Journal of Experimental Psychology: General
1998, Vol. 127, No. 3, 251–268

0096-3445/98/$3.00

Aging and Source Monitoring: Cognitive Processes and Neuropsychological Correlates

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This study shows that relative to younger adults, older adults are more adversely influenced by similar items when judging a memory's source, and the phenomenal features of their correctly and incorrectly attributed memories have greater overlap. The authors argue in accordance with the source monitoring framework that this age-related impairment in source accuracy is related to processes involved in binding features into complex memories and those involved in accessing and evaluating contextual features of memories. These processes are linked to medial temporal and frontal brain regions, respectively, as evidenced by correlations in older adults between source accuracy and neuropsychological tests often used to assess medial temporal and frontal function. The results suggest that adequate feature binding is particularly important when items from different sources share similar features and access–evaluation processes are particularly important after a delay.

Memories derived from imagination can be vivid and detailed, sometimes leading people to mistakenly believe that events that were only imagined actually had occurred. Errors of this sort range from minor confusions, such as mistakenly believing you put the wash in the dryer when you only thought about doing it, to confusions with serious implications, such as believing you have taken your medication when you have not or remembering that you saw a particular weapon at a crime scene when you only imagined it. *Reality monitoring* refers to the processes involved in discriminating between external and internal sources of information (Johnson & Raye, 1981). Although there are many situations in which younger adults make errors in judging a memory's source, older adults tend to show even less accurate reality monitoring (see Johnson, Hashtroudi, & Lindsay, 1993). For example, when younger and older adults performed and imagined performing complex actions such as wrapping a package or packing a picnic basket, older adults were worse at later identifying a memory's source than younger adults (Hashtroudi, Johnson, & Chrosniak, 1990). Likewise when older and younger adults performed and imagined themselves performing simple actions (e.g., moving an object to a specified location), source accuracy declined with age (G. Cohen & Faulkner, 1989; Guttentag & Hunt, 1988). Older adults have also been found to be less accurate than younger adults at discriminating between what they themselves said and what they imagined saying (Hashtroudi, Johnson, & Chrosniak, 1989; Hashtroudi, Johnson, Vnek, & Ferguson, 1994), in discriminating between words they either read or generated (Brown, Jones, & Davis, 1995; Rabinowitz, 1989), and in discriminating between words they heard or implicitly generated (Norman & Schacter, 1997).

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This research was supported by National Institute on Aging Grant AG09253. We wish to thank Carol Raye for her helpful comments on this article and Christine Voegeli for her help in testing participants and analyzing data.

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The Source Monitoring Framework and Aging

In order to understand age-related deficits in reality monitoring, it is necessary to understand the processes that create source confusions between perceived and imagined memories. According to the source monitoring framework (SMF) proposed by Johnson and colleagues (Johnson et al., 1993; Johnson & Raye, 1981), there are numerous factors that influence source judgments, including consistency with general knowledge, assessments of plausibility or coherence, and situational variables such as the cost of mistakes, the criteria the rememberer adopts in judging a memory's source, the social context, and the rememberer's motives (Johnson, 1988, 1997a; see also Ceci & Bruck, 1993; M. Ross, 1997; Zaragoza, Lane, Ackil, & Chambers, 1997). Of particular interest here, in many situations source attributions involve judgments based on the characteristics or features of the memory to be judged. In discriminating between internally generated and externally derived memories, people generally can rely on average differences in the relative amounts or quality of different features of the memories from different sources. For example, the SMF proposes that externally derived memories tend to have more perceptual, spatial, and temporal detail than do internally generated memories, and internally generated memories tend to have more information about the cognitive processes that were involved in creating the memory. In reality monitoring judgments, therefore, such contextual features[1] of a target memory can be used as a cue to determine its source. Source errors may then arise in situations in which the features of a target memory are typical of the class of memories from another source. For example, when the features for a specific imagined memory are like those of typical perceptually derived memories, it might then be mistakenly judged as having been perceived (e.g., if the imagined memory was rich in sensory detail, easy to generate, or both; Johnson, Foley, & Leach, 1988; Johnson, Raye, Foley, & Foley, 1981).

Recent experiments with younger adults have shown that not only do reality monitoring errors increase when a memory of an imagined event has features that are typical of the class of perceptually derived memories, but errors also increase systematically when the features of an imaginally derived memory increase in similarity to a specific perceptually derived memory (Henkel & Franklin, 1998b). When participants imagined seeing drawings of certain items (e.g., lollipop, banana), later they were more likely to mistakenly claim an imagined item had been perceived when it physically resembled or was conceptually related to an item that was actually perceived (e.g., magnifying glass, apple) than when there was no such similarity. This indicates that judgments about the source of a target memory can be influenced by information from other specific events. In making such errors, respondents were correct in claiming that the imagined item had been one of the items in the experiment, and they were correct in claiming that they had seen an item that had those perceptual or conceptual features. But they confused the features of the similar perceived and imagined items, that is, an associative deficit or "binding" problem resulting in source misattribution.

It has been proposed that older adults are less efficient at binding or integrating contextual information with a target memory (Chalfonte & Johnson, 1996; De Leonardis & Johnson, 1996; McIntyre & Craik, 1987) and that age deficits in some reality monitoring tasks result from reduced accessibility of source-specifying attributes in memory, such as perceptual detail, spatial and temporal information, and information regarding cognitive operations (Hashtroudi et al., 1990; Johnson, De Leonardis, Hashtroudi, & Ferguson, 1995). Consistent with this, older adults are less likely than younger adults to report that they consciously recollect contextual details surrounding a remembered event, although they are not necessarily impaired at knowing that the event occurred or in their confidence in the event's familiarity (Mantyla, 1993; Maylor, 1995; Parkin & Walter, 1992). And, in fact, older people are less likely to remember various contextual features, such as color or print style of materials (Kausler & Puckett, 1980; Park & Puglisi, 1985), the presentation modality of information (Craik, Morris, Morris, & Loewen, 1990; Kausler & Puckett, 1981a; Light, La Voie, Valencia-Laver, Albertson-Owens, & Mead, 1992; McIntyre & Craik, 1987), the gender of the presenter (Ferguson, Hashtroudi, & Johnson, 1992; Kausler & Puckett, 1981b), the location of items (Light & Zelinski, 1983; Park, Puglisi, & Sovacool, 1983; Pezdek, 1983), the orienting task performed on items (De Leonardis & Johnson, 1996), or whether a test item came from a videotape or from photographs (Schacter, Koutstaal, Johnson, Gross, & Angell, 1997). Source judgments may therefore be disrupted for older adults because any one or more of a memory's features (a) may not be available or (b) may not be sufficiently integrated with the target memory to allow for accurate attribution of its source (Chalfonte & Johnson, 1996).

Given that older adults have reduced memory for features of events and are less efficient at binding them together into a complex memory, they might be expected to be particularly sensitive to increases in similarity between target and other events. Consistent with this prediction is evidence that older adults' performance on external source monitoring tasks suffers more than that of younger adults from increases in similarity in the potential sources of a memory (Bayen & Murnane, 1996; Bayen, Murnane, & Erdfelder, 1996; Johnson et al., 1995). For example, source accuracy in determining which person said something is reduced more for older than younger adults when the similarity between speakers is increased (Ferguson et al., 1992). Such studies show that older adults make more erroneous judgments of a target memory's source when that memory is more similar *on average* to memories from a different source.

This study addresses not whether increases in similarity of different classes of memories brings about greater age-related source impairment, but whether relative to younger adults, older people have more impaired source accuracy as the similarity between *specific* individual imagined and perceived memories increases. Younger and older participants saw and imagined seeing line drawings of common objects. Some of the imagined items physically resembled a perceived item (e.g., lollipop and magnifying glass), and some were conceptually related to a perceived item (banana and apple). To encourage participants to focus on the items and their appearance, they were asked to rate how long it would take to draw the picture they were looking at or imagining (see Durso & Johnson, 1980). They were explicitly directed to generate images on the appropriate trials because evidence suggests that older adults do not necessarily spontaneously use imagery (Dirkx & Craik, 1992; Mason & Smith, 1977) but can perform as well as younger adults on a variety of memory tasks when instructed to use imagery (e.g., Craik & Dirkx, 1992; Fullerton, 1983; Treat & Reese, 1976; Whitbourne & Slevin, 1978; Wood & Pratt, 1987; Yesavage, Rose, & Bower, 1983). Later participants were given a surprise source test in which they indicated whether each item had been seen, imagined, or was new.

