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Aging and the seven sins of memory

Benton H. Pierce[1,*], Jon S. Simons[2] and Daniel L. Schacter[1,*]

[1]*Department of Psychology, Harvard University, William James Hall, 33 Kirkland St., Cambridge, MA 02138*
[2]*Institute of Cognitive Neuroscience, University College London, Alexandra House, 17 Queen Square, London WC1N 3AR, UK*

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Memory serves many different functions in everyday life, but none is more important than providing a link between the present and the past that allows us to re-visit previously experienced events, people, and places. This link becomes increasingly significant as we age: recollections of past experiences serve as the basis for a process of life review that assumes great importance to many older adults (Coleman, 1986; Schacter, 1996). Not surprising, then, a common worry among older adults is that forgetfulness, which may seem to be increasingly pervasive as years go by, will eventually result in the loss of the precious store of memories that has been built up over a lifetime. While much evidence suggests that various aspects of memory do decline with increasing age, it is clear that performance on some memory tasks remains relatively preserved (Naveh-Benjamin et al., 2001).

*Corresponding author. Tel.: 617-495-3855; fax: 617-496-3122.
E-mail address: dls@wjh.harvard.edu (D.L. Schacter).

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It has recently been proposed that the many and various ways in which memory can break down can be divided into seven fundamental categories, or "sins" (Schacter, 1999 , 2001). The first three sins – transience, absent-mindedness, and blocking – have been termed "sins of omission," and refer to types of forgetting. Transience involves decreasing accessibility of information over time; absent-mindedness entails inattentive or shallow processing that contributes to weak memories of ongoing events or forgetting to do things in the future; and blocking refers to the temporary inaccessibility of information that is stored in memory. The next four sins – misattribution, suggestibility, bias, and persistence – termed "sins of commission," involve distortions, inaccuracies or intrusions in remembering. Misattribution involves attributing a recollection or idea to the wrong source; suggestibility refers to memories that are implanted at the time of retrieval; and bias involves retrospective distortions and unconscious influences that are related to current knowledge and beliefs. Finally, persistence refers to pathological remembrances: information or events that we cannot forget, even though we wish we could.

While much has been written about memory failures in older adults, age-related memory problems have not been systematically examined from the perspective of the seven sins. Adopting such a perspective could help to sharpen our ideas about age-related memory changes, and could also help to point out areas in which research and ideas are lacking. This chapter provides an overview of the literature on age-related memory changes within the seven sins framework, with the aim of providing insights into the cognitive and neural basis of aging and memory.

1. Sins of omission

1.1. Transience

The gradual forgetting of memories over time is one of the most pervasive of memory's sins. The first experiments to document this fact were carried out by Ebbinghaus in 1885, who taught himself nonsense syllables and then assessed his memory for the items after various delays. He found that, soon after learning, his retention of the syllables diminished rapidly, and as time went on, he retained gradually fewer and fewer of them. The apparent transience of memories is especially troubling to older adults (Craik, 1977), and evidence suggests that the ability to retain information over time is indeed affected by aging. For example, many studies have demonstrated that elderly individuals find it more difficult than younger adults to remember lists of words that they were asked to learn (Huppert and Kopelman, 1989). This may be attributable either to poor acquisition of new information, to degradation of stored memories, or to failure to retrieve information that is still stored in memory.

Evidence suggests that older adults acquire information at a slower rate than younger individuals (Youngjohn and Crook, 1993), and that they are less likely to make use of strategies that promote the formation of rich, elaborate memory traces, even when instructions explicitly encourage this (Simon, 1979; Craik and Byrd, 1982; Rabinowitz and Ackerman, 1982). Investigations of age-related changes in

memory retention are complicated by the differences in acquisition between age groups, but researchers have sought to address these difficulties by varying the exposure of young and elderly individuals to the information that is to be remembered so that the groups can be equated on initial remembering, and by comparing within participants the amount of information that can be retrieved initially and after a delay, such that each individual serves as his or her own control. When one or other of these strategies was used to equate initial remembering, several studies found relatively little difference in forgetting rates between young and elderly adults over time (Rybarczyk et al., 1987; Petersen et al., 1992; Giambra and Arenberg, 1993), although others reported evidence of some age-related forgetting that could not be accounted for by acquisition differences (Huppert and Kopelman, 1989; Carlesimo et al., 1997). For example, Huppert and Kopelman (1989) found that elderly adults were significantly worse than young adults at recognizing studied pictures after delays of 24 h and one week, even when performance after a 10-min delay was covaried out.

A great deal of evidence suggests that the success of elderly individuals on memory tests depends, to a large extent, upon the support provided to facilitate retrieval. For example, the age-related deficit of elderly subjects is typically greater on free recall tasks, where they are simply asked to recall studied items in any order that they wish, than on cued recall tasks, where they are provided with a cue about the studied items, such as the fact that they were all animals (Bäckman and Larsson, 1992; Sauzeon et al., 2000). Similarly, performance impairments on tests of recall are very often substantially greater than on recognition tasks, in which participants select items that were studied from amongst non-studied distractors (Craik and McDowd, 1987; Davis et al., 2001). This latter difference may be a reflection of increased retrieval support in recognition tasks, or may be related to the widely held view that while recall tasks depend heavily upon conscious recollection of the study episode, selecting studied items from amongst distractors in a recognition task can be accomplished on the basis of judgments of familiarity (Mandler, 1980; Jacoby and Dallas, 1981). When older adults are given a recognition test in which they are asked whether they "remember" or consciously recollect contextual details about studying an item, or merely "know" the item was studied without conscious recollection (Tulving, 1985), they typically produce far fewer "remember" responses than younger adults, while "know" responses are less affected by age (Parkin and Walter, 1992; Mäntylä, 1993).

While there are often large age-related differences in memory after short delays, evidence suggests that young and elderly adults may perform relatively similar in remembering over longer periods of time. For example, in a study of memory for former one-season TV programs over the previous 15 years, older adults performed significantly worse for programs aired in the most recent five years, but there were far fewer age-related differences for programs from the prior 10-year period (Squire, 1989). Similar results were seen in the recall of personal autobiographical memories over the previous 20 years (Rubin et al., 1986), and over the entire life span (Howes and Katz, 1992). Indeed, some evidence suggests that older adults may remember more episodes from the years of early adulthood (i.e. around ages 10–30) than middle-aged adults (e.g. Rubin and Schulkind, 1997), suggesting that although,

over all, there is a tendency for memories to fade over time, episodes from particularly significant periods of life (such as teenage years) may be an exception to the general rule of transience (Conway and Pleydell-Pearce, 2000).

Neuropsychological and neuroimaging studies have provided insights into the neural bases of transience. Studies of patients with brain damage have highlighted the importance of medial temporal lobe regions such as the hippocampus for remembering (Scoville and Milner, 1957; Squire, 1982; Schacter, 1996). Patients with amnesia, such as the well-studied case, HM, who underwent bilateral resection of the hippocampus and surrounding structures to relieve symptoms of severe epilepsy, often exhibit profound transience, able to retain very little information for more than a few minutes (Milner et al., 1968; Corkin, 1984). It is difficult, however, from clinical studies to isolate whether the exhibited transience is attributable to deficits in the encoding, storage, or retrieval of information. Advances in neuroimaging technology using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have allowed separate investigation of encoding and retrieval processes.

Recent studies that have examined activations on a trial-by-trial basis have revealed areas in posterior medial temporal lobe, as well as inferior prefrontal cortex, whose level of activation at encoding was higher for information that was subsequently remembered than for information that was subsequently forgotten (Brewer et al., 1998; Wagner et al., 1998; Otten et al., 2001). The involvement of these prefrontal and medial temporal lobe areas at encoding would seem, therefore, to be an important factor in the transience of remembering. It has been theorized that changes in frontal lobe function, and perhaps medial temporal lobe function, contribute to age-related changes in retention (e.g. Moscovitch and Winocur, 1992; Prull et al., 2000). Recent neuroimaging studies have indeed implicated various aspects of frontal lobe function in age-related memory loss (e.g. Schacter et al., 1996c; Cabeza, 2002; Logan et al., 2002), and there is also evidence implicating changes in the medial temporal lobes (Grady et al., 1995; Sperling et al., 2001).

1.2. Absent-mindedness

Although the transience of memories is an abiding concern to older adults, the loss of memories over time is not the only cause of forgetting in everyday life; simple lack of attention during key phases of the remembering process contributes greatly to everyday forgetting. Many people are aware of occasions when, on arriving home, they quickly put their house keys down because the phone was ringing and then, later, had to hunt around for 20 min before finding them again. It is unlikely that this failure to recall the keys' location is attributable to a problem with retention per se, but is instead attributable to insufficient attention being paid to the keys in order to encode their location successfully. It is well established that dividing attention by having subjects perform a concurrent task while they are studying items for a later memory test results in poorer recall and recognition than when the subjects can pay full attention to the items (Craik et al., 1996, 2000).

Evidence suggests that lapses in attention play an important role in the absent-minded errors exhibited by elderly adults. Several studies have shown that when young adults are required to divide attention during encoding, their performance on recall and recognition tests can resemble that of older adults under full attention conditions (Craik and Byrd, 1982; Jennings and Jacoby, 1993). This apparent correspondence between divided attention and aging has been demonstrated in terms of behavioral performance, and also at the neural level. For example, Dywan et al. (1998) recorded event-related potentials (ERPs) in young and elderly adults during encoding, and found that under divided attention conditions, the performance of younger and older adults was similar both behaviorally and electrophysiologically. Likewise, N. D. Anderson et al. (2000), using positron emission tomography (PET), observed left inferior prefrontal activity in young adults associated with encoding under full attention conditions, which was reduced similarly under divided attention conditions and in older adults in the full attention condition.

