test battery to include a broader range of memory tests.

A second reason for including the MTL variable in the present experiments was to replicate its lack of association with source memory. In the present experiments, there was no hint of an effect of MTL function on source memory. Other researchers (Henkel et al., 1998; Mather, Johnson, & De Leonardiis, 1999), however, have reported correlations between source memory and our MTL composite measure. Henkel et al. (1998) found strong correlations between MTL functioning and source accuracy in a task that required older adults to judge whether the referent of a word was originally perceived as an object or merely imagined. (They also reported correlations with the FL factor but only when testing was delayed). Henkel et al. (see also Chalfonte & Johnson, 1996) suggested that MTL structures are important for binding various features of complex memories together and that the poorer performance of older adults with low MTL function reflected a binding problem. Our findings also suggested that some older adults failed to integrate item and context, but this problem in our experiments seemed clearly dependent on FL function. Although it seems possible or even likely that different tasks place different demands on the functions associated with these two brain regions, methodological differences between experimental paradigms may also play a role. So, for example, in our experiments the item and source memory tasks were conducted independently, allowing the source memory task to be accomplished without access to item memory. The finding that memories for item and source were uncorrelated in older adults further suggests that the two tasks were relying on different processes. In the Henkel et al. experiment, people were asked to make item memory and source memory judgments together (i.e., they indicated whether an item had been perceived, had been imagined, or was new). Thus, they may have been encouraged to engage in the same processes and access the same information for both tasks. The extent to which source memory relies on MTL function may therefore depend at least partly on task demands.

A final unexpected finding in these studies was the correlation between item and source memory that was observed in young adults—but not in older adults—when they were given the integrative orienting task (but not when given the item orienting task). There are a number of possible interpretations of this finding, but at this point all of them are speculative. At the very least, it implies that even when provided with an integrative orienting question, old people do not perform the source memory test in the same way as the young, but nevertheless they are able to achieve equivalent levels of performance. Further, it suggests that young people may be flexible in their approach to source memory problems depending on the quality and type of information that they have, whereas this may be less true for older adults. Finally, our claims that source memory tasks rely on different processes than item memory tasks have to be tempered. Although in our experiments with older adults, we have consistently found item and source memory to be dissociated with respect to frontal function, it seems reasonable to suggest, along with Henkel et al. (1998), that under some conditions the two tasks may tap similar processes. The task for future research is to map out these conditions so that we may gain further information concerning the cognitive and neural processes that underlie the encoding and retrieval of both focal and nonfocal aspects of an event.

Finally, it is worth commenting on the finding that in all of the studies, the high-FL group of older adults did not differ significantly from young adults in source memory. Thus, source memory deficits are not an inevitable consequence of aging. In our 100-person normative sample of community-dwelling older adults, 52 were categorized above the mean in frontal function; in our current sample of 212 people, 122 are above the mean. It may, therefore,
be the case that many older adults do not experience significant memory declines with age. Failure to take account of these individual differences may mask findings that are important for understanding the deficits that do occur and the reasons for them. The important differences may not be between young and old adults but may be between different subgroups of older adults who are aging differently.

References


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