On the basis of earlier findings for younger adults (Henkel & Franklin, 1998b), it was expected that both younger and older adults would show higher error rates in claiming to

[1] In the original Johnson and Raye (1981) framework, the term *contextual information* referred specifically to spatial and temporal information, but here *context* refers to any features that could be used to identify the source of a memory (see Chalfonte & Johnson, 1996, pp. 412–413, for a discussion of the distinction between *content* and *context*).

have perceived items that were only imagined when the imagined items either physically resembled or were conceptually related to an item they perceived compared to when imagined items had no physical or conceptual similarity to any perceived items. Furthermore, if increased age produces feature-binding deficits, older adults should be more likely to have information from perceived events enter into their judgments about an imagined memory's source. Inefficient binding can lead to features such as perceptual detail from a perceived memory becoming attributed to an imagined memory, causing the imagined memory to be judged incorrectly as perceived. Such binding deficits need not reduce source accuracy for perceived items in a reciprocal manner, however, because perceptual detail from an imagined item may add to the phenomenal experience that a similar perceived item was perceived (for another example of asymmetrical reality monitoring confusions, see Johnson, Taylor, & Raye, 1977). Thus, older adults should have higher error rates than younger adults for physically and conceptually similar imagined items compared to control items, but they would not necessarily have higher error rates for perceived items.

The relation between source monitoring and old–new recognition performance is important in studies of aging and memory because recognition memory often declines with age (Light, 1991), along with source accuracy (e.g., Gregory, Mergler, Durso, & Zandi, 1988; Guttentag & Hunt, 1988; Mitchell, Hunt, & Schmitt, 1986; Rabinowitz, 1989). A strong case that older adults have particular problems with source memory can be made when source accuracy is impaired in conditions where recognition performance is equivalent for younger and older adults, or where source accuracy and recognition are differentially influenced by the same manipulation, which has been found in several studies of older adults (Brown et al., 1995; G. Cohen & Faulkner, 1989; Dywan & Jacoby, 1990; Dywan, Segalowitz, & Williamson, 1994; Ferguson et al., 1992; Hashtroudi et al., 1989; McIntyre & Craik, 1987; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991; Spencer & Raz, 1995). Such studies show that age-related source deficits are not just a function of an overall decline in memory and are consistent with the idea that although old–new recognition and source monitoring are related, they often rely on different memory features and judgment processes (Johnson et al., 1993; Johnson, Kounios, & Nolde, 1996; Lindsay & Johnson, 1989; see also Jacoby, Kelley, Brown, & Jasechko, 1989).

To experimentally equate younger and older adults on recognition, one group of older adults received the memory test shortly after the presentation of materials, whereas younger adults were tested 2 days later. Because age differences in source memory appear to become more exaggerated over time (Brown et al., 1995; McIntyre & Craik, 1987; Schacter et al., 1991; Spencer & Raz, 1994), another group of older adults was tested with a 2-day retention interval.[2] Thus, the effects of similarity on source discriminability could be compared between younger and older adults when their recognition levels were equivalent and when their retention intervals were equivalent.

Phenomenal Qualities of Memories

The SMF predicts not only that older adults will have lower source accuracy but that the phenomenal qualities of their memories will differ from that of younger adults. To further explore factors that may underlie age-related impairments in source monitoring, the study assessed differences in the phenomenal features of memories correctly attributed to their source and those incorrectly attributed to a source and whether such differences vary with age. Is the expected age impairment in source monitoring reflected in greater overlap in the phenomenal features of memories correctly attributed to a source and those incorrectly attributed to a source, lower overall vividness of features, or both? To address this issue, participants answered an abbreviated memory characteristics questionnaire (MCQ) assessing the vividness of certain features for items they remembered (see Johnson, Foley, Suengas, & Raye, 1988; Johnson, Nolde, & De Leonardis, 1996; Mather, Henkel, & Johnson, 1997). On the basis of the SMF, we would expect there to be considerable overlap in the subjective experience of correctly and incorrectly attributed memories. In fact, in some studies when participants were asked whether they "remember" or simply "know" whether a word occurred previously on a series of word lists, memories incorrectly attributed to perception were subjectively as vivid and distinct (as indicated by "remember" responses) as memories that were indeed perceived (Payne, Elie, Blackwell, & Neuschatz, 1996; Roediger & McDermott, 1995). However, as also predicted by the source monitoring framework, when more specific aspects of memories were assessed using MCQ ratings, falsely attributed memories for words have been shown to differ from correctly attributed memories in that they inspire less confidence and have a reduced amount or quality of perceptual details, associated thoughts and feelings, contextual detail, and references to cognitive operations (Mather et al., 1997; Norman & Schacter, 1997). Additionally, several studies using more complex materials (e.g., pictures and words, perceived and imagined objects, perceived and imagined actions, sentences spoken by different people, pictures and misleading information as stimuli) have also found differences between falsely attributed and correctly attributed memories (Conway & Dewhurst, 1995; Dewhurst & Conway, 1994; Johnson, Nolde, et al., 1996; Lane & Zaragoza, 1995; Schooler, Gerhard, & Loftus, 1986). Thus it was expected that there would be differences on average in the phenomenal features of memories correctly attributed to their source and those falsely attributed to a source in our paradigm. Furthermore, such differences were expected to be attenuated in older adults, along with their expected decline in source accuracy.

Neuropsychological Correlates of Source Monitoring

Finally, this study examined memory performance in relation to neuropsychological measures of brain function in

[2] Pilot work indicated that younger adults were at ceiling with the immediate memory test, thus they were tested only with the longer delay here.

older adults. Because source errors can arise from numerous factors operating both when a memory was initially encoded and when its source is assessed, it is unlikely that "source memory" is localized in one specific brain region. According to the SMF, accurate source attribution depends on a variety of processes involved in initially binding features into complex memories and in the retrieval and evaluation of such features. Medial temporal regions are particularly critical in binding and relatively automatic reactivation, and frontal regions are particularly critical in strategic retrieval and evaluation (e.g., N. J. Cohen & Eichenbaum, 1993; Johnson et al., 1993; Moscovitch, 1994). Hence, the source monitoring framework suggests that impaired function in either brain region could produce source memory impairments (Johnson et al., 1993; Johnson, 1997a).

Frontal systems are implicated in such reflective activities as planning, self-regulation, organization of events, monitoring of irrelevant or interfering information, metamemory, and sustained mental activity such as strategic retrieval (Daigneault, Braun, & Whitaker, 1992; Moscovitch, 1994; Shimamura, 1995; Stuss & Benson, 1986; West, 1996), and thus would be expected to be recruited in making attributional decisions required in source memory, especially when source identification is difficult (e.g., Johnson, Kounios, et al., 1996). Direct evidence for the role of frontal regions in source memory comes from a number of studies of frontal-damaged patients showing impairments in source monitoring accuracy (e.g., Janowsky, Shimamura, & Squire, 1989; Schacter, Curran, Galluccio, Milberg, & Bates, 1996; Schacter, Harbluk, & McLachlan, 1984; Shimamura, Janowsky, & Squire, 1990).

Evidence also shows that normal aging is associated with neuroanatomic and neurochemical changes in frontal lobe areas, and there is some evidence for age differences in the pattern of prefrontal activation in episodic memory tasks (e.g., Kemper, 1984; Schacter, Savage, Alpert, Rauch, & Albert, 1996; West, 1996). It has been hypothesized that age-related declines in frontal lobe function may contribute to age-related deficits in source monitoring (e.g., Janowsky et al., 1989; Johnson et al., 1993; Schacter et al., 1984; Shimamura & Squire, 1991; Spencer & Raz, 1995), a view supported by the observed similarity of source memory disruptions for patients with frontal damage and older adults (Janowsky et al., 1989, Experiment 2). Additionally, in older adults, low scores on neuropsychological tests used to assess frontal lobe function were associated with a reduction in the subjective vividness of source-specifying features for remembered events (Parkin & Walter, 1992). Other evidence comes from correlations in older adults between measures of frontal function and their source performance (Craik et al., 1990; Fabiani & Friedman, 1997; Parkin, Walter, & Hunkin, 1995; Schacter et al., 1991; Spencer & Raz, 1994). However, in other studies these same measures of frontal functioning were not reliably correlated with source performance (Dywan et al., 1994; Johnson et al., 1995; Schacter et al., 1991; Spencer & Raz, 1994). Differences in findings across studies may be related to whether the processing demands tapped by the particular tasks used to measure frontal function match the processing demands of the particular source monitoring situation (e.g., Johnson et al., 1993). A study using a battery of neuropsychological tests to measure frontal function found that lower levels of source accuracy were related to lower scores on the frontal battery in older adults (Glisky, Polster, & Routhieaux, 1995). Insofar as the use of several tests to measure frontal function may provide a more sensitive index than any one particular test, older participants in our study were given this same battery of neuropsychological tests.

Also critical to successful identification of the source of an item in this paradigm, as we have argued, is the degree to which source-specifying features of the memory were initially integrated into a complex memory trace for that item. Similarity between specific study items may require especially effective binding to prevent later confusion in a source memory task. For example, the characteristics of two similar acquisition stimuli from different sources could become intermixed during encoding or while accessing information during retrieval, particularly if binding processes are impaired. If the characteristics that could be used to determine source are intermixed, source monitoring performance should be hurt.