Although dividing attention during encoding can substantially affect memory performance, it typically has less effect if it occurs during memory retrieval (Naveh-Benjamin et al., 1998). Another factor at encoding that can affect subsequent memory is the "depth of processing" that is carried out on the to-be-remembered information (Craik and Lockhart, 1972). For example, making some kind of semantic decision about a word, such as whether it specifies an abstract or concrete concept, typically results in better memory for that word than simply deciding whether the word is printed in upper or lower case letters (Craik and Tulving, 1975). Evidence suggests that elderly adults are less likely to spontaneously encode items as deeply as younger adults (Simon, 1979; Craik and Byrd, 1982; Rabinowitz and Ackerman, 1982). When they are encouraged to encode information elaborately, however, subsequent recall can be markedly improved (e.g. Holland and Rabbitt, 1992).

Neuroimaging investigations of depth of processing effects have converged with the divided attention studies described above in identifying left prefrontal regions as being implicated in absent-minded encoding errors (Kapur et al., 1994; Wagner et al., 1998 experiment 1; Baker et al., 2001; Otten et al., 2001). For example, Kapur et al. (1994) observed activation in left inferior prefrontal cortex when comparing semantic (deciding if a word specified a living or nonliving item) and nonsemantic (deciding if a word contained the letter "a") encoding tasks. Similarly, a recent study that compared encoding-related activation associated with living/nonliving and alphabetic decisions about words found greater activation during the semantic task in prefrontal, as well as in medial temporal, regions (Otten et al., 2001). Interestingly, this same study found that a subset of these regions, left inferior prefrontal cortex and left anterior hippocampus, exhibited greater activation for words that were subsequently remembered than for words that were subsequently forgotten. Together, these results suggest that the absent-minded memory errors often seen in elderly adults may be the result of reduced activity in these left prefrontal, and perhaps medial temporal, regions.

In addition to encoding factors that may be responsible for absent-minded memory errors in older adults, retrieval factors may also play an important role. One situation in which the influence of such factors can be observed is that of prospective

memory, or the realization of delayed intentions (Ellis, 1996). Different types of prospective memory tasks may be differentially affected by aging. For example, Einstein and colleagues (e.g. Einstein and McDaniel, 1990; Einstein et al., 1992) proposed a distinction between ''event-based'' and ''time-based'' prospective memory tasks. Event-based tasks refer to those in which a future action is to be performed when a particular external event occurs (e.g. giving someone a telephone message). These can be contrasted with time-based tasks in which one must perform a specific action at a specific time or after a certain time period has elapsed. Einstein and McDaniel (1990) suggested that minimal age differences would be found in event-based tasks because such tasks contain external cues that guide retrieval. However, in time-based memory tasks, no external cues are available, requiring one to use self-generated cues to prompt retrieval. This type of memory task in which a high level of self-initiated processing is required would be expected to produce the largest age differences.

Although several studies did, indeed, find an absence of age differences in event-based prospective memory tasks (e.g. Einstein et al., 1995; D'Ydewalle et al., 2001), other studies have reported significant age-related declines in these tasks (e.g. Maylor, 1996; Park et al., 1997). Einstein et al. (1997) suggested that this inconsistent age-related pattern of event-based prospective memory might be attributable to the nature of the background tasks that participants engage in until the prospective memory cue occurs. By increasing the demands of background activities (e.g. adding a digit-monitoring task), Einstein et al. showed that age-related declines in prospective memory emerged that were absent with less demanding background activity. In addition, Einstein et al. examined the effects of this increased background activity at encoding and at retrieval and found that age differences in prospective memory increased only when the digit-monitoring task was administered at retrieval. These results suggest that demanding ongoing activities, which tax the cognitive resources of older adults, add a working memory load that becomes more difficult for older adults to handle in conjunction with the to-be-performed action.

One implication of these findings is that prospective memory tasks that must be delayed over a substantial period of time may prove especially taxing for older adults, perhaps leading to prospective memory deficits even without a demanding secondary task at retrieval. As Einstein et al. (2000) have pointed out, many everyday prospective memory tasks must be delayed or postponed until there is an opportunity to perform them. For example, one may remember to make an important telephone call while in the back yard, but have to wait until in the house to actually make the call. Einstein et al. (2000, 2002) have examined the effects of maintaining intentions on prospective memory performance in older adults using a laboratory paradigm they call a ''retrieve-delay'' task. In this paradigm participants are required to wait for a brief period of time after encountering a target event before executing the appropriate action. Results of these studies showed that delaying execution of an intention, as briefly as 5 s, leads to substantial prospective memory forgetting in the older adults, even when the delay contained no concurrent activities. Furthermore, this age-related decline in prospective

memory performance persisted even after some older adults received strong instructions to rehearse the intention during the delay period. These results suggest that older adults' impaired performance in this task stems in part from their difficulty in keeping representations activated (Einstein et al., 2002). As Einstein et al. suggest, older adults would be advised to "do it or lose it."

Previous discussion examined the involvement of the frontal lobes during encoding processes and the potential link between these processes and absent-minded errors in older adults. However, frontal lobe involvement, and in particular, anterior prefrontal cortex, may also be important during retrieval processes required for older adults' successful performance on prospective memory tasks (e.g. Bisiacchi, 1996; Glisky, 1996; West, 1996; Burgess and Shallice, 1997; Burgess et al., 2000, 2001). One hypothesis concerning this form of memory focuses on the requirement to monitor the environment for a cue that signals the intended action to be performed (Bisiacchi, 1996; Burgess and Shallice, 1997). Such processes may be mediated by a supervisory attentional system linked to frontal lobe functioning (Shallice and Burgess, 1991; Burgess and Shallice, 1997). Furthermore, it has been proposed that once the environmental cue has been encountered and noticed, retrospective memory is required to search for the intended action (McDaniel, 1995; Einstein and McDaniel, 1996), a largely voluntary and strategic retrieval process that may require the involvement of prefrontal systems (Shimamura et al., 1991; Moscovitch, 1994). Other hypotheses concerning the role of the frontal lobes in prospective memory have also been proposed (Mäntylä, 1996; Burgess and Shallice, 1997; McDaniel et al., 1998, 1999).

Evidence consistent with the view that the frontal lobes, to a greater extent than other brain regions such as the medial temporal lobe, may be critical for prospective memory emerged from an aging study by McDaniel et al. (1998). These authors divided participants into four groups on the basis of their scores on two composite measures: one that assessed frontal lobe function, and the other that assessed medial temporal lobe function. McDaniel and colleagues found that high-functioning older adults on the frontal measure performed significantly better on a prospective memory task than did the low-functioning group. For the medial temporal groups, there was no significant difference in prospective memory performance between high-functioning and low-functioning older adults. McDaniel et al. suggested that these results support the general consensus that the frontal lobes play a key role in prospective memory (see Cherry and LeCompte, 1999 for other evidence of individual differences in older adults' prospective memory performance).

More direct evidence of frontal lobe involvement in absent-minded memory errors come from both human lesion cases (Burgess et al., 2000) and neuroimaging studies (Okuda et al., 1998; Burgess et al., 2001). Wes and Covell (2001), for example, recorded event-related potentials (ERPs) in younger and older adults while participants performed a prospective memory task. The researchers observed age-related reductions in the amplitude of ERP modulations related to prospective memory, suggesting that reduced efficiency of a frontally mediated neural system in older adults contributes to their prospective memory failures. Okuda et al. (1998) provided additional evidence of frontal involvement in prospective remembering

in a PET study with younger adults. Participants were required to perform a routine task (repeating spoken words) during scanning. In the prospective memory condition, participants were also required to also retain a planned action (to tap when prespecified words appeared) while performing other activities. Okuda et al. observed activation in a number of brain regions during prospective remembering, most notably the surface of the right frontal lobe (dorsolateral and ventrolateral regions), the front of the left frontal lobe (frontal pole), and inner parts of the frontal lobe near the midline. The importance of the frontal pole area for prospective memory was confirmed in two more recent PET studies by Burgess and colleagues (Burgess et al., 2001; Burgess et al., in press). Like the study by Okuda et al., these experiments contrasted conditions in which a cognitively-demanding task was undertaken that either did, or did not, require subjects to maintain a delayed intention to be acted upon when a particular cue was provided. Burgess et al. demonstrated that involvement of the region of the frontal pole in prospective memory was material- and stimulus-non-specific, was involved more in the maintenance than in the execution of the delayed intention, and could not be explained by differences in the difficulty of the two cognitively demanding tasks.

1.3. Blocking

When asked to report their most troublesome cognitive difficulty, older adults often cite an inability to retrieve the names of familiar people (Lovelace and Twohig, 1990). This inability to gain access to a target item after being given cues related to the sought-after information has been termed retrieval blocking (Roediger and Neely, 1982). Because one is aware of the block as it occurs, blocking represents an especially compelling sin of memory and a particular source of frustration in seniors.

