Journal of Experimental Psychology:
Learning, Memory, and Cognition
2007, Vol. 33, No. 2, 321–334

0278-7393/07/$12.00 DOI: 10.1037/0278-7393.33.2.321

Aging and the Misinformation Effect: A Neuropsychological Analysis

Henry L. Roediger III
Washington University in St. Louis

Lisa Geraci
Texas A&M University

Older adults' susceptibility to misinformation in an eyewitness memory paradigm was examined in two experiments. Experiment 1 showed that older adults are more susceptible to interfering misinformation than are younger adults on two different tests (old–new recognition and source monitoring). Experiment 2 examined the extent to which processes associated with frontal lobe functioning underlie older adults' source-monitoring difficulties. Older adults with lower frontal-lobe-functioning scores on neuropsychological tests were particularly susceptible to false memories in the misinformation paradigm. The authors' results agree with data from other false memory paradigms that show greater false recollections in older adults, especially in those who scored poorly on frontal tests. The results support a source-monitoring account of aging and illusory recollection.

Keywords: memory, misinformation effect, aging, frontal functioning

Loftus and Palmer (1974) introduced a laboratory paradigm for studying the experience of an eyewitness to a crime that has been widely used ever since. The basic question they asked was what effect an erroneous statement (or misinformation) about a past event would have on later recollections of the original event. In a typical misinformation experiment, college students view an event in the laboratory, such as a film or a series of slides depicting a crime or an accident. Afterward, they are given further information about the event, often in the form of a narrative that was allegedly written by a witness. Some details in the narrative are erroneous, and the point of interest is whether this misleading information obtained after viewing the original crime or accident will be incorporated into later recollections of the event. Relative to a control condition in which no misinformation is given, results typically demonstrate that subjects incorporate the misinformation into their recollections of the original scene (e.g., Loftus, Miller, & Burns, 1978; see Ayers & Reder, 1998, for a review). This result is called the misinformation effect and is one of many types of memory distortion that psychologists have studied over the past 30 years (see Roediger & McDermott, 2000, for a review).

The majority of these misinformation studies have been carried out using college students or children as subjects (see Loftus, 1979, 1991, for a review). However, older adults are often the victims and witnesses of crime, and so it is of great practical importance to know the extent to which older adults are susceptible to the negative consequences of encountering misleading information in an eyewitness situation. Surprisingly though, there have been relatively few studies examining the misinformation effect in older adults, and together these studies have proven largely inconclusive. The following experiments were designed to confirm the presence of the misinformation effect in older adults and to explore the theoretical underpinnings of possible age effects in misinformation acceptance. Our experiments approached the issue by examining effects of various encoding and retrieval conditions on acceptance of misinformation in younger and older adults (Experiment 1) as well as the effect of the neuropsychological characteristics of older adults on acceptance of misinformation (Experiment 2). We first consider the issues relevant to misinformation effects in older adults and then review the literature on this topic.

A priori, on the basis of past research and theorizing, there are different predictions one could make with regard to the effect of aging on susceptibility to misinformation. For example, one might predict that older adults would be less susceptible to misinformation because people must adequately encode and retrieve the misinformation for it to influence memory of an original event. If older adults have more difficulty encoding and retrieving the misinformation than do younger adults, then it may not interfere with later retrieval of the original information; if this is the case, then older adults would actually show a smaller misinformation effect than younger adults. Alternately, older adults might show a greater misinformation effect than younger adults because older adults may not remember the original event as well as younger adults. If the original scene is not encoded well, then older adults may be more likely to accept false information than younger adults who have encoded the original event well. As a third possibility, if older adults do encode the original event and the misinformation, they may still have problems correctly determining the source of their memories (whether the information was from the original event or the subsequent narrative) because of source-monitoring difficulties. Lastly, these various failures of memory could combine to produce what appears to be a similar level of susceptibility for younger and older adults—older adults could encode less misinformation but have greater source confusions than younger adults. Thus, alternate hypotheses can be garnered in support of

Henry L. Roediger III, Department of Psychology, Washington University in St. Louis; Lisa Geraci, Department of Psychology, Texas A&M University.

This research was supported by National Institute on Aging Grant R01AG17481.We thank Jane McConnell for her help in data collection and manuscript preparation.

Correspondence concerning this article should be addressed to Henry L. Roediger III, Department of Psychology, Washington University in St. Louis, 1 Brookings Drive, Campus Box 1125, St. Louis, MO 63130-4899. E-mail: roediger@wustl.edu

most possible outcomes of a misinformation experiment comparing younger and older adults. Indeed, as we discuss later, each predicted pattern of data has been obtained in the literature (e.g., Cohen & Faulkner, 1989; Coxon & Valentine, 1997; Marche, Jordan, & Owre, 2002).

Although different predictions can be made with respect to the effect of aging on susceptibility to misinformation, the weight of the empirical and theoretical evidence suggests that older adults will be more susceptible to misinformation than younger adults. At least two lines of evidence support this prediction. First, several studies show that older adults are more susceptible to illusory memories in other false memory paradigms. For example, older adults appear to be disproportionately susceptible to false memories that are created using the Deese–Roediger–McDermott (DRM) paradigm. In this paradigm, subjects study lists of words (e.g., *bed, rest, awake*) and later claim to have seen the related word that was never presented (e.g., *sleep*), often falsely recognizing it as frequently as words that were actually presented in the study list (Deese, 1959; Roediger & McDermott, 1995). Older adults are especially prone to this illusion (Balota et al., 1999; Chan & McDermott, in press; Kensinger & Schacter, 1999; Norman & Schacter, 1997; Schacter, Israel, & Racine, 1999), and the illusion appears to be so compelling for older adults that they are unable to avoid falsely recognizing the nonpresented word even when they are given multiple study–test trials (Watson, McDermott, & Balota, 2004) or a warning at test (McCabe & Smith, 2002). Roediger and McDaniel (2007) review this literature.

In addition, the processes that are known to mediate false memories in the misinformation paradigm have been shown to be disproportionately impaired in some older adults when compared with younger adults. As mentioned earlier, one explanation for why older adults experience more false memories in the misinformation paradigm than do younger adults is that they have problems with source monitoring (Johnson, Hashtroudi, & Lindsay, 1993). Much research shows that older adults have particular deficits in source monitoring in comparison with younger adults (e.g., Ferguson, Hashtroudi, & Johnson, 1992; Henkel, Johnson, & DeLeonardis, 1998; McIntyre & Craik, 1987; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991; Spencer & Raz, 1995). For example, older adults have more difficulty than younger adults in distinguishing whether they heard or saw something (Norman & Schacter, 1997), uttered a phrase aloud or read it silently (Hashtroudi, Johnson, & Chrosniak, 1989), or read something aloud versus simply having thought about it (Cohen & Faulkner, 1989, see Experiment 1). Older adults also have difficulty determining who said what (e.g., Naveh-Benjamin & Craik, 1996) and identifying where they learned information. For example, when nondemented older adults (McIntyre & Craik, 1987) and those with Alzheimer's disease (E. J. Marsh, Balota, & Roediger, 2005) are taught new facts, older adults and those with Alzheimer's are more likely than younger adults to attribute the source of their new knowledge to previous experience than to the study episode. The older adults fail to correctly determine that the source of their newly learned information was the recent study episode. Thus, there is empirical and theoretical support for the hypothesis that older adults are more susceptible to the misleading effects of misinformation on later retention than are younger adults. The theoretical arguments predict that if older adults encode the misinformation, then they should be more susceptible to the later interfering effects of the misinformation than would younger adults because they have difficulty recollecting and monitoring the source of their memories.

As mentioned earlier, the effect of aging on susceptibility to misinformation has not been studied extensively; when we began this line of work, there was only one extant report by Cohen and Faulkner (1989), who did find older adults more susceptible to misinformation than younger adults. Since we began the research reported in this article, several new studies on this topic have produced somewhat conflicting results. In fact, all possible patterns of data have been obtained. Some studies demonstrate that older adults are more suggestible to misinformation than younger adults (Cohen & Faulkner, 1989; Karpel, Hoyer, & Toglia, 2001; Loftus, Levidow, & Duensing, 1992; Mitchell, Johnson, & Mather, 2002), other studies demonstrate no age-related differences in suggestibility (Coxon & Valentine, 1997; Gabbert, Memon, & Allan, 2003), and one study demonstrates that younger adults can actually be more suggestible than older adults (Marche et al., 2002). In addition, studies using a variant of the misinformation paradigm with interfering mug shots in an eyewitness identification procedure have failed to find age differences in later misidentification of faces (Memon & Bartlett, 2002; Memon, Hope, Bartlett, & Bull, 2002; Searcy, Bartlett, & Memon, 2000).

It is unclear how to reconcile these disparate findings, but methodological differences and possible group differences in samples of older adults across experiments are important variables to consider. In the present studies, we used both a yes–no recognition test and a source-monitoring recognition test. The latter test permits us to measure more directly the source-monitoring abilities of younger and older adults. Multhaup, DeLeonardis, and Johnson (1999) showed a greater misinformation effect on a yes–no recognition test than on a source-monitoring test in which subjects were explicitly required to consider all possible sources of their memories. The implication is that the source-monitoring test, which requires subjects to explicitly consider the possible sources of information, taps latent source knowledge that older adults have but do not spontaneously use. However, the Multhaup et al. experiment did not include a younger adult control group, so one cannot draw the conclusion that the source-monitoring test provides a greater benefit to older than younger adults.