Research findings from brain-damaged individuals suggest that medial temporal regions are involved in processes that bind features into complex memories (Chalfonte, Verfaellie, Johnson, & Reiss, 1996; Johnson, 1992; Kroll, Knight, Metcalfe, Wolf, & Tulving, 1996; Squire, 1992; Squire & Knowlton, 1995), but the relation between temporal function and source performance in older adults has received relatively little attention. Older adults appear to have binding deficits over and above whatever deficits they show for individual features (Chalfonte & Johnson, 1996). Age-related neuropathology in the hippocampal system or diminished hippocampal activation (Cowell et al., 1994; Grady et al., 1995; Ivy, MacLeod, Petit, & Markus, 1992; Kemper, 1984; Meencke, Ferszt, Gertz, & Cervos-Navarro, 1983; Raz, Millman, & Sarpel, 1990; Selkoe, 1992) would be expected to contribute to a variety of memory deficiencies, including binding deficits that should produce source-accuracy impairments in some situations, as in this study. Although Glisky et al. (1995) found no relation between source accuracy and performance on a battery of various neuropsychological tests often used to assess medial temporal function, we also obtained scores using this medial temporal battery for older adults in the present study. Our reasoning was that the similarity between perceived and imagined items in the current study, as mentioned previously, should make source performance more sensitive to binding deficits.

It should be noted that the Glisky et al. (1995) frontal and medial temporal batteries have not been shown to specifically and uniquely assess functioning of frontal and medial temporal brain regions, respectively, nor have all of the individual tests. Furthermore, there may be age-related changes in performance on such tests independent of specific neuropathology in these particular brain regions (e.g., Reitan & Wolfson, 1994; Salthouse, Fristoe, & Rhee, 1996). Nevertheless, these tests are commonly used clinically, and thus it is of interest to determine with which specific aspects of episodic memory (e.g., old–new recognition, source identification) they are correlated. The patterns of such correlations can suggest future directions for research that more specifically link brain regions and performance on cognitive tasks.

In short, on the basis of the source monitoring framework, relative to younger adults, older adults were expected to show greater deficits in judging the source of related than unrelated items and to show greater similarity in the phenomenal characteristics of correctly and incorrectly attributed memories. Furthermore, older adults' source monitoring accuracy should be related to neuropsychological test scores assessing both frontal and medial temporal function.

Method

Participants

Twenty-four younger adults and 48 older adults (24 in each of two delay conditions) participated. The younger adults were Princeton University undergraduates (9 men, 15 women) who participated either in partial fulfillment of course requirements or for money. Their ages ranged from 19–23 years (M = 20.2 years). The older adults (14 men, 33 women) were community-dwelling residents from the Princeton, New Jersey, area who received payment for their participation. Their ages ranged from 64–83 years (M = 74.2 years). They reported no incidence of stroke or seizures, and the mean rating they gave to their general health on a 10-point scale (1 = *poor*, 10 = *excellent*) was 7.57.

Participants completed a vocabulary subscale of the Wechsler Adult Intelligence Scale–Revised (WAIS–R; Wechsler, 1981). The mean scores (maximum score = 30) for younger adults (22.4) did not differ from older adults (22.3), $t(60) < 1$. Additionally, mean number of years of formal education did not differ between the younger (M = 15.1 years) and older adults (M = 15.0 years), $t(60) < 1$.

Thirty-six of the older adults completed the battery of neuropsychological tests, 20 of whom had participated in the 2-day delay condition in the source monitoring experiment and 16 of whom had been in the 15-min delay condition.

Materials

The stimuli for the source monitoring experiment were 84 slides, half of which were for perceived trials and half for imagery trials. Each slide for the perceived trials showed a simple black-and-white line drawing of a common object with its name below it (see Figure 1 for examples). For the imagery trials, just the name of an object appeared at the bottom of the slide. There were three types of stimulus pairs, and in each pair one member was perceived and one was imagined. The members of a pair either physically resembled

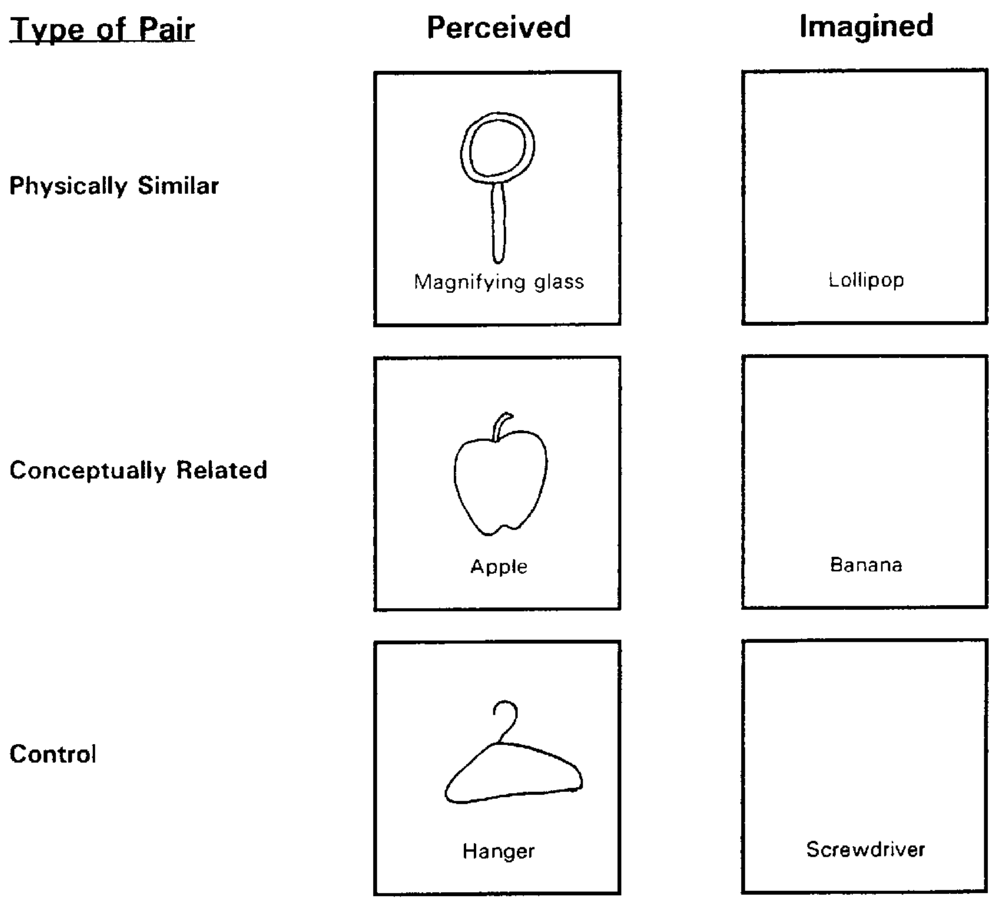

Figure 1. Example of perceptual and imagery trials for physically similar, conceptually related, and control items.

each other (with no conceptual relation), were conceptually related (with no physical resemblance), or had no physical resemblance or conceptual relation to each other (control items). Equal numbers of each pair type were used. Slides were randomly ordered, with a minimum of 10 trials between pair members. For half the pairs, the perceived member occurred first in the order of trials, and for the other half, the imagined member occurred first. A single random ordering was used for all participants.

Physical similarity was established by pilot participants' ratings of resemblance for pairs of imagined items (1 = *physically not at all similar,* 7 = *very similar*). The mean rating for pairs of physically similar items was 4.5 or higher, and for control and conceptually related pairs the mean rating was 2.0 or lower. Conceptually related items were defined as belonging to the same functional category (e.g., banana and apple as instances of fruit). These were selected by consensus of trained judges. Norms were also collected for the relative ease with which a given item could be imagined and for the item's physical complexity (number of pilot participants rating each item was at least 35). Across the three types of stimulus pairs, items did not differ significantly on these dimensions. The source test consisted of the names of 42 new items and the 84 old items in one randomized order. The new items had no resemblance or conceptual relation to the items in the slide presentation.

A battery of neuropsychological tests to measure frontal and medial temporal functioning was used (Glisky et al., 1995). Frontal lobe measures were the modified Wisconsin Card Sorting Test (WCST; Hart, Kwentus, Wade, & Taylor, 1988), the Controlled Oral Word Association Test (commonly known as FAS; Benton & Hamsher, 1976), the Arithmetic subscale from the Wechsler Adult Intelligence Scale–Revised (WAIS–R; Wechsler, 1981), and the Mental Control subscale and Digit Span (backward) subscale from the Wechsler Memory Scale–Revised (WMS–R; Wechsler, 1987). Medial temporal lobe measures were Logical Memory I, Verbal Paired Associates I, and Visual Paired Associates II (all from the Wechsler Memory Scale–Revised), and the Long-Delay Cued Recall measure from the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987).