Perhaps the best example of blocking is the tip-of-the-tongue state (TOT), an experience in which one is certain that information is in memory but is temporarily unable to retrieve it (Brown, 1991). A number of studies have confirmed that TOTs tend to increase with age (e.g. Maylor, 1990; Burke et al., 1991; Brown and Nix, 1996; Heine et al., 1999). These TOT increases in older adults have been observed in naturalistic situations involving diaries or questionnaires (Burke et al., 1991, Study 1; Heine et al., 1999; Brown, 2000; James and Burke, 2000), as well as in laboratory studies using names of famous people (e.g. Maylor, 1990) and rare words (e.g. Brown and Nix, 1996). It is worth noting, however, that despite reporting more TOTs than their younger counterparts, older adults appear to be equally capable of eventually resolving these TOT experiences if given enough time (Brown and Nix, 1996; Heine et al., 1999).

Explanations for higher TOT reports among elderly adults have focused primarily on two alternative hypotheses. The first, termed the inhibition hypothesis (Burke et al., 1991), states that TOT experiences are due in large part to the existence of interfering items or ''interlopers'' that hinder memory retrieval (e.g. Jones and Langford, 1987; Jones, 1989). These interlopers were originally called ''ugly sisters'' by Reason and Lucas (1984), referring to Cinderella's undesirable but dominating older sisters. These ugly sisters are incorrect items that are either semantically or

phonologically related to the sought-after target and occur recursively through the retrieval attempt. If older adults are less able to inhibit task-irrelevant thoughts (e.g. Hasher and Zacks, 1988; Zacks et al., 2000), they may be especially susceptible to the effects of these interfering items, resulting in an increased likelihood that a TOT state will be induced.

According to the inhibition hypothesis, older adults should experience more interlopers during TOT states than young adults. However, most studies that have examined this issue have found that older adults are less likely to generate such competing items during attempted retrieval (Cohen and Faulkner, 1986; Burke et al., 1988, 1991; but see Brown and Nix, 1996). These findings lend support to an alternative hypothesis of age-related TOT increases known as the *transmission-deficit hypothesis* (Burke et al., 1991), based on the notion that activation of the target word is incomplete (Brown, 1991). A key aspect of Burke et al.'s hypothesis is that words or concepts can be represented as interconnected nodes of information (semantic, lexical, and phonological nodes). According to Burke et al. (1991), aging weakens the connections between these nodes, reducing the transmission of activation from lexical nodes to connected phonological nodes, resulting in a reduced likelihood of phonological activation and an increase in TOT experiences.

A review of studies examining TOT states in older adults supports Burke et al.'s (1991) transmission-deficit hypothesis (Brown, 2000). As predicted by the hypothesis, older adults experience fewer related words (interlopers), as well as lower levels of partial information concerning the target word.

Although inhibition of competing items may not be a significant factor in increased TOT reports among elderly adults, other evidence suggests that inhibitory deficits may play a role in other blocking phenomena commonly found among seniors. For example, Hartman and Hasher (1991) devised a garden-path sentence task to assess whether older adults would be less likely to suppress or inhibit information that was highly familiar but no longer relevant. In this task, participants generated a final word for a series of sentences (e.g. the word "bowl" for the sentence "She ladled the soup into her ____"). For critical sentences, the participant-generated word was replaced by a plausible, but much less likely ending word (e.g. "lap"). Participants were instructed to remember the final word for a later memory test. On a later indirect memory test, participants were asked to provide endings for a series of new sentences that were moderately predictive of their final words (e.g. "Scotty licked the bottom of the ____" and "The kitten slept peacefully on her owner's ____"). Accessibility of the alternative endings was measured by how often participants used them to complete the new sentences above a baseline completion rate (priming).

Using this task, several studies have found that priming patterns differ across younger and older adults. Whereas younger adults show reliable above baseline completion using the target endings but not for disconfirmed endings (Hartman and Hasher, 1991; Hartman and Dusek, 1994; Hasher et al., 1997; May et al., 1999), older adults exhibit priming for both types of items (Hartman and Hasher, 1991; Hartman and Dusek, 1994; May and Hasher, 1998; Hasher et al., 1999; May et al., 1999). These findings suggest that when instructed during the study task to remember only the target items, younger participants are able to inhibit or suppress

the disconfirmed endings. Older adults, on the other hand, apparently are less able to inhibit the self-generated endings and show priming for those items as well as for the target items (but see Hartman, 1995 for a noninhibitory interpretation of the sentence completion data).

Less efficient inhibitory processes in older adults result in a sort of "mental clutter" in which extraneous information interferes with task relevant goals, producing a deleterious effect on memory performance (Zacks et al., 2000). For example, age-related increases have been found in the "fan effect" (Cohen, 1990; Gerard et al., 1991), which refers to the finding that the more associations that are linked to a concept, the more difficult is retrieval of any one association (i.e. the greater the "fan") (Zacks et al., 2000). Age deficits in inhibitory control have also been found in "directed forgetting" tasks in which older adults are less able than younger adults to suppress the processing and retrieval of items cued as to be forgotten (Zacks et al., 1996).

Older adults also show greater difficulty in ignoring distracting information in a selective attention task known as the negative priming or Tipper paradigm (Tipper, 1991). In this task, two stimuli are presented and participants are instructed to select one and ignore the other. On the next trial, the previously ignored distractor becomes the target, a task in which younger adults are slowed, thereby demonstrating "negative priming." Older adults, in contrast, fail to show reliable negative priming in this task (Hasher et al., 1991; McDowd and Oseas-Kreger, 1991, Stoltzfus et al., 1993). Logan and Balota (2000) provided another example of inhibitory control deficits that may be related to increased blocking in older adults. In this study, based on a paradigm devised by Smith and Tindell (1997), orthographically overlapping prime words are presented prior to a word fragment completion task (e.g. the prime word "ANALOGY" presented before the target fragment "A _ L_ _ G Y"). Logan and Balota found that the interfering prime word blocked or hindered retrieval of the target word ("ALLERGY"), an effect that was especially pronounced in older adults. This effect, according to the authors, is attributable to competing sources of spreading activation that are particularly difficult for older adults to control.

Another phenomenon in which inhibition may play a key role in memory blocking resembles the interference from the interlopers or "ugly sisters" mentioned earlier and is known as the "part-set cueing" effect. In part-set cueing, participants encode and retrieve lists of words, but are provided with some retrieval cues that are related to a previously studied word. The part-set cueing effect is the finding that provision of these retrieval cues inhibits or blocks retrieval of the target word, rather than enhances it (e.g. Slamecka, 1968; Roediger, 1974; Sloman et al., 1991). If older adults' inhibitory processes are relatively less efficient, resulting in a greater susceptibility to interference, might they show a greater part-set cueing effect than younger adults? Unfortunately, there are few studies that have explored this issue. Dolan et al. (2002) found that older adults recalled fewer remaining list items than did younger adults when given as few as three study items as cues, thereby demonstrating a relatively greater part-set cueing effect. Hultsch and Craig (1976), however, found a part-set cueing effect in younger but not in older adults, suggesting that the older participants were less

susceptible to recall inhibition. Clearly, these conflicting results prompt the need for further research into aging aspects of this phenomenon.

Inhibition may also play a prominent role in a phenomenon somewhat similar to part-set cueing. In this situation, the act of retrieving a studied item can inhibit subsequent recall of related items, a phenomenon referred to as *retrieval-induced forgetting* (e.g. M. C. Anderson et al., 1994; M. C. Anderson and Spellman, 1995). Age differences in such retrieval inhibition have been examined in list-learning studies that showed relatively intact blocking or suppression of non-retrieved items among older adults (e.g. Moulin, 2000). The phenomenon has also been examined in a paradigm involving more complex events such as reviewing photographs depicting events that participants themselves had performed (Koutstaal et al., 1999b). Here again, older adults' memory for non-reviewed events was diminished to a degree similar to that shown by younger adults, supporting the notion that this type of inhibition-induced blocking is relatively intact in advanced age.

In addition to part-set cueing and retrieval-induced forgetting, age equivalence in inhibitory control has been found in other tasks as well. For example, older adults appear as capable as younger adults in suppressing distractors in a spatial location task (Connelly and Hasher, 1993). In this study, younger and older adults were equally slowed in identifying a target stimulus (an "O") in a location that had just been occupied by a distractor (a plus sign), indicating equivalent response suppression in the two age groups. In addition, older adults show no deficits compared to the young when suppressing information that was unconsciously processed and not brought to conscious awareness (Holley and McEvoy, 1996), and actually show an increase compared to younger adults in repetition inhibition (i.e. the *Ranschburg effect*) (Maylor and Henson, 2000). Why then, should such tasks produce no age deficits while age impairments in inhibitory processes are found in other situations, such as garden-path sentences, the directed-forgetting paradigm, and various other tasks? In the latter examples, prior information that was recently relevant is maintained in a relatively accessible state, even though subsequent information or events may have rendered this information irrelevant or even incorrect (Koutstaal et al., 1999b). As Radvansky and Curiel (1998) have suggested, such prior information is both "strong," meaning that it is present at or near the focus of attention, and "wrong," meaning that it is contradictory, inappropriate, or both to current processing goals. Such strong and wrong information places a larger demand on suppression processes, thereby increasing the likelihood of observing an age difference in performance. Conversely, inhibitory tasks that involve automatic suppression of information, such as suppression of non-retrieved items in retrieval-induced forgetting, would be expected to show minimal age differences. Using a retrieval-induced forgetting task, for example, Moulin et al. (2002) found similar levels of inhibition in normal older adult controls and Alzheimer's disease (AD) patients, suggesting that inhibition in this task is automatic. Moulin et al. further suggested that inhibition is a multi-faceted, rather than a unitary construct.