Another possible difference among prior studies is in cognitive abilities of older adults. The usual methodological procedure is to compare a group of healthy older adults with younger adults, but of course populations and recruitment techniques may provide older adult groups of differing abilities across studies. The younger adults in these studies are almost always college students and are probably more homogeneous in abilities. In our second experiment, we explored cognitive differences in groups of older adults as a possible mediator of misinformation effects.

Because both encoding conditions and type of test may influence whether older adults are more susceptible to misinformation than younger adults, we manipulated both variables in Experiment 1 to examine their effects within a single experiment. Specifically, we manipulated the degree of initial learning of the misinformation by varying the number of presentations, and we manipulated the type of test by giving younger and older adults a yes–no recognition test or a source-monitoring test that directed attention to the possible sources of information. As noted above, differences in cognitive functioning among the older adult samples may also help explain the conflicting reports of age effects on susceptibility to misinformation. Older adults can vary greatly in their cognitive and neurological functioning, particularly the ability to correctly remember the source of information. The ability to retain source information is an ability that has been associated with efficient frontal lobe functioning (see Raz, 2000, for a review). Therefore, Experiment 2 examined the influence of older adults' frontal functioning, as measured by their performance on a battery of neuropsychological tests, on their susceptibility to misinformation. We describe the rationale for Experiment 2 more completely after reporting the first experiment.

Experiment 1

Experiment 1 examined the effects of initial encoding and type of test on younger and older adults' susceptibility to misinformation. We manipulated encoding of the misinformation by presenting it zero, one, or three times, and we also manipulated the type of test. Subjects received a final yes–no recognition test or a final source-monitoring test. Although Mitchell et al. (2002) reported that repetition of misinformation does not differentially increase the misinformation effect in older adults when compared with younger adults on a source-monitoring recognition test, repetition may still differentially increase older adults' susceptibility to misinformation when a yes–no recognition test is used. Yes–no tests do not require recollection of source information, so older adults may base responding more on familiarity relative to younger adults (Jacoby, 1999). In addition, if familiarity drives the misinformation effect for older adults more than younger adults, then older adults should show a larger misinformation effect only when the misinformation has been presented several times. If requiring older adults to retrieve source information permits them to correctly attribute misinformation to the narrative rather than to the original slides, then a source test may help reduce the misinformation effect relative to a yes–no test (and the reduction should be greater for older than for younger adults). Multhaup et al.'s (1999) research with older adults showed that they are more susceptible to misinformation when tested using a yes–no recognition test (in which familiarity may be more critical) than when tested using a source-monitoring test (which demands specific source recognition). However, Mitchell et al. (2002) showed that when performance of younger and older adults is directly compared using only a source test, the age effect remains; older adults are still more susceptible to misinformation than are younger adults. To determine whether the source-monitoring test differentially aids older adults' performance, we manipulated age and type of test within a single study.

In our research, we used two different misinformation scenarios rather than only one (which is standard), modeling a procedure we had used before (Roediger, Jacoby, & McDermott, 1996). The use of only one set of materials means that very few critical items (usually just two or four) contribute data per condition, and most of the literature is based on this sort of study. We attempted to increase our power over prior studies in the literature in two ways. First, we manipulated misinformation within-subjects. Subjects were exposed to both correct and misleading information subsequent to the original event. Second, we used a relatively large number of critical items. Subjects essentially participated in two experiments back to back: They viewed an event and received postevent information and then viewed a different event and received postevent information pertaining to that event. The two sets of materials contained six and nine critical items, respectively, which (although not a lot) is more than other experiments in the literature, which are based on a single set of items. Because the manipulation of misinformation occurred within-subjects, subjects still did not receive many items of misinformation.

Method

Subjects. Twenty-four younger ($M = 19.45$, $SD = 1.43$) and 24 older ($M = 75.00$, $SD = 6.30$) adults participated in this experiment. The younger adults were recruited from psychology classes and received course credit. Older adults were recruited from the Washington University Older Adult Subject Pool and received $10 for their participation in the experiment. The older subjects were all healthy, older adults who lived at home and drove themselves to the study. Education level was higher for older ($M = 14.5$, $SD = 2.04$) than for younger adults ($M = 13.5$, $SD = .83$), $F(1, 42) = 4.56$, $MSE = 2.59$, $\eta_p^2 = .10$, $p < .05$ (education information was missing for 4 younger adult subjects, but all were undergraduates). Older adults also had higher vocabulary scores ($M = 36.00$, $SD = 2.92$) than did younger adults ($M = 32.8$, $SD = 2.78$), $F(1, 46) = 14.26$, $MSE = 8.11$, $\eta_p^2 = .24$, $p < .05$, as measured by the Shipley Vocabulary Test (Zachary, 1986).

Design. The experiment used a $2 \times 2 \times 3$ mixed design in which age (younger and older adults) and test type (yes–no recognition or source monitoring) served as the between-subjects variables and number of presentations of the misinformation (0, 1, or 3) served as the within-subjects variable. The zero-presentation condition served as the baseline or control condition in which no misinformation occurred.

Materials. Two sets of slide sequences were used: One depicted a repairman stealing a wallet from an empty office (see McCloskey & Zaragoza, 1985), and the other portrayed a man shoplifting items from a campus bookstore (see Loftus, 1991). The narrative accounts referred to items from the original set of slides in either a neutral manner (e.g., in the neutral condition, a Maxwell House coffee can was described as just a coffee can) or in an incorrect manner (e.g., in the misinformation condition, the Maxwell House coffee can was described as a Folgers coffee can). The manner of description (as misinformation or as neutral) was counterbalanced across the critical items. To disguise this manipulation, we also included several filler items (eight from the office slides and nine from the bookstore) that did not vary in how they were mentioned in the narrative. Lastly, to manipulate the number of times subjects encountered the misinformation, we used three narrative accounts. The misinformation was present in zero, one, or all three accounts. There were nine critical items for the bookstore slide sequence and six critical items for the office slide sequence. Equal numbers of items were presented in each repetition condition; for the bookstore sequence, three critical items were presented in the zero-, one-, or three-presentations conditions, and for the office slide sequence, two critical items were presented in the zero-, one-, or three-presentation conditions. Across subjects, all critical items were completely counterbalanced over conditions.

At test, subjects were given statements such as, "Sam had to move a jar of Folger's coffee to make room for his toolbox" that referred to the critical items. Filler statements were also included to again disguise the critical items and to provide subjects with test items from all possible sources. Filler statements referred to events in only the slide sequence or in both the slide sequence and the narrative, whereas critical misinformation statements referred to details mentioned only in the narrative. In addition, the test included some new statements that referred to events not shown in the slides or mentioned in the narratives.

Procedure. Subjects viewed both slide shows, and the order of viewing was counterbalanced across groups of subjects. Before viewing each slide sequence, subjects were told that they would be given a test for the events in the slides. They were also given some orientation to the slides (e.g., the names of the main characters and the location) to provide referents for the upcoming memory tests. Slide sequences were presented at a rate of 5 s per slide.

Immediately after viewing each slide show, subjects were given three narrative accounts relating to the slide show that they had just viewed (either the office or bookstore), and the order of these three narratives was also counterbalanced across subgroups. Subjects were told that the descriptions they were going to read were written from memory by other subjects who had viewed the sequence several times and that they should read them carefully. Each narrative contained items that were presented incorrectly (the misinformation condition) and items that were presented neutrally (the neutral condition). Because the narrative was long and the type of information for the few critical items was manipulated within-subjects, few misinformation items were presented in the narrative.

Subjects received either a final yes–no recognition test or a final source-monitoring test for each slide sequence in the same order in which the slides were presented (i.e., the test for the bookstore slides was given first if it had been viewed first). Eleven younger and 12 older adults received the yes–no recognition test, and 13 younger and 12 older adults received the source-recognition test. For both types of test, subjects were given statements such as “Sam had to move a jar of Folgers coffee to make room for his toolbox.” In the yes–no recognition test, subjects were required to indicate whether the statement described events depicted in the slide sequence. For statements referring to critical misleading items, the correct answer was always “no,” so if the subject endorsed the sentence as referring to events in the slide sequence, then his or her answer was incorrect. If such errors were made more frequently when the item had been presented as misinformation than when it was presented in the neutral condition, then the misinformation effect was obtained. On the source-monitoring test in which subjects were given several possibilities for the statement (the object occurred in the slides, in the narrative text, in both the slides and narrative, or in neither place), the correct answer was always to indicate that the information referred to events presented only in the text.

Results and Discussion

The results are presented in Tables 1 and 2 for the yes–no and source-monitoring recognition tests, respectively. All responses in both tables represent errors. Data are given for the one- and three-misinformation-presentation conditions as well as for the neutral (no misinformation) condition in both tables. The misinformation effect (shown at the bottom of the tables for the various conditions) was calculated by subtracting errors in the neutral condition from those in the misinformation conditions. Because the critical misinformation items were presented only in the narrative, for both the yes–no recognition and source-recognition tests we examined all errors indicating that the item was present in the slides. Therefore, for the yes–no recognition test, we examined “yes” responses (to the item having been in the slide sequence); for the source test, we examined errors indicating that the misinformation was present in the slides (either only in the slides or in both the slides and the narrative). Because performance was similar across the two slide sequences, combined data were used in the analyses.