Procedure

Participants were tested individually. They were told that the study examined how people make judgments about things that are seen or imagined. They were told that they would see a series of slides and that they were to make a particular type of judgment for all the items. Participants were instructed that some of the slides showed a simple black-and-white line drawing of an object with the object's name beneath it, whereas other slides gave just the name of an object, and they were to imagine the item as a black-and-white line drawing similar in style to the pictures. Their task was to estimate how many seconds it took to draw each picture or how many seconds it would take to draw each imagined item (see Durso & Johnson, 1980). Participants were explicitly told to create an image of each object for the imagery trials and to base their judgment solely on the image and not upon other information about the object such as its complexity or size.

Participants were then given a brief practice session in which they were shown 8 slides and asked to make a drawing-estimation judgment for each. For the encoding phase of the actual experiment, 84 slides were presented for 6 s each by a carousel slide projector, during which time participants stated aloud their judgment of drawing time while the experimenter recorded their responses.

After the slide presentation, participants completed the vocabulary test. Fifteen minutes after the slide presentation, half of the older adults were given a surprise memory test in which the names of old and new items were given on a test form. They were to indicate whether each item had been presented as a picture, had been imagined, or was new. The test was self-paced, and the same random order was used for all participants. The other half of the older adults returned 2 days later for the surprise source monitoring test. All younger adults completed the source test 2 days after the encoding phase. After completing the source test, participants were given an abbreviated memory characteristics questionnaire. For the same list of items used for the source test, they rated the quality of their memory for the vividness of the appearance of each item and the vividness with which they remembered their thoughts or feelings when they first perceived or imagined the item. These ratings were on a scale from 0–5, with 0 corresponding to *no memory at all* for the item, and 5 corresponding to *extremely clear or vivid memory.* Participants then completed two standardized imagery questionnaires: the Vividness of Visual Imagery Questionnaire (Marks, 1973) and the Visual Imagery Control Test (Gordon, 1949). Older participants returned for a separate session to complete the battery of neuropsychological tests as well as the Dissociative Experiences Scale (Bernstein & Putnam, 1986).[3]

Results and Discussion

Source Monitoring Experiment

Data were analyzed using a multinomial model to extract estimates of old–new recognition and source accuracy from performance on the source monitoring task. Following the procedure described by Batchelder and Riefer (1990), data were sorted into 3 × 3 matrices containing the frequencies with which participants indicated whether an item was perceived, imagined, or new for each test item source (perceived, imagined, new; see Table 1). Parameter estimates for each condition are reported in Table 2. Higher values of D or d reflect higher accuracy in old–new recognition and source accuracy, respectively, whereas a value of zero on either parameter would indicate that performance was at chance levels. The parameters b and g denote different response biases (a value of .50 indicates no bias) and are discussed later.

This study addresses in particular errors in claiming an imagined item was perceived rather than vice versa. The materials consisted of simply depicted, common objects and the orienting task focused attention on an item's appearance. Thus, in the resulting memories, perceptual information should be particularly salient. Weighting perceptual information heavily in an attribution process would tend to produce more errors in which participants claimed to have seen an imagined item than vice versa, as noted in the introduction. Such an asymmetry in source accuracy for perceived and imagined items has been shown in previous studies involv-

[3] One study reported a relation between self-reported frequency of dissociative experiences and source accuracy (Winograd, Glover, & Peluso, 1996). No significant correlations were found in our study between the Dissociative Experiences Scale (DES) scores and source performance. However, dissociative experiences appear to decline with age (C. A. Ross, Ryan, Anderson, Ross, & Hardy, 1989; Torem, Hermanowski, & Curdue, 1992), and the mean scores found here were fairly low.

Table 1
Response Frequencies for Perceived (P), Imagined (I), and New (N) Items

Similarity/source	Younger (2-day) P	Younger (2-day) I	Younger (2-day) N	Older (15-min) P	Older (15-min) I	Older (15-min) N	Older (2-day) P	Older (2-day) I	Older (2-day) N
Physical									
P	163	56	117	141	58	137	120	43	173
I	77	229	30	76	240	20	151	114	71
N	92	77	839	27	53	928	130	106	772
Conceptual									
P	179	52	105	179	38	119	144	55	137
I	63	239	34	70	237	29	131	127	78
N	92	77	839	27	53	928	130	106	772
Control									
P	179	61	96	172	37	127	149	54	133
I	54	253	29	34	278	24	130	134	72
N	92	77	839	27	53	928	130	106	772

ing imagery of simple items (e.g., Johnson et al., 1981; Kahan & Johnson, 1990; Raye, Johnson, & Taylor, 1980). Thus it was expected that binding deficits would particularly affect source judgments for imagined rather than for perceived items.

The frequency matrices were analyzed using Batchelder and Riefer's (1990) Model 6c because it was expected on the basis of past research and theoretical considerations that recognition and source accuracy would differ for perceived and imagined items (see Henkel & Franklin, in press-a). Model-free measures of recognition and source accuracy support the validity of this assumption. When old–new recognition rates were calculated for each participant (proportion of [correct rejection of new items + perceived and imagined items correctly recognized as old]), recognition accuracy was found to be significantly higher for imagined (M = .84) than for perceived (M = .78) items, $F(1, 69) = 212.70$, $MSE = 0.01$, $p < .001$. Recognition accuracy for old items only (i.e., the proportion of old items correctly recognized as old, namely perceived items called perceived or imagined, and imagined items called perceived or imagined) also showed greater accuracy for imagined than for perceived items (M = .87 vs. .62, respectively), $F(1, 69) = 212.70$, $MSE = 0.03$, $p < .001$. Source accuracy (percentage of items correctly attributed to their source given correct identification of the items as old) was significantly lower for imagined (M = .69) than for perceived (M = .75) items, $F(1, 69) = 3.84$, $MSE = 0.10$, $p < .05$. These findings are

Table 2
Parameter Estimates for Perceived (Perc.) and Imagined (Imag.) Items Based on Model 6c

Age group (delay)/type of similarity	Recognition: Perc. (D_1)	Recognition: Imag. (D_2)	Source accuracy: Perc. (d_1)	Source accuracy: Imag. (d_2)	Response bias: b	Response bias: g
Younger (2-day)						
Physical	.58	.89	.49	.55	.17	.54
Conceptual	.62	.88	.56	.63		
Control	.66	.89	.48	.69		
Older (15-min)						
Physical	.56	.94	.60	.29	.08	.34
Conceptual	.62	.91	.77	.33		
Control	.59	.92	.77	.68		
Older (2-day)						
Physical	.33	.72	.59	.00	.23	.56
Conceptual	.47	.70	.49	.09		
Control	.48	.72	.51	.12		

Note. D_1 = probability of detecting a perceived item; D_2 = probability of detecting an imagined item; d_1 = probability of correctly discriminating the source of a perceived item; d_2 = probability of correctly discriminating the source of an imagined item; b = probability of guessing an item is old; g = probability of guessing an undetected item is perceived.

consistent with the source monitoring framework and with findings from previous studies (e.g., Johnson et al., 1981).

Model 6c was thus used to examine the effects of similarity of perceived and imagined items on source accuracy. Although Model 6c is not statistically differentiable from Model 6b (see Batchelder & Riefer, 1990), Model 6b imposes a restriction of equivalent levels of source discriminability for both perceived and imagined items and has freely varying parameters for different guessing biases. Such an interpretation of the data is less plausible theoretically and runs counter to the data from the empirical analyses (see also Henkel & Franklin, 1998a). Both Models 6c and 6b are saturated models, hence the goodness-of-fit measure alone does not constitute evidence for their theoretical soundness. Other models, however, such as Model 5c, which assumes that source discriminability does not differ for the two sources, and 5b, which assumes that item detectability does not differ across sources, did not provide an adequate fit.

Log-likelihood ratio tests (G^2) on the parameters from Model 6c were performed to examine the effects of similarity on recognition and source memory within age groups and to compare the younger group with each of the older groups. All analyses used an alpha level of .05. The critical value for comparisons with three matrices is 5.99, and for comparisons between two matrices, 3.84.

Old–new recognition. As is clear from Table 2, old–new recognition was significantly higher for imagined (D_2) than for perceived (D_1) items for all three groups (all G^2s > 24). Similarity did not, in general, affect recognition accuracy except that after a 2-day delay, older participants recognized fewer physically similar than conceptually related or control perceived items, G^2s > 7.

As expected, recognition was lower for older than for younger adults when both were tested after a 2-day delay (all G^2s > 13). When older adults were tested 15 min after acquisition, their recognition level did not differ from that of younger adults for any of the item types (all G^2s < 3).

The parameter b represents the bias for participants to claim an item was either old or new when they did not recognize the item. All three groups were more likely to guess that an unrecognized item was new rather than old ($b < .50$). This tendency was greater for older than younger adults with a 2-day delay, $G^2(1) = 13.95$, whereas the tendency was less for older adults with the 15-min delay relative to younger adults with the 2-day delay, $G^2(1) = 37.01$.