There exists little neuroimaging evidence concerning retrieval blocking, and none of it addresses blocking in older adults. Neuroimaging studies of the TOT phenomenon, perhaps the most common form of blocking, have been difficult to

conduct because of the relative infrequency of TOT states. Maril et al. (2001) used event-related fMRI to assess neural activity in younger participants who were attempting to answer general knowledge questions. Results showed that attempted retrieval accompanied by a TOT report was associated with selective activation in the anterior cingulate cortex and right prefrontal cortex, two areas that have been posited as components of a cognitive control system that mediates conflict resolution (Cohen et al., 2000; MacDonald et al., 2000). According to Maril et al., these cognitive control mechanisms may be recruited in an attempt to resolve the TOT induced conflict; impairment of such mechanisms may, therefore, underlie age-related differences in the TOT experience. TOT reports in younger adults are often accompanied by activation of partial information about the sought for target (e.g. the first letter or number of syllables). Older adults, as mentioned earlier, tend to report little partial information about the target and often describe their experience as "drawing a blank" (Cohen and Faulkner, 1986; Burke et al., 1991). The TOT state experienced by older adults, therefore, may be attributable to impairment of the processes associated with conflict detection and retrieval monitoring. Based on Maril et al.'s results, it might be predicted that older adults would show less activation in anterior cingulate and right prefrontal areas during a TOT experience. Evaluation of this prediction awaits future neuroimaging studies of older adults.

2. Sins of commission

2.1. Misattribution

Of the seven sins of memory, perhaps none has been examined in older adults as extensively as misattribution, an error of commission in which some form of memory is present, but is misattributed to an incorrect place, time or person (e.g. Jacoby et al., 1989b; Johnson et al., 1993; Schacter et al., 1998a). It is useful to classify misattribution into three types (Schacter, 1999). The first occurs when one correctly remembers an item or fact from a past experience, but misattributes the item to an incorrect source. This type of memory error is especially prevalent in elderly adults, who have been shown to have difficulty processing contextual information (Burke and Light, 1981; Spencer and Raz, 1995; Light, 1996). For example, older adults have more difficulty than the young in remembering whether information was presented auditorily or visually (Kausler and Puckett, 1981a), in lower or upper case letters (Kausler and Puckett, 1980, 1981a), in a particular color (Park and Puglisi, 1985), or by a male or female presenter (Kausler and Puckett, 1981b).

Source misattributions among elderly adults have been demonstrated in a variety of situations. For instance, Schacter et al. (1997b) found that older adults were prone to confuse whether they had seen an everyday action in a videotape or only in a photograph viewed several days later. Older adults are also more likely to have difficulty remembering which of two speakers presented various information (Schacter et al., 1991), particularly when the speakers are perceptually similar (Ferguson et al., 1992; Johnson et al., 1995). Even when they are permitted

additional study exposures to information in order to improve their memory, elderly adults still exhibit impairment at remembering the specific person who presented the information as well as contextual details such as the person's gender (Simons et al., submitted).

Not only do older adults tend to confuse external sources of information more than younger adults, they also tend to have difficulty discriminating between certain events they perceive versus those they just imagine; that is, they have difficulty with reality monitoring (cf. Johnson and Raye, 1981). For example, Henkel et al. (1998) found that older adults had more difficulty than their younger counterparts in remembering which of two perceptually similar objects (e.g. a lollipop and magnifying glass) had been actually perceived or just imagined. Age differences in reality monitoring have also been found in everyday activities such as packing a picnic basket (Hashtroudi, Johnson, and Chrosniak, 1990), possibly because of older adults' tendency to focus on thoughts and feelings at the expense of perceptual aspects of information. According to these authors, this tendency in older adults may arise from a breakdown in inhibitory mechanisms that limit the entrance of irrelevant information into working memory (cf. Hasher and Zacks, 1988). This breakdown, coupled with an increasing importance older adults place on personal experiences and values, may allow personal information such as thoughts and feelings to interfere with retrieval of other contextual information.

The type of source misattribution error described above can have serious consequences in older adults. For example, breakdowns in reality monitoring can lead to confusion regarding whether one has taken prescribed medication or just thought about doing so. In addition, source confusions involving face recognition have important implications for eyewitness testimony. To the extent that older adults mistakenly identify a person who was actually seen in another context, together with their increased tendency to base face recognition judgments more on a general sense of familiarity (Bartlett and Fulton, 1991; Bartlett et al., 1991), the veracity of older adults' eyewitness testimony is brought into question.

A second type of misattribution error is characterized by an absence of any subjective experience of remembering. For example, a spontaneous thought or idea is sometimes misattributed to one's own imagination, when in fact, the thought or idea was encountered in a prior experience (e.g. Schacter, 1987). This inadvertent plagiarism or *cryptomnesia* (e.g. Brown and Murphy, 1989; Marsh and Landau, 1995) is characterized by a lack of awareness of the prior encounter. Although cryptomnesia has not been studied extensively in older adults, age differences have been found in a related misattribution error known as the "false fame effect" (Jacoby et al., 1989a). In this phenomenon, participants first read a list of non-famous names that they are told are non-famous. Later, participants are shown a list containing some of these non-famous names (e.g. Sebastian Weisdorf), along with famous names (e.g. Ronald Reagan) and new non-famous names, and are asked to make fame judgments for each name. The tendency to rate the old non-famous names as famous more than new non-famous names is the false fame effect, arising presumably because the increased familiarity of the old non-famous names is not consciously opposed by recollection that these names are, indeed, non-famous (Jacoby et al., 1989a).

Older adults have been shown to be especially susceptible to the false fame effect (e.g. Dywan and Jacoby, 1990; Jennings and Jacoby, 1993), due to deficits in recollective processes along with familiarity processes that are relatively intact (Jacoby et al., 1996). Age-related increases in the false fame effect have been shown with faces as well as names (Bartlett et al., 1991). It should be noted, however, that these age deficits in spontaneous source monitoring (i.e. monitoring source information in the service of another task) have been shown to essentially disappear when stricter decision criteria are used during the source-monitoring test (Multhaup, 1995).

A third type of misattribution error occurs when one falsely recalls or recognizes an event that never happened. Although false memory research can be traced back at least to Bartlett (1932), who first demonstrated the reconstructive nature of memory, recent studies of such phenomena have focused primarily on a method pioneered by Deese (1959) and later modified and popularized by Roediger and McDermott (1995). In the Deese/Roediger-McDermott paradigm, participants are given a series of word lists containing words highly associated to a critical ''theme'' word that is not presented. For example, participants may hear or see a list composed of *thread*, *pin*, *eye*, *sewing*, *thimble*, and other words that converge on the non-presented word *needle*. On a later recall test, Roediger and McDermott reported that participants frequently intruded the critical theme word. Even more striking was the finding that on a subsequent recognition test, participants made false alarms to the critical lures at an astonishing rate (65%–80%). Indeed, false alarms rates to the critical lures were indistinguishable from the hit rates to the actual presented words.

This phenomenon has been studied extensively in older adults (Norman and Schacter, 1997; Tun et al., 1998; Balota et al., 1999; Kensinger and Schacter, 1999). These studies have provided some evidence for age-related increases in false alarm rates to the critical lures, along with false recall rates that are similar, if not slightly greater, than those shown by younger adults. This increased false memory effect in older adults has several potential explanations. One possibility is based on the notion of ''implicit associative responses'' – the idea that the non-presented critical lure is generated, either consciously or covertly, at the time of study in response to associated words (Underwood, 1965). According to this account, false recognition stems from a failure of reality monitoring, (i.e. a source confusion), where people cannot recollect whether they saw or heard the word at study or generated it themselves (Schacter et al., 1998a). Because of the source-monitoring deficits previously discussed, older adults would appear to be especially susceptible to false recognition of the critical theme words.

Another possibility for elevated false recognition levels in older adults is that they are impaired in their recollection of distinctive, item-specific information. Therefore, older adults rely more heavily than younger adults on memory for the general semantic features of the studied items or their ''gist.'' Koutstaal and Schacter (1997a) provided support for this gist-based account by presenting materials for which source confusions would be highly unlikely. These materials consisted of detailed colored pictures from various categories intermixed with unrelated pictures. When given a recognition test three days later, older adults showed considerably higher levels of false recognition to non-presented pictures from studied categories than did

younger adults. This age difference in false recognition was greatest for categories in which a large number of exemplars (18) had been presented for study, with older adults showing approximately twice as many false alarms (60–70%) as younger adults (25–35%). Koutstaal and Schacter suggested that presentation of numerous perceptually and conceptually similar pictures likely increased reliance on memory for the general features or gist of target items in the older adults compared with younger adults who were able to rely more on item-specific recollection of the studied items. Other relevant evidence has been offered supporting a gist-based account of age-related false recognition (e.g. Tun et al., 1998; Kensinger and Schacter, 1999; Koutstaal et al., 1999a).