Table 1
Experiment 1 Mean Proportion of Errors on the Yes–No Recognition Test Indicating That the Misinformation Was From the Slides

Item type and number of presentations	Age	
	Young	Old
Misinformation		
1 presentation	.29 (.08)	.62 (.08)
3 presentations	.29 (.08)	.68 (.10)
Neutral	.18 (.06)	.42 (.08)
Misinformation effect		
1 presentation	.11	.20
3 presentations	.11	.26

Note. The misinformation effect refers to the proportion of false alarms for items in the misinformation condition minus those in one of the other baseline conditions. Standard errors of the mean are in parentheses.

As shown in Tables 1 and 2, older adults were more likely to make misinformation errors than were younger adults when the misinformation had been presented once or three times, and this effect was (as predicted) greater in the yes–no recognition test than in the source-monitoring recognition test. Surprisingly, the number of presentations of misinformation had little effect. Note that the probability of errors in the neutral condition was much greater for older than for younger adults, a point to which we return below.

We used a $2 \times 2 \times 3$ mixed analysis of variance (ANOVA) to examine the effect of age (old vs. young), test type (yes–no recognition vs. source recognition), and number of presentations (0, 1, or 3) on the production of errors, where age and test type served as the between-subjects variables and number of presentations served as the within-subjects variable. F ratios, mean-square-error terms, and effect size (partial eta squared; η_p^2) are reported for all of the following significant effects (with significance levels set at $p < .05$). The ANOVA showed a main effect of age, $F(1, 44) = 12.73$, $MSE = .12$, $\eta_p^2 = .21$, indicating that older adults were overall more likely to recognize erroneous statements as having been presented in the slides than were younger adults ($M = 0.49$ for older and $M = 0.29$ for younger adults). There was no main effect of test type. However, there was a significant interaction between age and test type, $F(1, 44) = 3.92$, $MSE = .12$, $\eta_p^2 = .09$. Briefly, source-monitoring tests decreased false responding in older adults (relative to yes–no tests), but no difference existed in this comparison for younger adults.

Planned comparisons examined the locus of this age by test-type interaction and showed that errors across all conditions were greater for older adults ($M = 0.57$) compared with younger adults

Table 2
Experiment 1 Mean Proportion of Each Type of Response on the Source-Monitoring Test for Each Number of Presentations

Item type and number of presentations	Age	
	Young	Old
Misinformation		
1 presentation (responses)		
"Slides"	.05 (.03)	.07 (.03)
"Both"	.33 (.05)	.40 (.07)
Total false recognition	.38	.47
"Text"	.40 (.05)	.23 (.06)
"Neither"	.22 (.05)	.28 (.05)
3 presentations (responses)		
"Slides"	.04 (.02)	.00 (.00)
"Both"	.38 (.09)	.50 (.08)
Total false recognition	.42	.50
"Text"	.56 (.09)	.28 (.09)
"Neither"	.02 (.02)	.22 (.05)
Neutral (responses)		
"Slides"	.06 (.02)	.13 (.05)
"Both"	.18 (.04)	.18 (.06)
Total false recognition	.24	.31
"Text"	.09 (.04)	.17 (.06)
"Neither"	.67 (.03)	.50 (.08)
Misinformation effect (total false recognition)		
1 presentation	.14	.16
3 presentations	.18	.19

Note. Columns that do not sum to 1.00 are the result of responses omitted by subjects. Standard errors of the mean are in parentheses.

(M = 0.26) when given a yes–no recognition test, $F(1, 23) = 14.47$, $MSE = .04$, $\eta_p^2 = .39$. However, when subjects were given a source-monitoring test, older adults' level of errors across all conditions (M = 0.41) did not differ significantly from that of younger adults (M = 0.32), $F(1, 21) = 1.38$, $MSE = .03$, although the difference was in the expected direction. The effect size for this comparison was quite small ($\eta_p^2 = .06$), suggesting that many more subjects would have been required to detect any effect of age under our experimental conditions. Whereas younger adults' level of errors did not significantly differ as a function of type of test (recognition or source monitoring), $F(1, 22) < 1$, older adults showed more false alarms to the misinformation statement when they were given a yes–no recognition test than when they were given a source-monitoring test, $F(1, 22) = 3.15$, $MSE = .05$, $\eta_p^2 = .13$. This effect of test type for older adults replicates previous work showing that older adults can reduce misinformation errors when given a source test (Multhaup et al., 1999).

There was also a main effect of number of presentations on acceptance of misinformation, $F(2, 88) = 9.34$, $MSE = .04$, $\eta_p^2 = .13$, but this effect was due to the fact that younger and older adults were simply more likely to judge that items presented either in one or three of the narratives (Ms = 0.42 and 0.46, respectively) were from the slides than to judge items that were never presented as misinformation (M = 0.28) in the narratives. Thus, we did not find a repetition effect, as 0.42 and 0.46 were not significantly different from each other ($F < 1$, $\eta_p^2 < .01$). Simple effects tests showed that this pattern (indicating the effect did not increase with repetition) did not differ significantly for either age group. Thus, contrary to our prediction, repetition of the misinformation did not increase the misinformation effect in older adults, although the slight differences observed were in the expected direction for both tests.

One notable fact in these data is that older subjects were more likely to make errors than were younger adults, even in the neutral condition in which no misinformation had been provided. This effect was much larger for the yes–no test (42% erroneous responses for older adults vs. 18% for younger adults) than for the source-monitoring tests (31% vs. 24%). These data in the neutral condition also show that older adults are much more susceptible to false memories than younger adults on a yes–no test and that the source test reduces this difference. Errors in the neutral condition may be similar to those in the DRM paradigm in that the test item is accepted by virtue of being consistent with the information in the slide sequence even though it did not actually appear there.

Despite the differences in the neutral conditions, the misinformation effect data (shown in the bottoms of Tables 1 and 2 and graphically in Figure 1) showed the expected pattern: the misinformation effect for older adults was greater than that for younger adults, but for only the yes–no test. That is, despite the fact that older adults showed a very high proportion of errors in the neutral condition of the yes–no test, they still showed a much greater misinformation effect (.23 vs. .11). If differences in the neutral base rates were corrected in one of the standard ways for the yes–no test, the misinformation effect would be even greater in older adults than in younger adults, as discussed in the next paragraph. In the source-monitoring test, the misinformation effect did not differ between the two groups (.18 vs. .16 for older and younger adults, collapsing over the number of presentations variable).

The difference between younger and older adults in the neutral conditions in the yes–no and source-monitoring test could potentially compromise our claims. As noted in the preceding paragraph, the largest difference in neutral scores was for the yes–no test. If one computes the proportional increase above the respective neutral (baseline) conditions for younger and older adults in the standard way—(MI − Neutral)/(100 − Neutral) × 100, where MI = misinformation—then the misinformation effect shown by older adults is 40% and that of younger adults is 13% (collapsing over number of presentations). As noted above, the comparable misinformation effects from the raw scores for older and younger adults were 23% and 11%, respectively (again, collapsed over the two presentation conditions, which did not differ). Because the neutral conditions in the source-monitoring test did not differ as much, the proportional difference is about the same as before, with a 21% corrected misinformation effect for younger adults relative to 26% for older adults. No statistics can be applied to these aggregate data, of course, but the point is that the difference in the misinformation effect between older and younger adults is 27% for the yes–no test and only 5% for the source-monitoring test. Therefore, taking differences in neutral (baseline) scores in the two age groups into account does not alter our conclusion that the misinformation effect is greater for older adults in the yes–no test than it is in the source-monitoring test; if anything, the proportional analyses bolster that conclusion more strongly than the results based on the means in Tables 1 and 2.

These results demonstrate three main points. First, older adults were more error prone than younger adults in the misinformation paradigm. Second, we did not obtain evidence that repetition of the

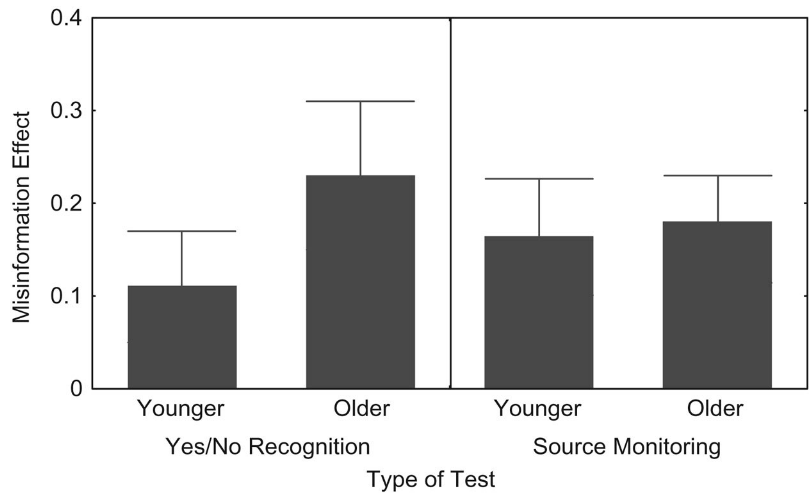

Figure 1. Misinformation effects on the yes–no and source-monitoring recognition tests for younger and older adults in Experiment 1. Error bars represent standard errors of the mean.

misinformation differentially mediates susceptibility to misinformation on subsequent tests for either younger or older adults, contrary to our prediction. Third, older adults were more affected by the type of test (yes–no recognition vs. source recognition) than were younger adults. When the test directed subjects to attend to all possible sources of information, older adults made significantly fewer errors than when they were given a standard yes–no recognition test. This outcome suggests that source-monitoring problems contribute to older adults' increased susceptibility to misinformation on yes–no tests. Experiment 2 examined whether older adults' neurological functioning, as assessed by neuropsychological tests, mediates the age effects reported in Experiment 1, as has been shown in other false memory paradigms (Roediger & McDaniel, 2007).