Source identification. Source accuracy was examined for each age group. Although for older adults tested at the 2-day retention interval, the pattern of source errors for imagined items (d_2) was as predicted, with reduced accuracy for physically and conceptually similar items relative to control items, source accuracy for imagined items did not significantly vary with similarity, $G^2(2) = 1.61$. This may be due to the extremely low source monitoring performance for imagined items. Source accuracy was consistently lower for imagined than perceived items (d_1) for older adults with the 2-day delay (all G^2s > 5).

For younger adults with the 2-day retention interval, source accuracy for imagined items that physically resembled a perceived item was marginally lower than when there was no such resemblance, $G^2(1) = 3.69, p < .06$. Thus, imagined items were more likely to be mistakenly judged as perceived when they were physically similar to perceived items. Source accuracy for imagined items was lower for conceptually similar items than for control items, but the difference was not significant, $G^2(1) = 0.71$. Thus, although the general pattern was the same as reported previously (Henkel & Franklin, 1998b), the effects of similarity on younger adults' memory for imagined items were weaker in our study. Differences in absolute levels of recognition and source memory may contribute to this insofar as Princeton undergraduates in our study had overall higher memory performance than the undergraduates from the State University of New York at Stony Brook in the prior work. Source accuracy did not differ between imagined and perceived items for physically similar or conceptually related items (G^2s < 1), though source accuracy for control items was higher when the items had been imagined rather than perceived, $G^2(1) = 4.06$.

The extremely low source accuracy of older adults relative to younger adults for imagined items when both groups were tested after a 2-day retention interval (all G^2s $>$ 29) is particularly striking given that older adults did not differ from younger adults in correctly identifying the source of perceived items (all G^2s < 1). Thus, older adults were far more likely than younger adults to mistakenly claim to have perceived items that were in fact imagined, whereas there was no age deficit in mistakenly claiming to have imagined items that were perceived. Furthermore, the parameter g reflects tendencies for participants to guess that an item was either perceived or imagined, and neither group with the 2-day delay had a greater tendency to claim that items were perceived rather than imagined, $G^2(1) < 1$. Hence it does not appear to be the case that older adults simply have a general tendency to claim items were perceived when they are uncertain or when their memory is vague.

When older adults had a much shorter retention interval (15 min), overall source accuracy was lower for imagined than for perceived items ($G^2 > 5$) and the predicted effects of similarity on source accuracy were found. That is, source accuracy for imagined items was lower when the items had either a physical or a conceptual similarity to a perceived item compared to when there was no such similarity; physical versus control: $G^2(1) = 7.39$; conceptual versus control: $G^2(1) = 6.31$. This shows that even with the relatively short delay, older adults were more likely to claim to have seen an imagined item when it had features similar to an item they did in fact see.

In comparing source accuracy for imagined items when younger and older adults were equated on recognition, no age deficit was found for control items, $G^2 < 1$. However, as expected, a clear age-related deficit was obtained for imagined items that physically resembled perceived items, $G^2(1) = 4.29$, and for imagined items that were conceptually related to perceived items, $G^2(1) = 6.88$. Thus, older adults were significantly more likely than younger adults to mistakenly claim that an imagined item had been perceived when the imagined item was either physically or conceptually similar to an item that had indeed been perceived.

Table 3
Mean Vividness Ratings of Memory Features for Perceived and Imagined Items as a Function of Aging

	Claimed source (actual source)					
	Source correct		Source errors		False alarms	
Feature/age group (delay)	Perceived (perceived)	Imagined (imagined)	Perceived (imagined)	Imagined (perceived)	Perceived (new)	Imagined (new)
Appearance						
Younger (2-day)	3.57	3.42	3.23	2.53	1.32	1.28
Older (15-min)	3.45	3.11	2.93	2.22	0.75	0.87
Older (2-day)	3.13	2.28	2.66	1.98	1.47	0.88
Associated thoughts						
Younger (2-day)	3.04	3.33	2.52	2.31	1.24	1.25
Older (15-min)	3.01	3.03	2.52	1.92	0.62	0.72
Older (2-day)	2.19	1.82	1.96	1.51	1.20	0.79

No age deficit in source accuracy for perceived items was observed when younger and older adults were equated on recognition. In fact, older adults with the short delay had superior source accuracy for perceived items in comparison to younger adults with the long delay, $G^2(2) = 8.37$. With regard to guessing bias as measured by parameter g, older adults with the 15-min delay had a greater tendency to guess that items were imagined in comparison to younger adults, $G^2(1) = 9.45$.

In summary, given equivalent levels of recognition, both younger and older adults showed a greater likelihood of erroneously claiming to have perceived an item that was imagined when a different object with similar perceptual features had indeed been seen. Although they correctly remembered that a particular item had been experienced in the slide presentation and they correctly remembered seeing something with those perceptual features, those perceived features were incorrectly attributed to the imagined item. Participants have evidence for perceiving features possessed by the target, but the evidence comes from a different item they experienced. Additionally, older adults were likely to mistakenly claim that an imagined item had been perceived when it was conceptually related to something they did actually see compared to when there was no conceptual relation. These findings thus show that increased similarity between specific imagined and perceived memories can decrease source accuracy, clearly demonstrating that reality monitoring can be influenced by features derived from other memories.[4]

Furthermore, susceptibility to information from other similar memories entering into judgments about a target memory's origin increases with age. Given comparable levels of recognition, older adults were more likely than were younger adults to mistakenly claim to have perceived items that were in fact imagined when a similar item had been perceived relative to control items. When older adults were given the same long retention interval as younger adults, the pattern of results again suggests that similarity produces age-related impairments in source judgments. However, overall source performance of older adults was extremely poor, which may have obscured age-related increases in the negative impact of similarity over time.

Memory Characteristics

Questionnaire ratings obtained after the source test on the MCQ assessed how vividly an item's visual appearance was remembered and how vividly participants remembered their thoughts or feelings when they first perceived or imagined the item.[5] These were on a scale from 0–5, with 0 corresponding to *no memory at all* for the item, and 5 corresponding to *extremely clear or vivid memory.* Ratings were compared between studied items correctly attributed to their source (i.e., *source correct*), studied items incorrectly attributed to a source (i.e., *source errors*, such as an imagined item misjudged as perceived), and new items incorrectly attributed to perception or imagery (i.e., *false alarms*). Memory characteristic ratings were thus analyzed in a Group (younger adults with 2-day delay, older adults with 15-min delay, older adults with 2-day delay) × Outcome (source correct, source error, false alarm) × Claimed Source (perceived or imagined) analysis of variance (ANOVA). Separate analyses were conducted for ratings of appearance and associated thoughts. For mean ratings in various conditions, see Table 3. All subsequent comparisons were post hoc Newman–Keuls t tests.

Ratings for appearance. The main effect for group was marginally significant, $F(2, 68) = 2.88$, $MSE = 3.18$, $p = .06$, and follow-up comparisons revealed that vividness ratings for the remembered appearance of items did not differ for younger adults tested at the 2-day delay ($M = 2.56$)

[4] Source errors for imagined items that physically resembled a perceived item did not differ when the imagined item had come before or after the perceived item in the original presentation of slides. For imagined items that were conceptually similar to a perceived item, errors were more prevalent when the perceived member of the pair had come before the imagined member rather than after it, but the opposite was found in a prior study that included a conceptual similarity condition (Henkel & Franklin, 1998b). Therefore there is to date no evidence for reliable order effects in this type of design, thus the data are discussed here collapsed across order.

[5] No age-related differences were found in initial imagery ability or imagery vividness, as measured by the Vividness of Visual Imagery Questionnaire and the Visual Imagery Control Test.

and older adults tested at 15 min (M = 2.22). Younger adults reported greater vividness than older adults with a 2-day delay (M = 2.06).

As illustrated in Figure 2, the main effect for outcome was significant, $F(2, 136) = 182.27$, $MSE = 0.88$, and post hoc tests showed that mean ratings were significantly higher for old items correctly attributed to their source (M = 3.16) than those incorrectly attributed to a source (M = 2.59), which in turn were significantly higher than ratings for new items incorrectly claimed as old (M = 1.09). Thus, even though errors may be made in indicating a memory's source, the features of the memory nonetheless were less vivid than if its source had been correctly judged. There was also a significant interaction between group and outcome, $F(4, 136) = 3.22$, $MSE = 0.88$. Subsequent comparisons indicated that whereas all three groups reported significantly higher vividness for correct source responses than for source errors, the difference in mean ratings for correct source responses and source errors was somewhat (though not significantly) smaller for older adults with the 2-day delay (.39) than for younger adults (.61) or older adults with the 15-min delay (.71). Furthermore, although mean ratings for reality moni-