Given this presumed greater reliance on gist-based responding by older adults and its deleterious effects on false recognition, are there manipulations that can reduce such responding and false recognition? One possibility involves the notion of developing non-overlapping representations of the study items (O'Reilly and McClelland, 1994; McClelland et al., 1995; Schacter et al., 1998a); that is, manipulating encoding conditions to enhance the availability of item-specific or distinctive information for reducing false memories. For example, Koutstaal et al. (1999) attempted to reduce the level of false recognition in older adults in the categorized pictures paradigm through the use of distinctive verbal elaborators at encoding – instructions that called attention to several perceptual and differentiating features of the object, which participants were then asked to notice during subsequent presentation of the object. In this item-by-item scrutiny during test, participants were asked to distinguish between objects that were in some way similar to ones encountered earlier and those that were entirely new, thereby discouraging the use of a gist-based strategy. In each case, additional encoding or retrieval support benefited older adults (in comparison with older controls who received no support). However, despite reduced false recognition in the older adults resulting from these instructional manipulations, their false recognition levels remained above those of the younger adults, even when encouragement to attend to differentiating features of objects was given at both encoding and retrieval. Apparently, more careful scrutiny of items can be beneficial to older adults, but does not eliminate their greater willingness to respond on the basis of general similarity information. It should be noted that findings showing age differences in face recognition (e.g. Bartlett and Fulton, 1991; Bartlett et al., 1991) can also be interpreted as supporting the tendency of older adults to rely on general similarity or resemblance in making recognition judgments.

Another example of distinctive encoding manipulations designed to reduce false recognition in older adults has been highlighted by Schacter and his colleagues. These studies follow the findings of Israel and Schacter (1997), who employed a distinctive encoding manipulation in the converging associates paradigm to reduce false recognition in younger adults. In this manipulation, black and white line drawings accompanied the words in one of the conditions, whereas in the other condition, words were presented alone. False recognition was substantially reduced in the distinctive (pictures plus words) condition compared to the "words-only" condition. Schacter et al. (1999) suggested that false recognition suppression in the

picture condition reflected participants' use of a *distinctiveness heuristic*: a mode of responding in which participants demand access to distinctive pictorial information before they are willing to call an item "old." Consequently, the absence of memory for such distinctive information induces participants to call an item "new." Using the same methodology with older adults, Schacter et al. (1999) demonstrated a strong reduction in false recognition responses for words accompanied by distinctive pictorial information relative to a condition in which words were presented alone. These results strongly suggest that older adults can suppress false recognition of semantic associates when using a distinctiveness heuristic. When other mechanisms are involved, however, older adults may fail to show normal suppression. For example, Kensinger and Schacter (1999) employed a method in which lists of semantic associates were presented and tested multiple times. Compared to a single study/test trial, Kensinger and Schacter found that false recognition of critical lures in younger participants was greatly reduced after five study/test trials. Older adults, however, failed to show any false recognition suppression after multiple study/test trials. Benjamin (2001) has extended these findings to a paradigm in which study trials are repeated but test trials are not. These results provide further evidence that older adults are more reliant on general similarity information or gist influences than are younger adults and have less item-specific recollection than younger adults (see Schacter et al., 1998b for a somewhat similar result in amnesic patients).

Absence of false recognition suppression in the Kensinger and Schacter (1999) study mirrors results obtained by Jacoby (Jacoby, 1999a; see also Jacoby, 1999b). Jacoby instructed participants to respond "yes" to words they had heard earlier and "no" to words they had seen earlier, with the read words having been presented multiple times. Although, repetition allowed younger adults to decrease false alarms to words read earlier, older adults demonstrated an opposite effect – false alarms increased as a function of repetition. Older adults apparently fail to use item-specific recollection that accrues from repetition of the study items to reject previously studied words, just as they fail to use repetition of target items in the Kensinger and Schacter (1999) paradigm to reject non-studied but related lure words.

Cognitive neuroscience has begun to make inroads into our understanding of misattribution. Several recent studies examined patterns of neural activity in younger adults using the Deese/Roediger and McDermott false recognition paradigm. Schacter et al. (1996b) investigated false recognition with PET, and Schacter et al. (1997a) and Cabeza et al. (2001) did so again with fMRI. In all three studies, participants heard lists of semantic associates prior to scanning, although in the Cabeza et al. study, participants watched a videotape in which the words were spoken by one of two speakers. Participants were later scanned while they made old/new judgments about previously studied words, the strongly associated critical lures, and unrelated lure words. The main finding from the Schacter et al. (1996b) and Schacter et al. (1997a) studies is that patterns of brain activity were similar for both true and false recognition, with some trends for differences. Cabeza et al. (2001), however, found a dissociation between two regions of the medial temporal lobe as a function of the type of information retrieved. Activity in the hippocampus was similar for true

and false items, suggesting that this area is involved in the recovery of semantic information. By contrast, activity in the parahippocampal gyrus was greater for true than for false items, suggesting this area's role in the recovery of perceptual or sensory information.

In all three studies, frontal lobe activation was quite prominent during both true and false recognition, suggesting that frontal regions may be involved in strategic monitoring processes that are invoked when participants attempt to determine whether a related lure word was actually presented earlier at study. These findings mesh well with recent neuropsychological evidence that damage to frontal regions is sometimes associated with increased false recognition (Parkin et al., 1996; Schacter et al., 1996a; Rapcsak et al., 1999). The findings are particularly relevant when addressing misattribution errors in older adults. As previously discussed, impaired source monitoring, which underlies many errors of misattribution, appears to be especially pronounced in older adults. One popular hypothesis concerning age-related deficits in source monitoring focuses on the role of the frontal lobes, with these deficits presumably arising from reduced frontal lobe integrity as a function of aging (Craik et al., 1990; Schacter et al. 1991; Glisky et al., 1995). This hypothesis is supported by structural findings indicating that the frontal lobes are differentially affected by aging (for reviews, see West, 1996; Raz, 2000). Despite the popular notion that frontal lobe impairments underlie age-related deficits in the processing of source or contextual information, it should be noted that much of the supporting evidence has been correlational in nature (e.g. Craik et al., 1990; Glisky et al., 1995).

More direct evidence has been provided by age-related source-monitoring studies using event-related potentials (ERPs). For example, Dywan et al. (2002) measured ERPs in younger and older adults in a repetition-lag paradigm (e.g. Jacoby, 1999a) in which successful rejection of new repeated test items required recollection of the item's context. Using an "exclusion" task (Jacoby, 1996), Dywan et al. found that older adults were much more likely than younger adults to misattribute the familiarity of the repeated new words to the study list, thereby replicating previous findings (e.g. Jacoby, 1999a; Dodson and Schacter, 2002). Furthermore, older adults generated ERP waveforms during the exclusion task that were significantly greater in amplitude at frontal sites than those of younger adults, suggesting to the authors that older adults are less able to quickly or automatically suppress the cortical response to items that are not targets, but are familiar due to repetition. Consequently, older adults must rely more heavily on controlled processes to make these types of source-monitoring decisions. Further direct evidence linking source-monitoring deficits in older adults to frontal functioning was provided in a recent PET study by Cabeza et al. (2000) who examined neural activity in younger and older adults when they were asked to identify which words had appeared in a prior list (item retrieval) or when words occurred within the list (temporal-order retrieval). In the younger participants, right prefrontal regions were activated more during temporal-order retrieval than during item retrieval. In contrast, the older participants did not show this asymmetrical pattern, suggesting that age deficits in context memory are due to frontal dysfunction. Future neuroimaging studies should investigate other types of

context or source memory in older adults to provide additional insights into their increased susceptibility to misattribution errors. In particular, direct investigation of frontal lobe activity during the encoding of item and contextual information is important in light of recent neuropsychological evidence suggesting that only a subset of older adults demonstrate source-monitoring deficits (Glisky et al., 2001). According to Glisky et al., impaired source monitoring is not a direct result of aging per se, but rather the result of reduced frontal lobe functioning which is found in a subset of elderly adults. Those individuals appear deficient in initiating the processes necessary to integrate item information with its context during encoding. Future neuroimaging studies are needed to confirm this hypothesized link between reduced frontal lobe activity in older adults and impaired item/context integration, particularly with regard to the suggestions of other researchers who have linked reduced item/context binding in older adults to impaired medial temporal lobe functioning (e.g. Chalfonte and Johnson, 1996; Henkel et al., 1998).

2.2. Suggestibility

Misattribution errors occur when an event or item is perceptually or conceptually similar to a previous one; errors that appear to be especially pronounced in older adults. False memories of entire events may also arise from suggestions that are made when one is attempting to recall an experience that may or may not have occurred. Suggestibility in memory refers to an individual's tendency to incorporate misleading information from external sources into one's personal recollection of an event (Schacter, 2001). These external sources may be other people, written materials or pictures, or even the media. Because the transformation of suggestions into false memories requires misattribution, suggestibility and misattribution are closely related. However, misattribution often occurs in the absence of suggestions, making suggestibility a distinct sin of memory. Given that they are increasingly prone to committing misattribution errors, it is natural to ask whether older adults are also more likely to fall victim to suggestibility. This question is of particular importance from a legal standpoint due to concerns that elderly individuals may lack credibility as eyewitnesses (for reviews, see Bornstein, 1995; Yarmey, 1996). In addition, an increased tendency on the part of senior adults to accept misinformation may make them especially susceptible to certain fraudulent schemes practiced by con artists (Jacoby, 1999).

To experimental psychologists, perhaps the most familiar example of suggestibility comes from the work of Loftus and colleagues concerning the effect of misleading post-event information on memory distortions (e.g. Loftus et al., 1978). In the classic studies of Loftus and colleagues (for a review see Loftus et al., 1995), experimental participants first viewed a slide sequence depicting an automobile accident in which a car stopped at a stop sign. Later, some of the participants were asked what happened after the car stopped at a yield sign. Compared to participants who received no misleading questions, the misled group was more likely to mistakenly claim that it had seen a yield sign. Explanations for this "misinformation effect" have been

controversial, although most studies acknowledge that source misattributions play an important role (e.g. Lindsay, 1990; Belli et al., 1992; Zaragoza and Lane, 1994).