Experiment 2

This experiment examined whether processes associated with executive frontal lobe functioning might underlie older adults' increased susceptibility to misinformation, as reported in Experiment 1 and in prior research. We were interested in the role of frontal lobe functioning because prior work has shown correlations between frontal functioning and older adults' source-monitoring abilities (e.g., McIntyre & Craik, 1987). The conclusion that frontal lobe functioning declines with age has also received support from several studies using various methodologies. For example, older adults sometimes show similar levels of source errors as do patients with frontal lobe lesions (Janowsky, Shimamura, & Squire, 1989), suggesting that older adults may have similar impairments of neurological functioning. Similarly, studies of event-related potentials and functional magnetic resonance imaging demonstrate activation in the frontal lobes on source tests (e.g., Nolde, Johnson, & D'Esposito, 1998; Trott, Friedman, Ritter, & Fabiani, 1997). In addition, performance on neuropsychological batteries designed to measure attentional control processes associated with frontal functioning show that older adults with poor performance on these tests have selective impairments in the ability to remember details of source but not to recognize the items themselves (Glisky, Polster, & Routhieaux, 1995; Glisky, Rubin, & Davidson, 2001). The Glisky et al. (1995) study shows that, when compared with those older adults who performed well on these neuropsychological tests of frontal functioning, those who performed poorly had difficulty determining the voice in which a sentence was spoken. However, these two groups of older adults did not differ in their ability to remember the sentences themselves. Thus, these results demonstrate that older adults' source-monitoring abilities are mediated by their level of frontal functioning, as measured by this battery of neuropsychological tests.

There is some evidence for contributions of medial-temporal lobes in source-monitoring tests when older adults are required to distinguish between perceptually similar features of a single event (e.g., Henkel et al., 1998). However, the majority of the research shows that working memory ability (Jaschinski & Wentura, 2002) and related frontal functioning abilities mediate source-monitoring accuracy when the retrieval task requires subjects to use controlled processes to distinguish between different contexts (e.g., Glisky et al., 1995, 2001). For these reasons, we were specifically interested in the role of frontal functioning on older adults' ability to monitor the source of their memories.

Failures in source monitoring lead to false memories in many instances, and indeed there is evidence that frontal functioning predicts false memories in older adults. For example, people with damage to the right frontal lobe have high levels of false recognition using various paradigms (Curran, Schacter, Norman, & Galluccio, 1997; Schacter, Curran, Galluccio, Milberg, & Bates, 1996). Similarly, neuroimaging studies demonstrate that false recognition in healthy adults using the DRM paradigm is associated with activation of the frontal lobes (Schacter, Buckner, Koutstaal, Dale, & Rosen, 1997; Schacter, Reiman, et al., 1996). Also, using the same neuropsychological tests as in Experiment 2, Butler, McDaniel, Dornburg, Price, and Roediger (2004) found that only older adults with lower frontal functioning showed more false recall for critical (related) lures than younger adults in the DRM paradigm. Older adults with higher frontal functioning showed levels of false recall similar to that of younger adults, but later work by Chan and McDermott (in press) shows that both frontal functioning and age made independent contributions to illusory recollections in the DRM paradigm. From these results, one might predict that poor frontal lobe functioning in older adults, and not simply the fact that they are older than young adults, would predict older adults' false memories in the misinformation paradigm; if so, individual differences in samples of older adults (possibly because of different recruitment methods) may partially explain the mixed pattern of data from previous misinformation studies using older adults.

To examine the effect of frontal lobe functioning on susceptibility to misinformation, in Experiment 2, we used a battery of cognitive tests taken from Glisky et al.'s (1995) factor analysis described previously (and used by Butler et al., 2004, among others). This battery of tests probably captures controlled memory processes associated with frontal lobe functioning better than any single test alone (Glisky et al., 1995, 2001). Following the general procedure used by these studies, we obtained composite scores from five neuropsychological tests and used them to classify subjects into groups of either high or low frontal-functioning older adults. Our main interest was whether older adults with relatively low frontal-functioning scores would be particularly susceptible to misinformation when compared with older adults with relatively high frontal-functioning scores.

In addition to neutral and misinformation conditions, we also included a consistent condition in this experiment, such that for some items the narrative provided correct information about the target items. Thus, the critical items were mentioned in the narratives in one of the following conditions: neutral (a Maxwell House coffee can seen in the slides was mentioned as just a coffee can), consistent (a Maxwell House coffee can seen in the slides was mentioned in the narrative as a Maxwell House coffee can), or misinformation (the Maxwell House coffee can in the slides was mentioned in the narrative as a Folgers coffee can). Inclusion of the consistent condition provides two possible baselines against which to measure the effect of misinformation. In this experiment, number of presentations of the misinformation was not manipulated because it had no effect in Experiment 1.

Method

Subjects. Sixty older adults between the ages of 65 and 85 ($M = 74.42$, $SD = 5.06$) were recruited from the same source as in Experiment 1 and were paid $10 an hour. All were healthy older adults who drove themselves to the laboratory to be tested. To classify older adults into high- and low-frontal groups, we used the five neuropsychological tests taken from Glisky et al.'s (1995) factor analysis that were found to be associated with frontal lobe functioning: the Wisconsin Card Sorting Task (Hart, Kwentus, Wade, & Taylor, 1988), the Verbal Fluency (or FAS) Test (Spreen & Benton, 1977), the Mental Control Test (taken from the Wechsler Memory Scale—Revised, Wechsler, 1987), the Mental Arithmetic Test (taken from the Wechsler Adult Intelligence Scale—Revised; Wechsler, 1981), and the Backward Digit Span (again taken from the Wechsler Memory Scale—Revised). On the basis of the subjects' performance on each of the tests, we used Glisky et al.'s (1995) formula and their sample data to obtain a single weighted z score for each subject to represent his or her level of frontal lobe functioning. Subjects whose z scores fell above zero were classified as high frontal functioning and those whose scores fell below zero were classified as low frontal functioning. On the basis of this procedure, we obtained 24 older adults who were classified as high frontal functioning and 36 older adults who were classified as low frontal functioning. Subjects in this study had previously taken the test battery and were selected on the basis of their scores. They had never previously participated in an eyewitness memory experiment.

In this study, we did not measure performance on neuropsychological tests associated with medial-temporal lobe functioning, but other studies have measured both frontal- and medial-temporal lobe functioning using neuropsychological test performance and found no correlation in performance between the two measures (Glisky et al., 1995). In addition, other studies have found that medial-temporal lobe functioning does not mediate the observed frontal lobe effect on false memories in older adults (Butler et al., 2004). In the Butler et al. study, only older adults with low scores on the battery of frontal lobe functioning tests were more susceptible to false memories than younger adults, and when the medial temporal lobe scores were examined for the groups with high- and low-frontal scores, there was no statistical difference in these scores across groups. For these reasons, we did not expect that tests of medial temporal lobe functioning would play a significant role in older adults' susceptibility to misinformation or mediate any possible effects of frontal lobe functioning in susceptibility to misinformation.

Demographic characteristics of the high- and low-frontal older adults were obtained. The average age was similar for the two groups ($M = 74.10$, $SD = 5.22$ for the high-frontal group, and $M = 74.60$, $SD = 5.01$ for the low-frontal group). Education was slightly higher for the high-frontal group ($M = 15.98$, $SD = 2.34$) than for the low-frontal group ($M = 14.36$, $SD = 2.33$), $F(1, 58) = 6.93$, $MSE = 5.44$. $\eta_p^2 = .11$. Shipley vocabulary scores were also higher for the high-frontal older adults ($M = 36.83$, $SD = 2.65$) than for the low-frontal older adults ($M = 33.81$, $SD = 3.74$), $F(1, 58) = 11.76$, $MSE = 11.22$, $\eta_p^2 = .17$. However, even the low-frontal-functioning older adults had vocabulary scores equivalent to (actually slightly higher than) those of the younger adults tested in Experiment 1 ($M = 32.80$).

Design. We used a 3×2 mixed-subjects design, with narrative presentation condition (consistent, misinformation, and neutral) and test type (yes–no recognition and source-monitoring test) serving as the within-subjects variables and with frontal status (high versus low) serving as the between-subjects variable.

Materials. We used the same two sets of slide sequences from Experiment 1. Again, subjects received three separate narrative accounts for each slide sequence. However, in this experiment, we did not manipulate number of presentations of the critical items. Instead, critical items were mentioned in all three narratives to ensure that they were encoded. In addition, this experiment used a consistent condition; thus, the critical items were referred to in the narratives in one of the following conditions: neutral (a Maxwell House coffee can was mentioned as just a coffee can), consistent (a Maxwell House coffee can was mentioned as a Maxwell House coffee can), or misinformation (a Maxwell House coffee can was mentioned as a Folgers coffee can).

To enhance our power to detect high- or low-frontal-functioning differences across the two tests, we manipulated type of test within subjects such that subjects received both a yes–no recognition test and a source-monitoring recognition test after viewing each slide sequence. The source test always followed the yes–no recognition test and required subjects to specify the source of the misinformation as appearing either in the slides only, in the text only, in both the slides and the text, or in neither.