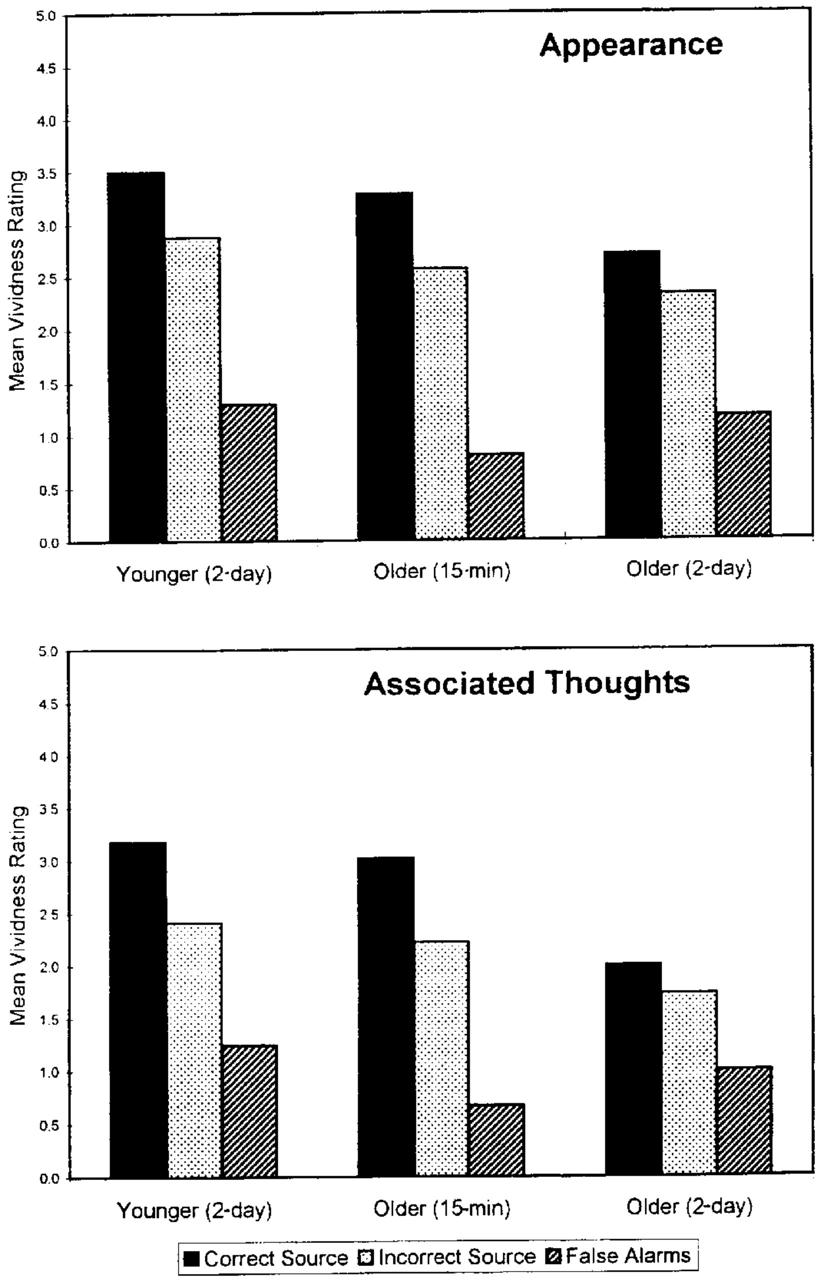

Figure 2. Mean vividness ratings for source correct, source errors, and false alarms in relation to age.

toring errors were significantly higher than for false alarms for both older adults tested at 15 min and younger adults, this difference was not significant for older adults tested at the 2-day delay, consistent with their relatively poor recognition and source performance.

The main effect for claimed source revealed higher ratings for items claimed as perceived (M = 2.50) than those claimed as imagined (M = 2.06), consistent with the source monitoring framework (Johnson et al., 1993), $F(1, 68) = 17.91$, $MSE = 1.15$ (see Table 3). A significant interaction between outcome and claimed source was also found, $F(2, 136) = 3.10$, $MSE = 0.80$. Subsequent analysis showed that for both correct source responses and source errors, vividness ratings were higher for items claimed to be perceived than those claimed to be imagined. Ratings, however, did not differ for false alarms judged as perceived versus those judged as imagined. Thus, old items claimed to have been seen (including those that were indeed seen as well as those that were imagined but misjudged as perceived) have more visual information and detail than old items claimed to have been imagined.

Ratings for associated thoughts. There was a significant main effect for group for the ratings of vividness with which people remembered associated thoughts regarding an item, $F(2, 68) = 4.10$, $MSE = 4.34$. Follow-up comparisons showed a pattern similar to that reported for appearance ratings: Younger adults (M = 2.28) did not differ from older adults tested at the 15-min delay (M = 1.97), whereas younger adults reported greater vividness of associated thoughts than did older adults with a 2-day delay (M = 1.58; see Figure 2).

The main effect for outcome again was significant, $F(2, 136) = 150.85$, $MSE = 0.76$, and comparisons showed subjectively higher vividness of associated thoughts for old items correctly attributed to their source (M = 2.74), followed by those incorrectly attributed to their source (M = 2.12), followed by new items incorrectly claimed as old (M = 0.97). Again there was a significant interaction between group and outcome (see Figure 2), $F(4, 136) = 7.48$, $MSE = 0.76$. Post hoc tests revealed that this pattern of higher ratings for correct source attributions, followed by source errors, followed by false alarms held for the younger and older (15-min) groups. However, ratings by older adults with the 2-day delay did not differ for source errors and correct source responses, though both were higher than ratings given to false alarms. Hence, for older adults with the long delay, the vividness of information about associated thoughts did not reliably distinguish between studied items correctly attributed to their source and studied items incorrectly attributed to a source.

In summary, the MCQ findings show that the features of a memory incorrectly attributed to a source were less vivid than if its source had been correctly judged. For older adults with a 2-day delay in comparison to younger adults, the vividness of information about associated thoughts did not as strongly distinguish studied items correctly attributed to their source and studied items incorrectly attributed to a source. A similar (though not significant) tendency was observed for appearance ratings. Hence, with the long delay and accompanying marked age-related decline in source performance, aging appears to be associated with greater overlap in the subjectively available features of correctly and incorrectly attributed memories.

Recognition and Source Accuracy in Relation to Neuropsychological Test Scores

Mean scores of older adults on each of the nine neuropsychological tests are shown in Table 4. Performance on each neuropsychological test did not differ significantly for participants in the 2-day and the 15-min delay conditions of the source experiment. The overall level of performance on individual tests appeared comparable to Glisky et al.'s (1995) sample and other samples cited in their Table 1, though medial temporal scores from their sample were somewhat higher than found here or in the norms they report.

Data from the neuropsychological battery were analyzed in the same manner as Glisky et al. (1995). Because

Table 4
Neuropsychological Test Scores ($M \pm SD$) for Older Adults With 2-Day and With 15-Min Delay Source Test

Test/subscale	Delay: 2-day	Delay: 15-min	Combined
Wisconsin Card Sorting	4.2 ± 1.5	4.5 ± 1.9	4.4 ± 1.7
Controlled Oral Word Association (FAS)	44.3 ± 14.1	46.3 ± 11.0	45.2 ± 12.6
Wechsler Adult Intelligence Scale—Revised			
Arithmetic	12.6 ± 3.2	13.2 ± 2.9	12.9 ± 3.0
Wechsler Memory Scale—Revised			
Digit Span (backward)	7.9 ± 2.5	8.1 ± 2.5	8.0 ± 2.5
Mental Control	5.7 ± 0.6	5.6 ± 0.7	5.7 ± 0.6
Logical Memory I	20.3 ± 7.1	18.8 ± 5.0	19.7 ± 6.2
Verbal Paired Associates I	16.0 ± 4.1	14.9 ± 4.4	15.5 ± 4.2
Visual Paired Associates II	4.6 ± 1.5	4.5 ± 1.6	4.4 ± 1.7
California Verbal Learning			
Long-Delay Cued Recall	9.7 ± 3.2	9.8 ± 2.9	9.8 ± 3.0

performance on these tests can decline with age alone, regression analyses were used to remove the variance attributable to age from each participant's nine individual test scores. Residual scores from 7 participants were identified as outliers for a given test,[6] and these individual outlying scores were removed from subsequent analyses. The correlation matrix of residual scores was then submitted to a principal factors analysis. Using an orthogonal rotation (varimax), the factor analysis yielded two factors that corresponded to the medial temporal and frontal factors found by Glisky et al. (eigenvalues > 1). (An oblique rotation, oblimin, was run, and the factors were still found to be orthogonal.) Factor 1 (corresponding to medial temporal measures) accounted for 26% of the total variance, and Factor 2 (corresponding to frontal measures) accounted for an additional 18% of the variance.[7] Four tests loaded into Factor 1 (loadings > .3), and five tests loaded into Factor 2 (see Table 5). Although the values of the loadings differed from those reported by Glisky et al. (see their Table 2), the tests loading onto each factor were consistent with their findings.