Older adults' susceptibility to misleading post-event information has been examined in a number of studies (e.g. Cohen and Faulkner, 1989; Loftus et al., 1992; Coxon and Valentine, 1997; Karpel et al., 2001). Cohen and Faulkner (1989), for example, showed a film of a kidnapping to younger and older adults and then had them read a narrative concerning the film. Compared to a misled younger group, older adults who read an account containing misleading information were more likely to claim that this information had been originally witnessed in the film. Loftus et al. (1992) employed a similar method and also found that older adults were more likely to accept misleading suggestions concerning an event witnessed earlier. However, Loftus et al. found that the older adults also showed much less accurate more for non-misleading items than did the younger age group. This finding suggests that poor memory may prevent older adults from detecting a discrepancy between the post-event information and the original event, thereby making them more likely to be influenced by misleading suggestions.

The notion that age differences in suggestibility are attributable to overall differences in levels of memory is termed the trace strength hypothesis (e.g. Brainerd and Reyna, 1988). Brainerd and Reyna suggested that weak memory traces that result from inadequate learning or accelerated forgetting make the acceptance of misleading post-event information more likely. The results of the Loftus et al. (1992) study appear to support the trace strength hypothesis. However, Loftus et al. did not conduct a correlational analysis on individual scores. It is therefore possible that the older adults who were the most suggestible were not also the least accurate on the non-misleading questions (cf. Coxon and Valentine, 1997). To directly test the trace strength hypothesis, Coxon and Valentine (1997) examined the suggestibility of children, young adults, and elderly adults in a misinformation paradigm and found no relationship between recall accuracy and susceptibility to misleading information. These results, therefore, seem to refute the trace strength hypothesis (but see Marche et al., 2000; Karpel et al., 2001).

As previously discussed, source-monitoring impairments may play an important role in the sin of suggestibility, reflecting the reconstructive nature of memory (e.g. Bartlett, 1932; Bransford and Johnson, 1973). Because of older adults' well-established problems with recollecting the source of their memories (e.g. Schacter et al., 1997c), it is reasonable to assume that these source-monitoring deficits make seniors increasingly likely to accept misleading information (Karpel et al., 2001). However, it is also of interest whether older adults can avoid suggestibility effects under certain conditions, as has been demonstrated in younger adults. For example, Lindsay and Johnson (1989) used a misinformation technique with younger adults in which half the participants received a standard yes/no recognition test for items in the original event. The remaining half of the participants were administered a source-monitoring test in which they were asked to classify items as having been seen in the original event (a picture), the subsequent narrative text, both sources, or neither (i.e. a new item). Participants given the standard yes/no recognition test displayed the typical suggestibility effect; those who had read the misleading

text attributed more suggested items to the picture than those who had not been given misleading information. Conversely, the misled participants given the source-monitoring test displayed no suggestibility effect, prompting Lindsay and Johnson (1989) to claim that the source-monitoring test encouraged participants to more carefully examine the information used to make a recognition decision, thereby reducing the suggestibility effect. That is, the source-monitoring test encouraged participants to adopt stricter decision criteria when making source attributions (Johnson et al., 1993).

Multhaup et al. (1999) used a similar method to examine whether older adults would exhibit a reduction in the suggestibility effect, given that adoption of stricter decision criteria through careful source monitoring has been shown to reduce older adults' source misattributions in the false fame paradigm (Multhaup, 1995). Multhaup et al.'s results were as predicted; older adults given a source-monitoring test failed to show the suggestibility effect, in contrast to participants given a yes/no test, who did show the effect. Suggestibility, therefore, may be reduced in older adults when they more carefully consider the source of the misleading information.

In addition to the encoding strength, source-monitoring, and discrepancy detection explanations discussed thus far, Karpel et al. (2001) have suggested that older adults may be relatively more susceptible to the suggestibility effect because of impairments in feature memory and binding (Chalfonte and Johnson, 1996). Because of the difficulty in distinguishing these alternative hypotheses on an empirical level, Karpel et al. argued for a parsimonious explanation based on non-specific (i.e. process-general) effects of age-related memory on suggestibility. Clearly, however, further research is needed to test the relative contributions of these different memory processes.

Despite the theoretical and applied importance of suggestibility, no neuroimaging studies have examined it in any age group. However, as Schacter (2000) has suggested, one possible approach, at least in younger adults, would be to investigate individual differences in suggestibility, building on previous PET studies that have correlated across-individual differences in various behavioral performance levels with patterns of blood flow (e.g. Kosslyn et al., 1996; Nyberg et al., 1996; Alkire et al., 1998). For example, Hyman and Billings (1998) showed that young adults who scored highly on various scales presumed to measure suggestibility were more likely to create false memories of a childhood event. Schacter (2000) proposed that through the use of such a procedure, highly suggestible individuals could be identified who might show reliable differences in brain activity associated with cognitive processes engaged during autobiographical retrieval. It might be possible to identify neural activity that distinguishes between acceptance of misleading post-event information and the correct rejection of such information. Such neural patterns of activity may mirror those found on certain source-monitoring tasks, which would provide further support to the source-monitoring account of age-related increases in suggestibility and would conflict somewhat with Karpel et al.'s (2001) hypothesis that such increases are attributable to non-specific effects of aging.

2.3. Bias

Not only is memory affected by suggestion, it can also be influenced and even distorted by present knowledge, beliefs, and expectations (i.e. schemas; for a review, see Alba and Hasher, 1983). Likewise, recollections of past experiences can be colored by one's current mood and emotional state (Bower, 1992; Ochsner and Schacter, 2000). These distorting influences of current knowledge, beliefs, and feelings on memory for a previous event are referred to as bias (Schacter, 1999, 2001). Biases in recollection have been observed in younger adults in several domains (for reviews, see Dawes, 1988; Ross, 1989; Ross and Wilson, 2000). One of the most common examples of this memory error is the operation of a consistency bias in retrospection, referring to the tendency to exaggerate the consistency between one's past and present attitudes, beliefs, and feelings (e.g. Marcus, 1986; McFarland and Ross, 1987; Levine, 1997; Scharfe and Bartholomew, 1998).

Although very little is known about the operation of such biases in older adults, there are reasons to suspect that increased age may be associated with an increased tendency to bias recollections of past experiences. As Mather and Johnson (2000) have pointed out, older adults are more reliant than their younger counterparts on categorical or schematic information when making source attributions. For example, Hess and Slaughter (1990) found that older adults are more likely than younger adults to falsely recognize objects in a visual scene if those objects were considered likely to have been presented in the scene (e.g. a sink in a kitchen scene). Conversely, older adults were less likely than the young to correctly identify a previously presented object if that object was not typically associated with the scene (e.g. a television in a kitchen scene). In a similar vein, Mather et al. (1999) reported that elderly adults were more likely than younger adults to misattribute the statement, "I was the editor of the paper in high school," to someone who had been previously described as a writer, when in fact the statement had come from a different speaker. When statements were speaker consistent, however, older adults were just as accurate as the young. This greater reliance on stereotypes or other general knowledge when attempting to remember an event may be less effortful (i.e. less cognitively demanding) for older adults than reliance on other types of information, making this bias especially likely to occur (Mather and Johnson, 2000).

Another type of bias that has been explored in older adults involves what Mather and Johnson (2000) have termed choice-supportive asymmetries, describing peoples' tendency to remember the choices they make in a fashion that minimizes negative feelings or regret (Mather et al., 2000). In particular, choice-supportive source monitoring involves attributing (and misattributing) more positive features to the options one chooses and, conversely, attributing (and misattributing) more negative features to the options forgone. To investigate whether older adults are more inclined to engage in choice-supportive source monitoring, Mather and Johnson (2000) presented older and younger adults with various scenarios for which they were asked to make choices (e.g. between two houses or two job candidates), with each option containing both positive and negative features. Participants were asked to review how they felt about the options they chose, to simply review the details of their

decisions, or to perform an unrelated filler task. When later instructed to attribute features to the options, older adults attributed significantly more positive features to the options they chose than to the ones they had forgone. Younger adults displayed a similar pattern of choice-supportive source monitoring in the affective review condition, but were less inclined to display the bias in the other two conditions. Furthermore, these age differences persisted even when both age groups were equated on recognition accuracy and identification of source. These results suggest that when people focus on emotional aspects of a past event, their recollections of the event may be biased in an emotionally gratifying direction. As Mather and Johnson (2000) point out, older adults may be more motivated to regulate their emotions than younger adults (for reviews see Blanchard-Fields, 1997; Labouvie-Vief, 1997; Carstensen et al., 1999), making them more likely to engage in choice-supportive source monitoring, a bias that may help them avoid disappointment and regret.