Procedure. The procedure was the same as in Experiment 1, with the following exceptions. First, the number of times subjects encountered information in the three conditions was held constant (all items were encountered three times in the same condition across the three narratives). Also, the type of test was manipulated within subjects; subjects took a yes–no recognition test followed by a source test for each slide sequence. The same items were included on each test. Of course, having the source test follow the yes–no test leads to possible contamination of the former by the latter. We used this procedure for practical reasons to boost power in the experiment (each of our 60 subjects was involved in 2 hr of neuropsychological pretesting prior to 1 hr of experimental testing). Of course, if different patterns of results occur on the two tests (as we expect), the fact of the prior yes–no test would probably not have differentially affected the source test across the two subject groups.

Results and Discussion

The results are presented in Tables 3 and 4. Table 3 shows the means from the yes–no recognition test broken down by subject group (high or low frontal functioning) and narrative condition (neutral, consistent, and misinformation). Table 4 shows the means from the subsequent source-recognition test, again broken down by subject group and condition. The misinformation effect (the difference between the misinformation condition and the other conditions) is shown at the bottom of the tables, using both the standard neutral condition and the consistent condition as baselines. Briefly, low-frontal-functioning older adults showed a much greater tendency to commit errors than did high-frontal-functioning older adults on both tests except in the consistent information condition (in which there was no difference). The misinformation effect was also much greater for low- than for high-frontal-functioning older adults, except in the yes–no test with the neutral baseline. The neutral baseline itself was much higher for low than for high-frontal-functioning older adults on both tests (.50 to .26, respectively). When the baseline differences are taken into account by using the proportional analysis described for Experiment 1, low-frontal-functioning older adults also showed a somewhat greater misinformation effect than did high-frontal-functioning older adults even on the yes–no test (.52 to .42, respectively). The statistical analyses are reported next.

Table 3
Experiment 2 Mean Proportion of Errors on the Yes–No Recognition Test Indicating That the Misinformation Was From the Slides

Item type	Frontal lobe functioning status: High	Low
Misinformation	.57 (.05)	.76 (.04)
Neutral	.26 (.05)	.50 (.04)
Consistent	.25 (.05)	.22 (.04)
Misinformation effect		
Neutral baseline	.31	.26
Consistent baseline	.32	.54

Note. Standard errors of the mean are in parentheses.

Table 4
Experiment 2 Mean Proportion of Each Type of Response on the Source Monitoring Test

Item type	Frontal lobe functioning status: High	Low
Misinformation (responses)		
“Slides”	.07 (.04)	.18 (.05)
“Both”	.42 (.06)	.62 (.05)
Total false recognition	.49	.80
“Text”	.26 (.06)	.13 (.03)
“Neither”	.25 (.06)	.08 (.02)
Neutral (responses)		
“Slides”	.09 (.03)	.14 (.04)
“Both”	.27 (.05)	.37 (.05)
Total false recognition	.36	.51
“Text”	.23 (.06)	.13 (.04)
“Neither”	.40 (.05)	.35 (.05)
Consistent (responses)		
“Slides”	.10 (.03)	.09 (.03)
“Both”	.26 (.05)	.23 (.04)
Total false recognition	.36	.32
“Text”	.22 (.06)	.13 (.04)
“Neither”	.41 (.07)	.54 (.05)
Misinformation effect (total false recognition)		
Neutral baseline	.13	.29
Consistent baseline	.13	.48

Note. Standard errors of the mean are in parentheses.

First, we examined the effect of frontal status (high and low) on misinformation errors (indicating that the misinformation was present in the slides) as a function of the test type (yes–no recognition vs. source monitoring). As in Experiment 1, for both the recognition and source tests, subjects were asked whether the misinformation item (e.g., the Folgers can) was from the slide sequence. Thus, regardless of whether the item was presented in the narrative accounts in a neutral, consistent, or incorrect (misinformation) manner, the correct answer to the question was always “no,” so errors were claims that the item had appeared in the slides (“yes” judgments). For the source test, as in Experiment 1, we examined responses indicating that the misinformation was present in the slides, whether it was judged to be only in the slide sequence or in the slide sequence and in the narrative. Because performance was similar across the two slide sequences, all subsequent analyses used combined data.

We next consider the overall effect of type of test on misinformation acceptance. *F* ratios, mean-square error terms, and effect size (η_p^2) are reported for all of the following significant effects. Using the neutral condition as the baseline, we calculated the misinformation effect in the standard way and then examined the effect of subject group (high- and low-frontal-functioning older adults) and test type (yes–no recognition and source monitoring) on the misinformation effect. This analysis showed no main effects of frontal status or test type (although *p* was at .07 for the effect of test, with more errors in the yes–no test). However, the interaction between the two variables, $F(1, 58) = 11.16$, $MSE = .04$, $\eta_p^2 = .16$, was significant, indicating that high- and low-frontal-functioning older adults were differentially affected by the type of test. The source-monitoring test greatly reduced the misinformation effect in high-frontal-functioning subjects but did not have much effect in low-frontal-functioning subjects. This result makes sense if low-frontal-functioning older adults have difficulty using source information. We note that this result also holds true (in fact, it is even stronger) when baseline differences in the neutral condition are taken into account. The misinformation effects using the standard proportional analysis described previously were .42 and .52 for high- and low-frontal-functioning older adults on the yes–no test, but were .20 and .59 for the source-monitoring test.

Next, we calculated the misinformation effect using the errors in the consistent condition as a baseline, because high- and low-frontal-functioning older adults were matched on this measure (misinformation minus consistent scores). The fact that the scores in the consistent condition were equal was a bit of a surprise, but this fact is useful for providing an equivalent baseline against which to measure the misinformation effect. This ANOVA showed a main effect of frontal status, $F(1, 58) = 10.61$, $MSE = .21$, $\eta_p^2 = .15$, indicating that low-frontal-functioning older adults ($M = .50$) made more misinformation errors than did high-frontal-functioning older adults ($M = .23$). There was also a main effect of test type, $F(1, 58) = 7.53$, $MSE = .04$, $\eta_p^2 = .12$, indicating that all subjects were more prone to errors when given a yes–no recognition test ($M = .44$) than when given a source-monitoring test ($M = .35$). The interactive effect of frontal status on type of test was marginally significant, $F(1, 58) = 3.47$, $MSE = .04$, $p = .07$, $\eta_p^2 = .06$, showing that the older adults with high frontal functioning were aided more (had a greater reduction in the misinformation effect) by the source test than were low-frontal-functioning older adults. Although marginally reliable, the fact that the same pattern of results occurred with both neutral and consistent conditions lends validity to the claim. Further, if the baselines are taken into account in both the yes–no and source-monitoring tests using the consistent conditions as baselines, the same pattern occurs: The corrected proportion of errors for high- and low-frontal-functioning older adults are .43 and .69 for the yes–no test and .20 and .70 for the source-monitoring test. In short, all the results point in the same direction. We now consider statistical analyses of the two tests separately.

Yes–no recognition results. In this analysis we examined performance on the yes–no recognition test alone (see Table 3), again collapsing across slide sequences. We used a 2 × 3 mixed ANOVA to examine the effect of frontal status (high and low) on acceptance of misinformation in the three presentation conditions (consistent, neutral, misinformation). This analysis showed a main effect of frontal status on errors (proportion of "yes" responses), demonstrating that low-frontal-functioning older adults were more error-prone (.49) than were high-frontal-functioning older adults (.36), $F(1, 58) = 10.08$, $MSE = .09$, $\eta_p^2 = .10$. As expected, there was also a main effect of presentation condition, showing that people had the greatest proportion of errors in the misinformation condition ($M = .68$), followed by the neutral condition ($M = .41$), with the least number of errors in the consistent condition ($M = .23$), $F(2, 116) = 51.90$, $MSE = .05$, $\eta_p^2 = .53$. Lastly, a significant interaction showed that errors in each of the three conditions depended on subjects' frontal status, $F(2, 116) = 6.16$, $MSE = .05$, $\eta_p^2 = .10$. Planned comparisons further showed that low-frontal-functioning older adults were more likely to accept false information in the misinformation condition ($M = .76$) than were high-frontal-functioning older adults ($M = .57$), $F(1, 58) = 6.76$, $MSE = .06$, $\eta_p^2 = .09$. However, as noted previously, low-frontal-functioning older adults were also significantly more likely to accept misinformation than the high-frontal-functioning older adults in the neutral condition, $F(1, 58) = 12.27$, $MSE = .06$, $\eta_p^2 = .17$ (low $M = .50$ and high $M = .26$), showing that low-frontal-functioning older adults appear to be overall more susceptible to memory errors regardless of specific interference from misinformation.

Because of the high proportion of errors in the neutral condition, especially for low-frontal-functioning older adults, we found no significant differential effect of frontal status on the misinformation effect when it is calculated using the errors in the neutral condition as a baseline on the yes–no recognition test. As noted above, however, the proportional analysis correcting for baseline differences does show a numerically greater misinformation effect for low-frontal-functioning older adults (.52 to .42). More importantly, when we use the equivalent error rates in the consistent condition as a baseline, low-frontal-functioning older adults showed greater susceptibility to misinformation than high-frontal-functioning older adults, $F(1, 58) = 4.58$, $MSE = .13$, $\eta_p^2 = .10$ (.54 for low and .32 for high; see Figure 2). We examined the specific effect of the consistent information on later acceptance of misinformation. It is interesting that the high-frontal-functioning older adults did not differ from the low-frontal-functioning older adults in rejecting the misinformation when they were presented with slide-consistent information in the narratives. Thus, they were no more likely to benefit from correct information than were the low-frontal-functioning older adults, although the fact that high-frontal-functioning older adults did not show improvement in the consistent relative to the neutral condition is puzzling.