The residual score from each neuropsychological test for each participant was converted to a *z* score (to standardize the scores from the varied scoring formats and ranges), and their composite score for a given factor was calculated by assigning equal weighting to each test (i.e., *z* scores were averaged across the four tests contributing to the medial temporal factor and across the five tests contributing to the frontal factor). The relation between these composite scores and memory performance as measured by multinomial parameter estimates was analyzed, using an alpha level of .05 for all analyses. To obtain measures of overall recognition and source monitoring accuracy (i.e., collapsed across the two sources, as done by Glisky et al., 1995), parameter estimates were derived from Batchelder and Riefer's (1990) Model 4. Because the manipulated retention interval in the source monitoring experiment yielded significantly different levels of recognition and source accuracy, analyses were conducted separately for the two conditions (2-day or 15-min delay).

When older adults had a 2-day delay in the source experiment, overall source accuracy was correlated with both frontal composite scores ($r = .59$) and temporal composite scores ($r = .48$).[8] Overall recognition accuracy was not significantly correlated with either the frontal ($r = -.11$) or temporal ($r = .08$) battery. When older adults were given a 15-min delay before the source test, there was a correlation between overall source accuracy and temporal scores ($r = .61$),[9] but there was no significant relation between overall source accuracy and frontal scores ($r = .10$) nor between recognition and either the frontal ($r = .08$) or temporal ($r = .32, p > .23$) battery.

The empirical measures derived from the forced-choice task used by Glisky et al. (1995) to assess item recognition and source monitoring differed from the multinomial measures derived from the source monitoring task used here. Although no measures directly analogous to those used by Glisky et al. can be derived from the current data, when empirical measures for old–new recognition (hits + correct rejections) and source accuracy (proportion of items correctly attributed to their source given correct recognition as old) were examined, the results for the 2-day delay condition were similar to those found using multinomial measures, though the correlations between source accuracy and both frontal scores ($r = .45, p < .06$) and medial temporal scores ($r = .44, p < .07$) were somewhat lower. Likewise, for the 15-min delay condition temporal scores were correlated with source accuracy ($r = .55$), and no correlation was found between frontal scores and source accuracy, consistent with analyses using multinomial measures. However, temporal scores were significantly correlated with old–new recognition accuracy for the 15-min delay group ($r = .54$), which was not shown in the multinomial analyses but is consistent with Glisky et al.'s results.

It should be noted that scores from the self-reported assessment of health were not significantly correlated with either the frontal or temporal measures. General verbal IQ as measured by WAIS–R scores was significantly correlated with both frontal composite scores ($r = .48$) and temporal composite scores ($r = .39$). However, WAIS–R scores were not correlated with measures of recognition or source accuracy (D_1, D_2, d_1, d_2).

In summary, our study replicates Glisky et al.'s (1995) finding of a relation between the frontal battery and source

Table 5
Loadings Extracted From the Orthogonal Rotation of the Factor Analysis

Test/subscale	Factor 1 (temporal)	Factor 2 (frontal)
Wisconsin Card Sorting	—	.48
Controlled Oral Word Association (FAS)	—	.32
Wechsler Adult Intelligence Scale—Revised		
Mental Arithmetic	—	.71
Wechsler Memory Scale—Revised		
Digit Span (backward)	—	.71
Mental Control	—	.45
Logical Memory I	.66	—
Verbal Paired Associates I	.83	—
Visual Paired Associates II	.67	—
California Verbal Learning		
Long-Delay Cued Recall	.77	—
Eigenvalues	2.45	1.50

Note. Dashes indicate data were not obtained.

[6] Outlier scores involved 4 participants from the 2-day delay group and 3 from the 15-min delay group. Each of the 7 participants was an outlier on only one test. These tests were Mental Control (3 participants), Logical Memory (1 participant), CVLT (1 participant), FAS (1 participant), and WCST (1 participant).

[7] The variance accounted for by the two factors in our study was considerably less than that reported by Glisky et al. (1995).

[8] In separate analyses of each source, this was true for imagined items ($r = .52$, and $r = .61$, respectively) but not for perceived items ($r = .18$, and $r = .15$, respectively).

[9] Again, this was the case for imagined items ($r = .60$) but not for perceived items ($r = .41, p > .10$).

accuracy, but this was found only in the condition in which overall source accuracy was extremely low, that is, when older adults had a 2-day delay before the source test. Glisky et al.'s participants also showed relatively poor source performance, albeit with a much shorter retention interval, presumably because of the difficulty in discriminating between two external sources (voices heard on tape). Hence, a relation between this frontal battery and source accuracy has been found in situations where source performance is fairly low (i.e., when older adults were given a 2-day delay or when they had a relatively difficult source-discrimination task). In general, we would expect more difficult source tasks to recruit more reflective frontal functions (e.g., attempts to retrieve additional information or to note differences between memories in qualitative characteristics). That is, when frontal functioning declines, it should be more apparent on more difficult source tests where frontal functions are needed. Past work using one or two individual measures of frontal function has been inconsistent in establishing a relation between source deficits for older adults and reduced frontal function (e.g., Craik et al., 1990; Johnson et al., 1995; Spencer & Raz, 1995). Using a battery of tests that measure a variety of aspects of frontal function presumably increases the chances that frontal and source monitoring tests will recruit common reflective processes.

Our findings also showed that source accuracy was related to scores on the medial temporal battery, suggesting a model that attributes source processes to frontal lobe functioning alone would be too simplified. Given the evidence that medial temporal structures are involved in the binding of contextual features in complex memories (Chalfonte et al., 1996; Johnson & Chalfonte, 1994; Kroll et al., 1996), we would expect that in settings in which confusions between the specific features of perceived and imagined memories are likely to occur, binding deficits as a result of reduced medial temporal processing would lead to lower source accuracy, as indeed was found.

Glisky et al. (1995) reported an association between item recognition and medial temporal scores. Our results showed such an association for older adults with the 15-min delay (using hits + correct rejections) but not for the 2-day delay group. The weak relation between medial temporal scores and item recognition in our study (it did not show up significantly with multinomial measures for either the 15-min or 2-day group) suggests that as in the case of source accuracy, which neuropsychological indexes correlate with item-recognition performance depends on the specific features of the task. In this experiment, our primary interest was in creating a situation in which source identification might correlate with both frontal and medial temporal scores in order to obtain evidence consistent with the idea that both brain regions play a role in source memory. Future studies will be directed at investigating the relative roles of medial temporal and frontal regions in old–new recognition.[10]

General Discussion

Our findings show that both younger and older adults tended to mistakenly claim they perceived an imagined item when the imagined item had similar perceptual or conceptual features to an item that was in fact perceived, relative to when there was no such similarity. This supports the argument that judgments of a target memory's source can be influenced by information that is derived from other specific events (Henkel & Franklin, 1998b) and is also consistent with the source monitoring framework, which predicts that greater similarity between potential sources of memories generally leads to greater source errors (Johnson et al., 1993).

This study in particular addressed whether older adults are even more susceptible to source errors as the similarity between specific imagined and perceived memories is increased. The answer to this question was yes. When age groups were equated on old–new recognition by testing younger adults after 2 days and older adults after 15 min, an age-related deficit in source monitoring was found for imagined items that were physically or conceptually similar to perceived items but not for unrelated items. This did not simply reflect a greater bias for older adults to claim that items were perceived because, if anything, at the 15-min retention interval, older participants were more likely to guess "imagined." This pattern indicates that older people are not simply prone to make more errors in source judgment tasks; rather they are more likely to be influenced by similar features from another perceived memory in judging an imagined memory's source. Older individuals are not simply "confused" in a generic way when faced with a demanding source task. Rather, their misattributions arise from deficits in specific processes that ordinarily differentiate episodic memories that have similar features.

One way such source errors could occur is if participants have memory records of features (e.g., round-shape) that are not tightly bound to the context of their occurrence (e.g., magnifying glass), which can thus influence judgments about other items (e.g., lollipop). Consistent with the idea that older adults might have binding deficits (Chalfonte & Johnson, 1996) linked to an increased incidence of neuropathology in medial temporal regions (e.g., Ivy et al., 1992), there was a correlation in the group of older adults tested at 15 min between source accuracy and scores on a neuropsychological, medial temporal test battery.

When older participants were given the same 2-day retention interval as younger adults, we did not observe an even greater age-related deficit in source accuracy from increasing similarity as might be expected, perhaps because older adults showed such a great overall impairment in

[10] It may be that asking participants to engage in source monitoring (and deriving old–new recognition scores as done here) may shift the basis of their old–new recognition from features that ordinarily might do for item recognition (e.g., in a forced-choice test as used by Glisky et al., 1995) to different or more complex sets of features needed for source monitoring (e.g., De Leonardis, Nolde, & Johnson, 1996). This view is consistent with past work showing that different test formats through which memory is assessed have important consequences for the ways in which memories are evaluated by participants (De Leonardis et al., 1996; Dodson & Johnson, 1993; Johnson et al., 1997; Mather et al., 1997).

source accuracy for imagined items. That is, similarity effects were likely to have been obscured by a floor effect. At the 2-day delay, there was an age-related item-recognition deficit as well as a deficit in source memory. However, global age-related declines in recognition alone provide an unlikely account for the large source deficit because old–new recognition and source monitoring were differentially affected by the item's source (i.e., recognition was higher for imagined than for perceived items, yet source monitoring was worse for imagined items, providing another demonstration that recognizing an item as old is not necessarily the same as being able to correctly identify its source; e.g., Johnson & Raye, 1981). Furthermore, older people did not have a greater tendency than younger people to claim items were perceived when uncertain (see values for g in Table 2). Thus the high rate of source errors made by older adults at the 2-day delay reflects age-related differences in the ability to identify the source of a memory and not just differences in their ability to remember the items themselves.