Yet another form of bias that has been examined in older adults refers to the subtle influences of past experience on current judgments about other people or groups. For example, the *fundamental attribution error* (Heider, 1958; Ross and Nisbett, 1991) is the tendency to overestimate the extent to which the outcome of an event is attributable to internal, dispositional factors and to underestimate the contribution of external, situational factors (see Gilbert and Malone, 1995 for a similar construct termed the *correspondence bias*). Several studies have examined age differences in such dispositional biases, with conflicting results. Blanchard-Fields (1996) reported that older adults were more likely than younger adults to attribute the causes of certain events to dispositional factors, but only when the events involved negative relationship situations. Furthermore, there was significant variability within the negative scenarios – some situations produced age differences in attributions, while others did not. Follett and Hess (2002) investigated the fundamental attribution error in young, middle-aged, and older adults, and found that the younger and older groups were more prone to the bias than the middle-age group. These authors suggested that age-related differences in this bias may stem from two factors: (1) variations in the complexity of thought processes hypothesized to underlie the process of attribution (e.g. dialectical thought, preference for complex explanations for events), and (2) reduced cognitive resources in older adults that may reduce their tendency to consider situational factors and make attributional adjustments. However, as Blanchard-Fields (1999) points out, it is important to include other factors when discussing age differences in attributional processes. That is, factors such as stereotypes, schematic beliefs and values, and motivational goals need to be considered along with cognitive processing variables if we are to better understand how this aspect of social cognition changes as we age.

Also of interest in the domain of biases are automatic influences that may bias older adults' assessments of other people. Evidence exists that automatic processes used to make social-cognitive judgments are relatively spared in older adults, whereas mechanisms that rely on controlled processes are impaired (Hess and Follett, 1994; Hess et al., 1996). Hess et al. (1998) examined age differences in the effect of previously activated trait information on judgments about people. Participants were first exposed to a series of positive or negative trait terms in a

memory task, and then performed an ostensibly unrelated task in which they were asked to form an impression of a target person while reading a description of his behavior. Hess et al. found that older adults were more likely to form impressions of the target person that were biased toward the previously primed traits, whereas younger adults demonstrated greater awareness of the primed traits and were more likely to correct for the impact of the primes, especially when the source of the priming influence was made available through distinctive contextual cues. These results suggest that in certain situations, such as those involving common advertising schemes, older adults may be more susceptible to unintended influences or biases, particularly with regard to their diminished ability to identify the source of the bias and counteract it (Hess et al., 1998; Hess, 1999).

In a similar vein, von Hippel et al. (2000) found that older adults relied on stereotypes more, and were more prejudiced, than younger adults when evaluating a target person that had been previously described in a certain way (i.e. a student athlete named Jamal or an honors student named John). Compared to young adults, older adults rated John as relatively more intelligent and Jamal as relatively less intelligent. Furthermore, this greater reliance on stereotypes in the elderly adults remained even when they were instructed to ignore the background information on the target individual. von Hippel et al. also found that older adults had more difficulty on an inhibition task, suggesting that along with the historical periods in which older adults came of age, inhibitory deficits also contribute to their greater tendency than younger adults to rely on stereotypes and to be racially biased.

Bias in older adults has been shown to extend even to attitudes toward their own age group. Hummert et al. (2002), for example, recently measured non-conscious or implicit social cognition regarding aging in young adults and two sets of older adults (young–old and old–old). Using an instrument designed to measure attitudes and stereotypes indirectly (the Implicit Association Test; Greenwald, McGhee, and Schwartz, 1998), Hummert et al. found that the old–old participants were actually more biased in favor of youth (and against old age) than were the young participants. Similar findings were reported by Nosek et al. (2002) who collected thousands of responses from respondents who completed the Implicit Association Test at an Internet web site. Although older respondents were more positive toward old relative to young when explicit attitudes were measured, their implicit attitudes revealed a strong negative bias toward old age that was equivalent to that shown by younger respondents. The results of these two studies suggest that an implicit bias toward youth and against old age exists in individuals of all ages. This widespread bias is not surprising when considering that younger and older adults share similar stereotypes regarding aging (e.g. Brewer and Lui, 1984; Hummert et al., 1994; Hummert, 1999).

As with suggestibility, neuroimaging has contributed very little evidence to the study of retrospective biases or the subtle biases inherent in social cognition. Indeed, with respect to many of the retrospective biases typically examined in psychological studies, the long temporal intervals between assessing what people know or believe at Time 1 and the later recollection of what people knew or believe at Time 2 make neuroimaging impractical (Schacter, 2000). However, some of the retrospective biases discussed earlier, which involve much shorter time intervals, may be tractable

from a neuroimaging perspective, particularly with regard to aging. For example, the previously discussed work of Mather et al. (1999) may present an especially appropriate way to investigate the neural substrates of bias in older adults.

Mather et al. (1999) examined neuropsychological correlates of stereotype reliance in older adults. These authors found that accurate source identification of statements that were inconsistent with the speaker who read them, a task that presumably requires extensive reflective activity, was correlated with scores on a battery of neuropsychological tests purported to reflect frontal lobe functioning. In contrast, correct attribution of statements that were speaker consistent, a task requiring much less reflective activity during retrieval, was not correlated with frontal scores. Instead, this schema-consistent source monitoring was correlated with scores on a medial temporal lobe battery. In this situation, correct attributions require both the general encoding of the schema about each person and the initial binding and subsequent reactivation of qualitative characteristics (e.g. emotional expression) that were associated with each speaker; these processes may be dependent on medial temporal lobe functioning (e.g. Squire, 1992; Cohen and Eichenbaum, 1993; Johnson and Chalfonte, 1994; Squire and Knowlton, 1995).

Mather et al.'s paradigm appears to be well suited for use in an fMRI study. In particular, direct evidence of reduced frontal-lobe activity when older adults make incorrect source attributions in a schema-inconsistent situation would support the notion that their susceptibility to certain biases may be attributable to impaired frontal-lobe functioning. Another potential area in which to explore age-related biases from a neuroimaging perspective involves those inherent in implicit social cognition. As we have seen, older adults may be particularly susceptible to automatic influences when making certain social judgments. A potential model for examining such biases in older adults could be provided by neuroimaging research on the phenomenon of priming, a type of implicit memory that involves changes in the processing of an object as a result of recent exposure to the object (Tulving and Schacter, 1990). Neuroimaging studies involving younger adults have shown consistent changes in activity in various cortical regions during priming (for reviews, see Schacter and Buckner, 1998; Wiggs and Martin, 1998). Such neural patterns of activity during priming have also been found in older adults (Bäckman et al., 1997). Perhaps the logic and design of such studies in younger adults could be applied to the investigation of biases in implicit social cognition, with a further extension into the examination of such biases shown by older adults.

2.4. Persistence

The first three of memory's sins – transience, absent-mindedness, and blocking – involve forgetting a fact or event that one wants to remember. We have seen that older adults are especially susceptible under certain conditions to these memory errors. The final sin of persistence, however, refers to remembering a fact or event that one would prefer to forget (Schacter, 1999). Persistence is characterized by intrusive recollections of traumatic events, ruminations over negative events and symptoms, and even by chronic fears and phobias.

We have previously discussed that older adults have difficulty inhibiting or suppressing irrelevant information (e.g. Hasher and Zacks, 1988). Particularly relevant are the findings from directed forgetting tasks, in which older adults appear to be less able than their younger counterparts to inhibit information that they were instructed to forget (Zacks et al., 1996). Given these inhibitory deficits, does it follow that older adults are especially prone to unwanted and potentially disabling memories? Unfortunately, there is little evidence pertaining to this issue. For example, traumatic events tend to be remembered repetitively and intrusively (e.g. Herman, 1992; Krystal et al., 1995) and attempts by traumatized individuals to avoid or suppress such unwanted memories are often unsuccessful (for a review, see Koutstaal and Schacter, 1997b). Experimental evidence to this effect has been provided by McNally, Metzger, Lasko, Clancy, and Pitman (1998) who examined "directed forgetting" of traumatic and non-traumatic words in middle-aged women with post-traumatic stress disorder resulting from documented sexual abuse and matched controls who had a history of sexual abuse but no PTSD. Control participants remembered fewer of the trauma-related words that they were instructed to forget than those they had been instructed to remember. PTSD participants, however, showed no directed-forgetting effect, indicating a loss of cognitive control over the encoding and retrieval of trauma-related material. Although no such studies have been conducted with older adults with PTSD, it may be informative to consider that older adults appear to be no more susceptible to negative psychosocial outcomes following traumatic events than younger adults, and in some instances, appear to cope better than their younger counterparts (Hyer, 1999; Weintraub and Ruskin, 1999). This observation suggests that to the extent that repetitive, intrusive memories contribute to the etiology of PTSD, older adults appear to be no more susceptible to such unwanted memories. Whether those older adults with PTSD also show reduced cognitive control over unwanted, traumatic stimuli remains unknown.

Ruminative tendencies represent another example of persistence with potential clinical significance. Excessive rumination over depressive symptoms is associated with, and can contribute to, the prolonging of depressive episodes (Nolen-Hoeksema, 1991). Furthermore, these ruminative tendencies can enhance the persistence of negative memories in individuals with dysphoric moods (Lyubormirsky et al., 1998). Although little is known about the effects of aging on ruminative tendencies, it appears that older adults are no more susceptible than are younger adults, and perhaps are less so. Knight et al. (2000), for example, examined depressed mood and rumination in several age groups both before and after the 1994 earthquake in the Northridge community of Los Angeles. The oldest adults (76+ years of age) showed better psychological adjustment following the earthquake than the two younger groups, including a lesser tendency to ruminate about the earthquake. Perhaps this reduced tendency to ruminate over negative experiences contributes to the enhanced ability of older adults to regulate their emotions, particularly with regard to the frequency of negative emotions (cf. Gross et al., 1997; Isaacowitz et al., 2000).