Source-monitoring test results. We turn now to the data from the source-monitoring recognition test (see Table 4). This test encouraged subjects to consider the different possible sources of information by giving them the choice of sources; they indicated whether the statement referred to events either in the slides, in the text, in both the slides and text, or in neither. To examine the misinformation effect on this test, we first conducted an ANOVA on the errors to say that the item had been present in the slides (adding together "slides" and "both slides and text" errors). This analysis showed a significant main effect of frontal status, $F(1, 58) = 5.41$, $MSE = .12$, $\eta_p^2 = .09$, demonstrating that across conditions, low-frontal-functioning older adults made more errors than did high-frontal-functioning older adults (.54 vs. .40). As expected, there was also a main effect of narrative condition, $F(2, 116) = 26.84$, $MSE = .06$, $\eta_p^2 = .32$, showing that subjects made the most errors in the misinformation condition ($M = .64$), followed by the neutral condition ($M = .43$), then followed by the consistent condition ($M = .34$). We also obtained a significant interaction between frontal status and condition, $F(2, 116) = 7.82$, $MSE = .06$, $\eta_p^2 = .12$. Planned comparisons showed that low-frontal-functioning older adults were significantly more likely to accept the misinformation in the misinformation condition than were high-frontal-functioning older adults, .80 to .49, $F(1, 58) = 19.60$, $MSE = .06$, $\eta_p^2 = .25$.

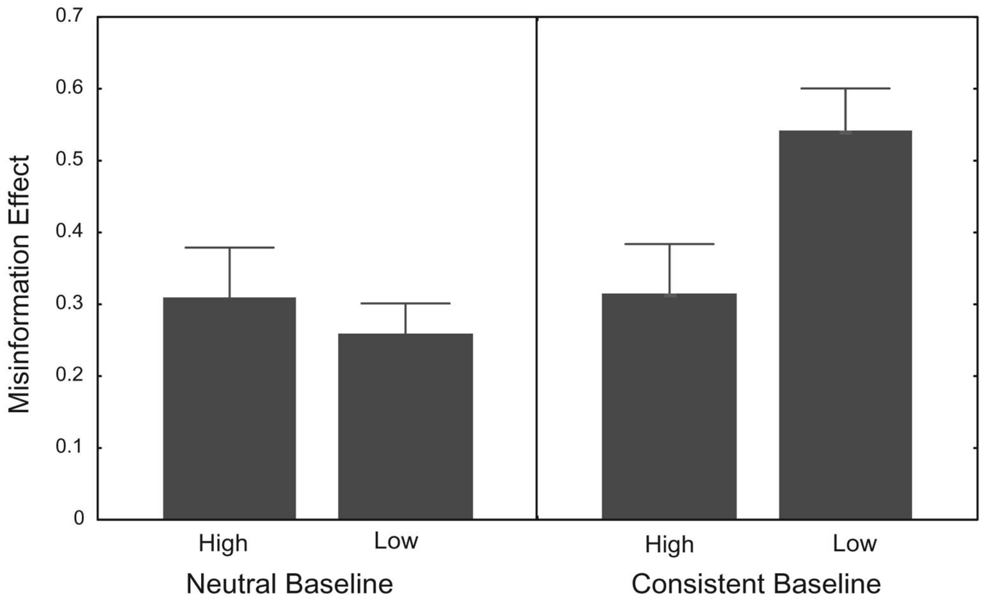

Figure 2. Misinformation effects on the yes–no recognition test in Experiment 2 using both the neutral condition (left panel) and the consistent condition (right panel) as the baseline. Error bars represent standard errors of the mean.

Given this pattern, we examined the size of the misinformation effect for the high- and low-frontal-functioning older adults using both the neutral items and the consistent items as a baseline. First, we subtracted all the errors indicating that the critical item had been present in the slides (adding together "slides" and "both the slides and the text" responses) in the neutral condition from those indicating that the critical item had been present in the misinformation condition. Using a one-way ANOVA on these data, we found that low-frontal-functioning older adults showed a greater misinformation effect than did high-frontal-functioning older adults, $F(1, 58) = 4.19$, $MSE = .11$, $\eta_p^2 = .07$ (low = .29 and high = .13). Similarly, when we used the errors in the consistent condition as a baseline (subtracting these errors from those in the misinformation condition), we again found that low-frontal-functioning older adults showed a greater misinformation effect than did high-frontal-functioning older adults, $F(1, 58) = 14.62$, $MSE = .12$, $\eta_p^2 = .20$ (low = .48 and high = .13). We present the data graphically in Figure 3. If baselines are taken into account with a proportional analysis, the patterns just reported are even larger: With the neutral condition used as the baseline, low-frontal-functioning older adults showed a .59 misinformation effect and high-frontal-functioning older adults showed a .20 effect. The comparable figures for the consistent baseline are .70 and .20.

Lastly, we examined the effect of frontal status on correct responses to the source test, that is, to saying that the misinformation response occurred in the narrative but not in the slides. As expected, high-frontal-functioning older adults gave a significantly higher proportion of correct "text" judgments to the misinformation than did low-frontal-functioning older adults, $F(1, 58) = 3.92$, $MSE = .04$, $\eta_p^2 = .06$.

Overall, these results demonstrate that frontal lobe functioning as measured by neuropsychological tests mediates older adults' susceptibility to false memories in the misinformation paradigm. The low-frontal-functioning older adults showed a greater tendency to make errors on both recognition tests than did high-frontal-functioning older adults (except in the consistent information condition). The low-frontal-functioning older adults were also more susceptible to the negative effects of misinformation than were high-frontal-functioning older adults on both recognition tests. We also found that when high-frontal-functioning subjects took a source-monitoring test that directed them to consider the various sources of information after the yes–no test, they were able to reduce the magnitude of the misinformation effect. No comparable reduction occurred for low-frontal-functioning older adults on the source test relative to the yes–no test. This outcome demonstrates that taking a yes–no test before a source test does not produce some general confounding effect on later performance (say, by raising the error rate on the source test), because one group showed improved performance on the source test and the other group did not. Low-frontal-functioning older adults endorsed more false memories overall and showed a greater misinformation effect than did high-frontal-functioning older adults on the source-monitoring test.

Subsidiary analyses. Vocabulary scores and years of education were significantly higher for high-frontal-functioning older adults than for low-frontal-functioning older adults in our samples and thus serve as a possible confound. To examine whether these differences affected our results, we dropped the 12 low-frontal-functioning subjects with the lowest vocabulary scores to equate performance on this dimension between the two groups. Because we had tested 36 low- and 24 high-frontal-functioning older adults, dropping 12 from the former group brought the samples to equal size. When we examined the data on the yes–no recognition tests for these equated groups, the patterns of results were the same. For example, for the entire sample of low-frontal-functioning older adults, performance was .76, .50, and .22 for the misinformation,

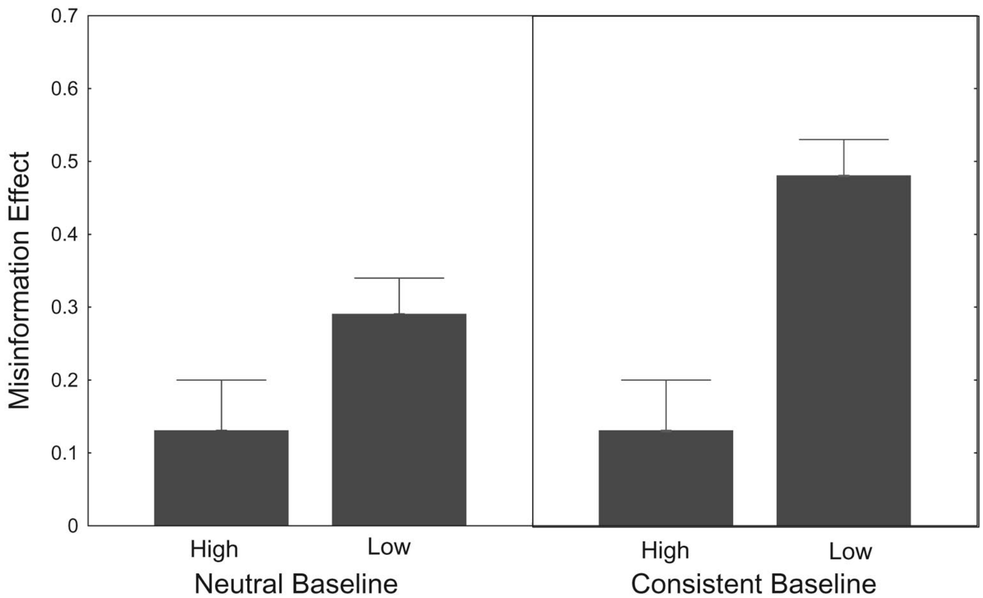

Figure 3. Misinformation effects on the source-monitoring recognition test in Experiment 2 using both the neutral condition (left panel) and the consistent condition (right panel) as the baseline. Error bars represent standard errors of the mean.

neutral, and consistent conditions, respectively; the corresponding means were .71, .51, and .22 for those 24 scoring highest on the vocabulary test. Examining Table 3, it is apparent that the performance of low-frontal-functioning older adults equated on vocabulary with the high-frontal-functioning older adults still showed much higher error rates in the misinformation and neutral conditions. We performed similar analyses equating the two groups on education levels, again by dropping the 12 low-frontal-functioning older adults with the lowest levels of education. The same patterns of results reported remained in our results. We also conducted additional analyses like this that are not reported here. The conclusion is that neither education nor vocabulary differences between our groups account for the results of Experiment 2.