As was found for older adults tested at 15 min, in the 2-day group there was a significant correlation between source accuracy and medial temporal scores. In addition, there was a significant correlation between source accuracy and scores on a frontal test battery. The emergence of a correlation between source accuracy and frontal scores at the 2-day delay but not at the 15-min delay is consistent with the expectation that frontal regions should be more important the more difficult the retrieval and evaluation demands of the source task (Johnson et al., 1996). That is, after a delay, source monitoring is more likely to require more systematic, frontally based, reflective source monitoring processes, such as retrieving additional confirming or disconfirming evidence and comparing the relative amounts and types of information in the present and previously tested items (Johnson, 1997a). Thus either binding or retrieval–evaluation deficits can produce errors in source accuracy. That these processes make distinctive contributions to source monitoring is supported by the fact that for older adults the medial temporal and frontal batteries were both correlated with source accuracy but not correlated with each other.

Some investigators have suggested that old–new recognition and source memory are based on medial temporal and frontal systems, respectively (e.g., Glisky et al., 1995). Our results are more consistent with the idea that old–new recognition and source identification differ in the degree or specificity of the source information required (e.g., Johnson et al., 1993) than the idea that they correspond to fundamentally different processes. That is, recognition and source identification sometimes do rely on the same features of memories, but the two can be dissociated when they do not (Johnson & Raye, 1981; Johnson et al., 1993). For example, it is especially likely that old–new recognition and source accuracy will be dissociated when individuals rely on undifferentiated familiarity for old–new decisions because familiarity is often not sufficient for accurate source attributions (e.g., Jacoby et al., 1989). Conversely, requiring participants to engage in cognitive operations for items from two sources at encoding may increase both old–new recognition and source accuracy, as long as the operations are different for the two sources (e.g., see performance for older adults in Experiment 1, Johnson et al., 1995). A central point is that neither old–new information nor source information is a single thing but rather there are various aspects of memories (e.g., undifferentiated familiarity, color, location, voice, person, modality, time, associated thoughts), and each can be available with varying levels of specificity (e.g., location: at the Psychology Building, in my office, on my desk; person: a person, a man, a student, Scott; e.g., Johnson et al., 1993). In any given situation, an aspect that is useful for old–new recognition is not necessarily diagnostic for source identification, producing a dissociation between old–new recognition and source identification (e.g., Johnson et al., 1996).

One way to investigate the multifeatured nature of memories is to ask participants about their subjective experience when remembering (e.g., Gardiner & Java, 1993; Johnson et al., 1988). In our study, a memory characteristics questionnaire was used to assess qualitative features of participants' memories. For younger adults tested at the 2-day interval and for older adults tested at 15 min, the perceptual features and associated thoughts and feelings for a memory whose source was correctly judged were on average more vivid than the features for a memory whose source was misjudged. This indicates that the qualities of veridical and falsely attributed memories are somewhat different, consistent with research showing a greater degree of subjective sense of conscious recollection for old items whose source was correctly attributed, followed by old items whose source was incorrectly attributed, followed by new items that were falsely recognized (Lane & Zaragoza, 1995). This is also consistent with research showing differences in accurate and inaccurate memories in the more specific qualities assessed by an MCQ (Mather et al., 1997; Norman & Schacter, 1997). Hence, people could presumably improve their source accuracy and be less influenced by similarity of features from other memories entering into judgments about a target memory's source by applying more stringent criteria. For example, Mather et al. (1997) showed that under some circumstances more careful consideration of the features of memories while judging their source (induced by making MCQ ratings) leads to improved source accuracy. However, in the current study, the MCQ ratings were made separately after all source judgments were complete and thus could not have influenced source accuracy. (For other results showing the beneficial effect of more specific source evaluation, see Dodson & Johnson, 1993; Lindsay & Johnson, 1989; Multhaup, 1995; Zaragoza & Lane, 1994.) Presumably, weighting features and setting such criteria appropriately for a given task involves frontal functions.

At the 2-day delay, older adults' memories were subjectively less vivid than those of younger adults,[11] and the

[11] This decreased vividness presumably reflects differences in vividness for memories' features rather than differences in initial imagery ability. No age differences were found on two standardized imagery questionnaires, which is consistent with past work showing that older adults do not have deficiencies in generating images or in the qualitative vividness of their imagery (e.g., Campos &

extent to which perceptual information and associated thoughts were more vivid for correctly attributed than for incorrectly attributed memories was somewhat less marked for older adults (see also Fell, 1992; Norman & Schacter, 1997; Schacter et al., 1997). This loss of subjectively available information presumably contributes to the age-related deficits in recognition and source accuracy. When older adults had a relatively short 15-min retention interval, subjective vividness was not significantly lower than was found for younger adults at the 2-day delay nor was the difference between ratings for accurate and inaccurate judgments significantly less for older than younger adults. Yet older adults' source accuracy was more impaired than that of younger adults. However, because the MCQ was given after the source test was completed, one possibility is that at the 15-min interval, older adults had information (as assessed by the MCQ) that they did not use on the source test, accounting for their lower source performance (see also Multhaup, 1995). Alternatively (or in addition), the features assessed by our abbreviated MCQ may not have included all the features that distinguish the quality of the memories of younger and older adults. Furthermore, subjective ratings may not be sensitive enough to detect the more subtle differences in a memory's phenomenal features that influence source judgments but that are not necessarily accessible through self-report measures.

In short, our study clearly shows that compared to younger adults, older adults after a short retention interval have more difficulty in identifying an imagined object as imagined rather than perceived when they have perceived an item with similar features. Over time, their source monitoring difficulty becomes more general (showing up on unrelated items as well as related items) and more severe. At a 2-day retention interval, the magnitude of the difference in subjective qualities of memories that were attributed to the correct and incorrect source was smaller for older than for younger adults. Together these results suggest that older adults are more likely to have difficulty assembling and reassembling the attributes that make up complex memories.

On the basis of the neuropsychological batteries used by Glisky et al. (1995), both medial temporal and frontal battery scores were positively associated with older adults' source accuracy in our paradigm. Temporal scores were correlated with source accuracy at both 15-min and 2-day retention intervals, and frontal scores were correlated with source accuracy at the 2-day retention interval. These results provide evidence consistent with the source monitoring framework, which proposes that medial temporal and frontal regions both play important, but somewhat different, roles in source memory. Medial temporal regions are important for binding features into complex memories and for relatively effortless reactivation processes, whereas frontal regions are important for more effortful or strategic retrieval, for maintaining the activation of representations, and for more complex evaluative processes, including setting appropriate criteria (Johnson, 1997a, 1997b; Johnson et al., 1993; see also N. J. Cohen & Eichenbaum, 1993; Moscovitch, 1989, 1994; Shallice et al., 1994; Squire & Knowlton, 1995; Winocur, Moscovitch, & Stuss, 1996). Thus the difficulties older adults have in source monitoring do not reflect a deficit in a single system dedicated to "source" but rather arise from deficits in the more general component processes required for source monitoring (e.g., Johnson, 1992; Johnson & Hirst, 1993)—processes that account for feature binding, retrieval, evaluation, setting criteria, and so forth.

Consistent with this SMF view, past research has suggested that age deficits in source judgments can be reduced under conditions likely to improve the binding of the most diagnostic features of memory or to improve the evaluative processes used in attributing memories to sources. For example, when older adults are encouraged to focus on factual rather than affective features of their memories, the age deficit in source accuracy is diminished (Hashtroudi et al., 1994), as it is when relatively more personally engaging information is judged (Brown et al., 1995). Additionally, age-related source deficits can be reduced when older people are induced to rely on more stringent or specific criteria to evaluate the source of their memories (Multhaup, 1995). Future research in which binding and evaluative conditions are manipulated and brain activity of both younger and older adults is assessed through electrophysiological or brain-imaging techniques (e.g., Johnson, 1997b; Johnson, Kounios, et al., 1996) would help verify and extend our findings.

Sueiro, 1993; Gissurarson, 1992; Hashtroudi et al., 1990; Pierce & Storandt, 1987; White, Ashton, & Brown, 1977) or less self-rated ability to control and manipulate their imagery (Pierce & Storandt, 1987). Although older adults do perform more slowly and less accurately on mental rotation tasks (e.g., Herman & Bruce, 1983), other imagery processes such as generating and scanning images do not decline with age (Dror & Kosslyn, 1994).

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Received March 10, 1997
Revision received July 30, 1997
Accepted July 30, 1997 ■