Other examples of persistence are less extreme than its occurrence in PTSD and depressed mood. For example, studies by Wegner and associates have shown that instructing people not to think about a particular object or item (e.g. do not think

about white bears) can result in a rebound effect. That is, items that participants are instructed to suppress are subsequently produced at higher rates than are items for which no suppression instructions were given (Wegner and Erber, 1992). Although we know of no data concerning thought suppression in older adults, the age-related deficits in inhibitory control previously discussed might result in reduced thought suppression ability in seniors. If such reductions were found, an interesting prediction follows that older adults would also show a reduced rebound effect.

Our understanding of persistence, at least in younger adults, has been aided by neuroimaging studies showing the importance of the amygdala in persisting emotional memories. For example, Cahill et al. (1996) performed PET scans while participants viewed emotional or non-emotional films. Amygdala activity during viewing of the emotional films was highly correlated ($+0.91$) with later recall of the emotional films, whereas no correlation was observed for recall of the non-emotional films. In a similar vein, a fMRI study conducted by LaBar et al. (1998) found amygdala activation during acquisition and extinction of conditioned fear. There is reason to believe that similar results may be found in older adults. For example, normal aging is associated with only modest reductions in amygdaloid volume (Smith et al., 1999). In addition, memory in older adults benefits from the emotional arousal level of stimuli (Hamann et al., 2000; Kazui et al., 2000). Furthermore, this memory enhancement effect of emotional stimuli is similar in younger and older adults (Kensinger et al., 2002; also see Carstensen and Turk-Charles, 1994).

It could also be informative to use neuroimaging in future aging studies employing the thought suppression paradigms pioneered by Wegner and associates (e.g. Wegner and Erber, 1992). For example, would similar patterns of neural activity, particularly in prefrontal cortex, be observed in younger and older adults during successful suppression of specified thoughts (e.g. thinking about white bears)? Such similar patterns might be expected based on related fMRI research conducted by Nielsen et al. (2002). In their study, which used a task that required younger and older adults to inhibit prepotent responses to repeated letters, successful inhibition in all age groups was associated with activation in right prefrontal and parietal areas. Furthermore, successful inhibition in the older adults was associated with activation in additional areas in the left hemisphere, particularly in left lateral prefrontal cortex. These findings suggest that elders can compensate for declining performance in inhibition tasks by recruiting additional brain regions (Nielsen et al., 2002; also see Cabeza, 2002). Successful performance during thought suppression tasks, likewise, may be associated with a similar pattern of neural activity in older adults, reflecting the need to recruit additional brain regions to reach a performance level equal to that of younger adults (Cabeza, 2002).

2.5. Conclusions

The increasingly large literature on memory changes in older adults has spawned a variety of theoretical frameworks to account for such changes (e.g. Light, 1996).

In this chapter, we have attempted to add to the literature on memory and aging by examining age-related changes from the perspective of a framework in which everyday memory shortcomings are divided into seven basic "sins" (Schacter, 1999, 2001). We discussed each of these from an aging perspective, including recent findings from cognitive neuroscience that have added to our understanding of such errors in older adults. Let us now review some of the main conclusions concerning aging and each of the seven sins.

The sin of transience – the gradual forgetting of facts and events over time – is observed in older adults to varying degrees. Whereas laboratory tasks have demonstrated convincingly that older adults retain new information less well than younger adults, similar memory performance is observed in both age groups for events from more distant periods, including recall of personal autobiographical memories from particularly significant life periods. Likewise, age differences in the sin of absent-mindedness tend to emerge on some tasks but not others. As the work of Einstein and colleagues have shown (e.g. Einstein et al., 2000, 2002), older adults tend to perform well on prospective memory tasks when such tasks can be carried out with minimal delay and with few background activities that are concurrent. Delaying an intention, however, or imposing other resource demanding activities in conjunction with the to-be performed action, increases the probability that older adults will commit absent-minded errors. The sin of blocking, referring to the temporary inaccessibility of information, is a particularly frustrating memory shortcoming in older adults. The tip-of-the-tongue state – the most thoroughly researched example of blocking – occurs more frequently as we age, due perhaps to an age-related reduction in the phonological activation of target words. Other blocking phenomena that occur more frequently in elderly adults may be due to age-related inhibitory deficits, particularly when the information that must be inhibited or suppressed is relatively accessible.

Misattribution represents a class of memory errors that have been well examined in older adults. This error represents a memory distortion in which some form of memory is present, but is misattributed to an incorrect time, place or person. Older adults were shown to be more likely than their younger counterparts to commit such misattributions across a wide range of situations, including recent findings showing that older adults are sometimes susceptible to false recognition errors in the Deese/Roediger-McDermott paradigm. More research is needed to further examine the causes of older adults' propensity for committing such misattributions, including neuroimaging studies that may highlight age-related brain activation differences in encoding and retrieval processes. The sin of suggestibility, which is closely related to misattribution, is also more prevalent in old age. This finding is not surprising, given that the ability to avoid the influence of suggestions requires one to monitor the source of the suggestive inference, a cognitive process that has been shown to be deficient in older adults (cf. Johnson et al., 1993). As was noted, however, older adults can reduce suggestibility through supporting retrieval instructions that help them focus on the source of the suggestion (Multhaup et al., 1999).

The sin of bias has been documented in older adults, including such examples as the consistency bias (e.g. Hess and Slaughter, 1990), choice-supportive asymmetries

(Mather and Johnson, 2000), the fundamental attribution error (e.g. Follett and Hess, 2002), stereotyping (von Hippel et al., 2000), and even implicit biases toward aging itself (e.g. Nosek et al., 2002). Compared with younger adults, older adults are more susceptible to several of these biases in certain situations. In particular, the memories of older adults tend to be biased when they rely on schematic information or other general knowledge when attempting to remember an event – processes that may be less demanding on older adults' cognitive resources. In addition, older adults may be susceptible to certain automatic influences (e.g. stereotypes) when making assessments of others. Because such automatic processing tends to be relatively spared in old age, whereas more effortful, consciously controlled processes are impaired, older adults may prove more vulnerable to certain advertising ploys in which they fail to identify and counteract the source of the biasing influence. Finally, the sin of persistence appears to be a memory shortcoming that is not manifested in older adults to a greater degree than in younger adults. We suggested that the relatively greater ability of older adults to regulate their emotions implies that certain types of persistence (e.g. depressive ruminations) may actually decrease with advancing age. However, more conclusive evidence supporting this conjecture awaits future studies. Furthermore, laboratory research examining more mundane forms of persistence (e.g. thought suppression of innocuous stimuli) in older adults is needed to determine whether suppression of more traumatic memories generalizes to non-emotional events.

Schacter (1999, 2001) suggested that rather than viewing the seven sins of memory as flaws in system design that the course of evolution should have corrected, these memory errors can be viewed as useful by-products of otherwise adaptive features of memory. When discussed from an aging perspective, it may be useful to view the seven sins of memory as adaptations that have been affected by neurological changes in the aging brain. For example, transience may be viewed as a case of adaptive forgetting (cf. Bjork and Bjork, 1988), in that information that is no longer useful should be forgotten. This type of information, such as old phone numbers or where we parked the car yesterday, is no longer needed and will tend not to be retrieved and rehearsed. Such irrelevant information loses out on the strengthening effects of post event retrieval and thereby becomes less accessible over time. With aging, neurological changes, including those affecting encoding processes, may result in accelerated forgetting of recently learned information. By contrast, certain events from more distant periods may be more personally relevant to older adults, and will have been retrieved and rehearsed much more frequently, thereby proving more resistant to transience.

When examining aging aspects of the three sins that involve distortion of prior experiences – misattribution, suggestibility, and bias – similar ideas can be applied. For example, many instances of misattribution, and at least some instances of suggestibility, involve failure to remember the source of an event – the precise details of where we saw a familiar face, who told us a particular fact, or whether we witnessed an event ourselves or only read or hear about it later. When encoding of such details is incomplete, or when they become inaccessible over time, individuals become vulnerable to the kinds of misattributions associated with false recognition or

cryptomnesia, and may also be more prone to incorporating post event suggestions regarding details of an event that is only vaguely remembered. As Schacter (1999) has pointed out, an adapted system would find little need to record specific contextual details of every event that we experience; rather, it would likely retain information that is needed in the environment in which it operates (cf. J. R. Anderson and Schooler, 1991). With advanced age, it may be even less useful to retain the myriad of specific details surrounding our everyday experiences. Furthermore, less efficient neural processes in the aging brain that are involved in the encoding and subsequent retrieval of source-specifying information make it even more likely that older adults will tend to rely on general similarity or gist information when remembering past events. Such reliance on gist at the expense of specific or verbatim information may be a functional strategy for older adults given their diminished cognitive resources, but may make them more vulnerable to certain types of misattribution and suggestibility. Likewise, increased reliance on less cognitively demanding categorical information may make older adults more susceptible to certain biases.

We have seen that cognitive neuroscience has begun to provide information that increases our understanding of these seven memory flaws. Evidence suggests that progressive disruption to the functioning of frontal lobe regions occurs during aging (West, 1996; Raz, 2000), such that older adults show reduced engagement of particular frontal lobe regions, or indeed recruit additional regions, compared with younger adults (Cabeza, 2002; Logan et al., 2002). This frontal lobe disruption may be associated with reductions in the cognitive control of memory processes, to which the memory impairments documented here may be attributable. Future research from a cognitive neuroscience perspective should give us additional insights into how the seven sins of memory are manifested in older adults, including potential neural "signatures" that may identify each type of error in older adults and how such signatures may differ from those found in younger adults. Ultimately, such studies may more clearly identify the basic neural processes involved in the seven sins of memory and how such processes change as we age.

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