General Discussion

These experiments showed that older adults are more susceptible to the deleterious effect of misinformation than are younger adults and that their increased susceptibility is mediated by their neuropsychological functioning, as measured by standard tests designed to assess frontal lobe functioning. We also asked whether number of presentations of misinformation (one time or three times) and type of test (yes–no recognition or source monitoring) would affect performance of these groups. Experiment 1 showed that in both presentation conditions (one time and three times), older adults demonstrated a greater misinformation effect than younger adults. Contrary to one hypothesis from the introduction, we did not find that older adults' susceptibility to misinformation was mediated by differences in encoding of the misinformation; regardless of whether subjects encoded the misinformation one time or three times, older adults were more likely to endorse the misinformation as having been present in the original event than were younger adults. The fact that the number of presentations did not affect performance surprised us and is inconsistent with prior research, so this outcome bears further scrutiny in future research.

In addition to showing a greater misinformation effect by the standard measure (misinformation errors minus errors in the neutral condition) in the yes–no recognition test of Experiment 1, older adults were more prone to errors even in the neutral condition when no misinformation was presented. We assume this effect is like that found in DRM false memory experiments in which older adults often show a greater propensity to false recall and false recognition for items that are consistent with prior events than are younger adults (e.g., Balota et al., 1999; see Roediger & McDaniel, 2007, for a review). At any rate, we clearly found no evidence to suggest that older adults are less susceptible to misinformation due to their not encoding the misinformation well from the narrative, because they showed the effect when the misinformation was presented one time or three times.

Experiment 1 also examined whether explicitly prompting older adults to consider source information at retrieval would reduce the misinformation effect (relative to another group's performance on a yes–no test or relative to younger adults' performance). The data showed that, when given a source test, the older adults' misinformation effect was reduced to the level of the younger adults when they had encountered the misinformation multiple times but that no difference occurred when they had seen the misinformation only once. Thus, the source-monitoring test did permit older adults to reduce misinformation errors when the source of the information as coming from the narrative was made more salient. This finding is consistent with research by Multhaup et al. (1999), who also showed that older adults were less susceptible to misinformation when given a source test than a yes–no recognition test. Multhaup et al. tested only older adults in their research, but another study by Mitchell et al. (2002) directly compared older adults with younger adults on a source-monitoring test in an eyewitness paradigm and found that older adults were still more susceptible to misinformation than were younger adults. When we examined the effect of both variables (age and type of test) in a single experiment, we found that when the misinformation was well encoded (presented three times), the source test helped older adults reduce the misinformation effect (relative to the yes–no test), but when the misinformation was not well encoded (presented only one time), any benefit from the source test was negligible. Somewhat curiously, younger adults actually performed slightly worse (showed a larger misinformation effect) in the source-monitoring test than in the yes–no recognition test, which is similar to a finding by R. L. Marsh, Hicks, and Davis (2002) showing that, under certain conditions, source-monitoring tests can actually increase false recognition.

Experiment 2 examined whether older adults' acceptance of false information was mediated by their frontal lobe functioning, which has been associated with difficulties in source monitoring (Glisky et al., 1995, 2001). Our results showed that the low-frontal-functioning older adults showed greater false recognition overall, regardless of the type of narrative they read or the type of memory test they took, than did the high-frontal-functioning older adults. When older adults took a subsequent source-monitoring recognition test that required consideration of all possible sources of information after taking a yes–no test, the misinformation effect was reduced for high-frontal-functioning older adults (.31 on the yes–no test and .13 on the source test). However, older adults with low-frontal-functioning performed approximately the same on both tests (.26 versus .29). Clearly, only high-frontal-functioning older adults are able to use source information well in reducing their errors in this task.

Although our studies were not designed to unravel the inconsistencies in the literature noted in the introduction, they do show that the cognitive functioning of older adults may be one critical variable that has not been examined in the prior literature. If recruitment of older adults leads to disproportionate numbers of subjects with lower functioning as assessed by neuropsychological tests, then the misinformation effect (and other memory errors) may be maximized. Chan and McDermott (in press) point out that the cognitive status of younger adults should also be taken into account.

Our results provide support for theories of cognitive aging that stress the role of frontal functioning in mediating performance. Structural and functional brain imaging studies reveal differences between younger and older adults both in volumetric measures of frontal lobes (Raz, 2000) and in recruitment of areas during memory retrieval (Cabeza, Anderson, Locantore, & McIntosh, 2002). Further, frontal lobe dysfunction has been implicated as the source of difficulties in attentional control and monitoring difficulties that older adults experience (see Balota, Dolan, & Duchek, 2000; Raz, 2000, for reviews). Frontal lobe functioning has also been shown to be negatively correlated with how much older adults rely (appropriately or inappropriately) on stereotypic information and their knowledge of previous choices in making source attributions (Mather, Johnson, & DeLeonardis, 1999). The various lines of evidence converge on the hypothesis that frontal functioning is critical in age-related changes in memory performance; poorer frontal functioning is associated with both decreases in veridical recall–recognition and increases in false recall–recognition.

In Experiment 2, older adults who scored lower on tests of frontal functioning were particularly susceptible to the effects of misinformation and also showed elevated error rates even in the neutral conditions. These findings are consistent with other recent work showing that low-frontal-functioning older adults experience more false memories than younger adults in the DRM paradigm, whereas high-frontal-functioning older adults show levels of false recall similar to those of younger adults (Butler et al., 2004). Older adults' difficulties with source monitoring have been attributed to problems in binding features of source-relevant information at encoding (Chalfonte & Johnson, 1996; Mitchell, Johnson, Raye, Mather & D'Esposito, 2000) and to problems spontaneously assessing contextually defined source information at retrieval (Henkel et al., 1998). Although our study was not designed to distinguish between these two accounts of source monitoring, we did find an effect of the type of test in both experiments, so our results are at least consistent with the view that older adults have difficulty spontaneously accessing information about sources of information during retrieval.

An apparent paradox in our results is that high-frontal-functioning older adults in Experiment 2 were able to reduce their level of errors on a source-recognition test relative to a yes–no test, yet in Experiment 1, younger adults (who are presumed to be mostly high-frontal-functioning) showed similar error rates on the two types of test. We cannot be sure why this outcome occurred, but it may be that younger adults use source information even when taking a yes–no test and that no improvement occurs when they are given a source-monitoring test. High-frontal-functioning older adults, however, may only access source information when provided with a source-monitoring test that prompts them to do so. Multhaup et al. (1999) also showed improvement in older adults on a source-monitoring test relative to a yes–no test. However, R. L. Marsh et al. (2002) actually showed that younger adults in a false recognition paradigm were not aided by a source-monitoring test. Subjects in their study actually made somewhat more false recognition errors in the source test, and our younger subjects actually showed a tendency in the same direction in Experiment 1. Resolving this puzzle must await further research.

In sum, our results show that older adults are generally more susceptible to the negative effects of misinformation on retention of previously presented events relative to younger adults. Further, our results also show that frontal functioning appears to mediate these age-associated increases in susceptibility to misinformation; older adults with relatively low attention and monitoring abilities are particularly susceptible to false memories that arise from source confusions. These results are accounted for quite well by the source-monitoring framework (Johnson et al, 1993) and the frontal hypothesis of cognitive aging (e.g., Raz, 2000). These results complement previous research showing that measures of frontal functioning are related in important ways to mnemonic differences in cognitive aging (Roediger & McDaniel, 2007).

References

Ayers, M. S., & Reder, L. M. (1998). A theoretical review of the misinformation effect: Predictions from an activation-based memory model. *Psychonomic Bulletin and Review, 5,* 1–21.

Balota, D. A., Cortese, M. J., Duchek, J. M., Adams, D., Roediger, H. L., III, McDermott, K. B., & Yerys, B. E. (1999). Veridical and false memories in healthy older adults and in dementia of the Alzheimer's type. *Cognitive Neuropsychology, 16,* 361–384.

Balota, D. A., Dolan, P. O., & Duchek, J. M. (2000). Memory changes in healthy older adults. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 395–409). Oxford, United Kingdom: Oxford University Press.

Butler, K. M., McDaniel, M. A., Dornburg, C. C., Price, A. L., & Roediger, H. L., III. (2004). Age differences in veridical and false recall are not inevitable: The role of frontal lobe functioning. *Psychonomic Bulletin & Review, 11,* 921–925.

Cabeza, R., Anderson, N. D., Locantore, J. K., & McIntosh, A. R. (2002). Aging gracefully: Compensatory brain activity in high-performing older adults. *NeuroImage, 17,* 1394–1402.

Chalfonte, B. L., & Johnson, M. K. (1996). Feature memory and binding in younger and older adults. *Memory & Cognition, 24,* 403–416.

Chan, C. K., & McDermott, K. B. (in press). The effects of frontal lobe functioning and age on veridical and false recall. *Psychonomic Bulletin & Review.*

Cohen, G., & Faulkner, D. (1989). Age differences in source forgetting: Effects on reality monitoring and on eyewitness testimony. *Psychology and Aging, 4,* 10–17.

Coxon, P., & Valentine, T. (1997). The effects of the age of eyewitnesses on the accuracy and suggestibility of their testimony. *Applied Cognitive Psychology, 11,* 415–430.

Curran, T., Schacter, D. L., Norman, K. A., & Galluccio, L. (1997). False recognition after right frontal lobe infarction: Memory for general and specific information. *Neuropsychologia, 35,* 1035–1049.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58,* 17–22.

Ferguson, S. A., Hashtroudi, S., & Johnson, M. K. (1992). Age differences in using source-relevant cues. *Psychology and Aging, 7,* 443–452.

Gabbert, F., Memon, A., & Allan, K. (2003). Memory conformity: Can eyewitnesses influence each other's memories for an event? *Applied Cognitive Psychology, 17,* 533–543.

Glisky, E. L., Polster, M. R., & Routhieaux, B. C. (1995). Double dissociation between item and source memory. *Neuropsychology, 9,* 229–235.

Glisky, E. L., Rubin, S. R., & Davidson, P. S. R. (2001). Source memory in older adults: An encoding or retrieval problem? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 1131–1146.

Hart, R. P., Kwentus, J. A., Wade, J. B., & Taylor, J. R. (1988). Modified Wisconsin Card Sorting Test in elderly normal, depressed, and demented patients. *Clinical Neuropsychologist, 2,* 49–56.

Hashtroudi, S., Johnson, M. K., & Chrosniak, L. D. (1989). Aging and source monitoring. *Psychology and Aging, 4,* 106–112.

Henkel, L. A., Johnson, M. K., & DeLeonardis, D. M. (1998). Aging and source monitoring: Cognitive processes and neuropsychological correlates. *Journal of Experimental Psychology: General, 127,* 251–268.

Jacoby, L. L. (1999). Deceiving the elderly: Effects of accessibility bias in cued-recall performance. *Cognitive Neuropsychology Special Issue: The cognitive neuropsychology of false memories, 16,* 417–436.

Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia, 27,* 1043–1056.

Jaschinski, U., & Wentura, D. (2002). Misleading postevent information and working memory capacity: An individual differences approach to eyewitness memory. *Applied Cognitive Psychology, 16,* 223–231.

Johnson, M. K., Hashtroudi, S., & Lindsay, S. D. (1993). Source monitoring. *Psychological Bulletin, 114,* 3–28.

Karpel, M. D., Hoyer, W. J., & Toglia, M. P. (2001). Accuracy and qualities of real and suggested memories: Nonspecific age differences. *Journals of Gerontology: Series B. Psychological Sciences & Social Sciences, 56B,* 103–110.

Kensinger, E. A., & Schacter, D. L. (1999). When true memories suppress false memories: Effects of ageing. *Cognitive Neuropsychology, 16,* 339–415.

Loftus, E. F. (1979). *Eyewitness testimony.* Cambridge, MA: Harvard University Press.

Loftus, E. F. (1991). Made in memory: Distortions in recollection after misleading information. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in theory and research* (Vol. 27, pp. 187–215). New York: Academic Press.

Loftus, E. F., Levidow, B., & Duensing, S. (1992). Who remembers best? Individual differences in memory for events that occurred in a science museum. *Applied Cognitive Psychology, 6,* 93–107.

Loftus, E. G., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning and Memory, 4,* 19–31.

Loftus, E. G., & Palmer, J. C. (1974). Reconstruction of automobile destruction: An example of the interaction between language and memory. *Journal of Learning and Verbal Behavior, 13,* 585–589.

Marche, T. A., Jordan, J. J., & Owre, K. P. (2002). Younger adults can be more suggestible than older adults: The influence of learning differences on misinformation reporting. *Canadian Journal on Aging, 21,* 85–93.

Marsh, E. J., Balota, D. A., & Roediger, H. L., III. (2005). Learning facts from fiction: The effect of healthy aging and early stage dementia of the Alzheimer's type, *Neuropsychology, 19,* 115–129.

Marsh, R. L., Hicks, J. L., & Davis, T. T. (2002). Source monitoring does not alleviate (and may exacerbate) the occurrence of memory conjunction errors. *Journal of Memory and Language, 47,* 315–326.

Mather, M., Johnson, M., & DeLeonardis, D. (1999). Stereotype reliance in source monitoring: Age differences and neuropsychological test correlates. *Cognitive Neuropsychology, 16,* 437–458.

McCabe, D. P., & Smith, A. D. (2002). The effect of warnings on false memories in young and older adults. *Memory & Cognition, 30,* 1065–1077.

McCloskey, M., & Zaragoza, M. S. (1985). Misleading postevent information and memory for events: Arguments and evidence against memory impairment hypothesis. *Journal of Experimental Psychology: General, 114,* 1–16.

McIntyre, J. S., & Craik, F. I. M. (1987). Age differences in memory for item and source information. *Canadian Journal of Psychology, 41,* 175–192.

Memon, A., & Bartlett, J. (2002). The effects of verbalization on face recognition. *Applied Cognitive Psychology, 16,* 635–650.

Memon, A., Hope, L., Bartlett, J., & Bull, R. (2002). Eyewitness recognition errors: The effects of mugshot viewing and choosing in younger and older adults. *Memory & Cognition, 30,* 1219–1227.

Mitchell, K. J., Johnson, M. K., & Mather, M. (2002). Source monitoring and suggestibility to misinformation; Adult age-related differences. *Applied Cognitive Psychology, 16,* 1–13.

Mitchell, K. J., Johnson, M. K., Raye, C. L., Mather, M., & D'Esposito, M. (2000). Aging and reflective processing of working memory: Binding and test load deficit. *Psychology and Aging, 15,* 527–541.

Multhaup, K. S., DeLeonardis, D. M., & Johnson, M. K. (1999). Source memory and eyewitness suggestibility in older adults. *Journal of General Psychology, 126,* 74–84.

Naveh-Benjamin, M., & Craik, F. I. M. (1996). Effects of perceptual and conceptual processing on memory for words and voice: Different patterns for young and old. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 49A,* 780–796.

Nolde, S. F., Johnson, M. K., & D'Esposito, M. (1998). Left prefrontal activation during episodic remembering: An event-related fMRI study. *NeuroReport, 9,* 3509–3514.

Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and

older adults: Exploring the characteristics of illusory memories. *Memory & Cognition, 25,* 838–848.
Raz, N. (2000). Aging of the brain and its impact on cognitive performance: Integration of structural and functional findings. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (2nd ed., pp. 1–90). Mahwah, NJ: Usum Associates.
Roediger, H. L., III, Jacoby, J. D., & McDermott, K. B. (1996). Misinformation effects in recall: Creating false memories through repeated retrieval. *Journal of Memory and Language, 35,* 300–318.
Roediger, H. L., III, & McDaniel, M. A. (2007). Illusory recollections of older adults: Testing Mark Twain's conjecture. In M. Garry & H. Hayne (Eds.), *Elizabeth Loftus: Contributing to science, law, and academic freedom* (pp. 105–136). Hillsdale, NJ: Erlbaum.
Roediger, H. L., III, & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 803–814.
Roediger, H. L., & McDermott, K. B. (2000). Distortions of memory. In F. I. M. Craik & E. Tulving (Eds.). *The Oxford handbook of memory* (pp. 149–164). Oxford, England: Oxford University Press.
Schacter, D. L., Buckner, R. L., Koutstaal, W., Dale, A., & Rosen, B. (1997). Late onset of anterior prefrontal activity during true and false recognition: An event-related fMRI study. *NeuroImage, 6,* 259–269.
Schacter, D. L., Curran, T., Galluccio, L., Milberg, W. P., & Bates, J. F. (1996). False recognition and the right frontal lobe: A case study. *Neuropsychologia, 34,* 793–808.
Schacter, D. L., Israel, L., & Racine, C. (1999). Suppressing false recognition in younger and older adults: The distinctiveness heuristic. *Journal of Memory and Language, 40,* 1–24.
Schacter, D. L., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1991). The relation between source memory and aging. *Psychology and Aging, 6,* 559–568.
Schacter, D. L., Reiman, E., Curran, T., Sheng Yun, L., Bandy, D., McDermott, K. B., & Roediger, H. L. (1996). Neuroanatomical correlates of veridical and illusory recognition memory: Evidence from positron emission tomography. *Neuron, 17,* 1–20.
Searcy, J., Bartlett, J. C., & Memon, A. (2000). Influence of post-event narratives, line-up conditions, and individual differences on false identification of young and older eyewitnesses. *Legal & Criminological Psychology, 5,* 219–235.
Spencer, W. D., & Raz, N. (1995). Differential effects of aging on memory for content and context: A meta-analysis. *Psychology and Aging, 10,* 527–539.
Spreen, O., & Benton, A. L. (1977). *Neurosensory Center Comprehensive Examination for Aphasia—Revised*. Victoria, Canada: University of Victoria Neuropsychology Laboratory.
Trott, C. T., Friedman, D., Ritter, W., & Fabiani, M. (1997). Item and source memory: Differential age effects revealed by event-related potentials. *NeuroReport, 8,* 3373–3378.
Watson, J. M., McDermott, K. B., & Balota, D. A. (2004). Attempting to avoid false memories in the Deese/Roediger-McDermott paradigm: Assessing the combined influence of practice and warnings in young and old adults. *Memory & Cognition, 32,* 135–141.
Wechsler, D. (1981). *Wechsler Adult Intelligence Scale—Revised manual.* San Antonio, TX: Psychological Corporation.
Wechsler, D. (1987). *Wechsler Memory Scale—Revised manual.* New York: Psychological Corporation.
Zachary, R. A. (1986). *Shipley Institute of Living Scale—Revised manual.* Los Angeles: Western Psychological Services.

Received January 10, 2006
Revision received September 24, 2006
Accepted October 4, 2006 ■