
The Seven Sins of Memory

Insights From Psychology and Cognitive Neuroscience

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Though often reliable, human memory is also fallible. This article examines how and why memory can get us into trouble. It is suggested that memory's misdeeds can be classified into 7 basic "sins": transience, absent-mindedness, blocking, misattribution, suggestibility, bias, and persistence. The first three sins involve different types of forgetting, the next three refer to different types of distortions, and the final sin concerns intrusive recollections that are difficult to forget. Evidence is reviewed concerning each of the 7 sins from relevant sectors of psychology (cognitive, social, and clinical) and from cognitive neuroscience studies that include patients with focal brain damage or make use of recently developed neuroimaging techniques. Although the 7 sins may appear to reflect flaws in system design, it is argued instead that they are by-products of otherwise adaptive features of memory.

Question: If Vernon Jordan has told us that you have an extraordinary memory, one of the greatest memories he has ever seen in a politician, would that be something you would care to dispute?

Clinton: No. I do have a good memory. At least I have had a good memory in my life . . . It's also—if I could say one thing about my memory—I have been blessed and advantaged in my life with a good memory. I have been shocked and so have members of my family and friends of mine at how many things that I have forgotten in the last six years—I think because of the pressure and the pace and the volume of events in a president's life, compounded by the pressure of your four-year inquiry, and all the other things that have happened.

When President Clinton testified before Kenneth Starr's grand jury, his numerous lapses of memory prompted investigators to query him about his reputation for prodigious recall. The logic implicit in their question, later articulated explicitly by Starr in his own testimony to the House committee investigating impeachment charges, seems clear: How could someone with such a seemingly exceptional memory forget as much as Clinton did about the details of his encounters with Monica Lewinsky? Starr's lawyers were, to put it mildly, suspicious about the self-serving aspects of Clinton's failures to recall potentially damning incidents and statements. Although their skepticism may indeed be warranted, the contrast between Clinton's reputation for extraordinary memory on the one hand, and his claims of sketchy recollections for his encounters with Lewinsky on the other, also illustrates a fundamental duality of memory.

I have previously referred to this duality as memory's "fragile power" (Schacter, 1996). The power of memory is

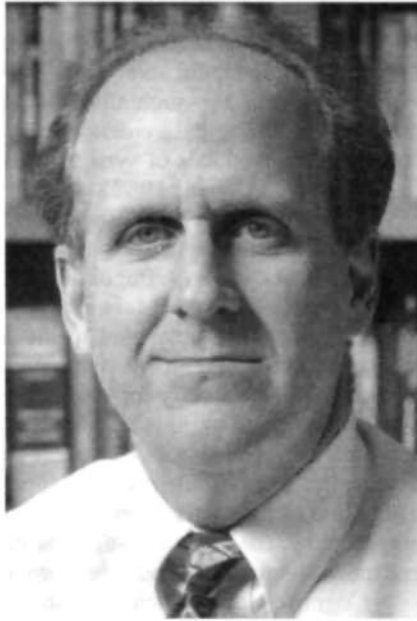
evident when one contemplates what the various forms of memory make possible in our everyday lives: a sense of personal history, knowledge of facts and concepts, and learning of complex skills. Because of memory's importance in everyday life, it is easy to see why Vernon Jordan would be struck by Clinton's "extraordinary memory" and how that ability would enhance Clinton's prospects as a politician. But, as Clinton professed to have learned during his term as President, memory also has a darker, more fragile side. People may forget events rapidly or gradually, distort the past in surprising ways, and sometimes experience intrusive recollections of events that they wish they could forget.

This darker side of memory has occupied center stage in recent scientific, clinical, and popular discussions. As most psychologists are acutely aware, a bitter controversy has raged throughout the 1990s concerning the accuracy of recovered memories of childhood sexual abuse (see, for instance, Conway, 1997; Freyd, 1996; Herman, 1992; Kihlstrom, 1995; Lindsay & Read, 1994; Loftus, 1993; Pope, 1996; Poole, Lindsay, Memon, & Bull, 1995; Read & Lindsay, 1997; Schacter, Norman, & Koutstaal, 1997). Some recovered memories have been corroborated and appear to be accurate, but there are also good reasons to believe that many such memories are inaccurate (e.g., Lindsay & Read, 1994; Schacter, 1996; J. W. Schooler, 1994). False memories of childhood sexual abuse are associated with devastating psychological consequences for accusers and their families (Loftus & Ketcham, 1994; Pendergrast, 1995). As the debate concerning recovered memories has raged, memory researchers have focused increasingly on developing experimental paradigms to explore illusory or false memories in which people confidently claim to recollect events that never happened (for

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review and discussion, see Estes, 1997; Roediger, 1996; Schacter, Norman, & Koutstaal, 1998).

Although false memories have been discussed intensively in recent years, forgetting is perhaps the most familiar of memory's indiscretions. Psychologists and neuroscientists have studied forgetting ever since Ebbinghaus (1885) applied experimental methods to the study of memory and provided quantitative estimates of forgetting. The general public, too, has become increasingly concerned with forgetting, even prior to the release of Clinton's forgetting-filled grand jury testimony. As highlighted by a recent cover story concerning memory in *Newsweek* (Cowley & Underwood, 1998), millions of aging babyboomers in addition to Clinton are trying to understand why they now forget more frequently than in the past and what, if anything, they can do about it (e.g., Crook & Adderly, 1998).

We are all affected by memory's shortcomings in our everyday lives, and scientists have studied them for decades. But there have been few attempts to systematically organize or classify the various ways in which memory can lead us astray and to assess the state of the scientific evidence concerning them. Given the scientific attention paid recently to the fallibility of memory, and the important real-world consequences that are sometimes associated with forgetting and distortion, such an undertaking would appear to be both timely and potentially useful.

I suggest that memory's transgressions can be divided into seven basic "sins." I call them transience, absent-mindedness, blocking, misattribution, suggestibility, bias, and persistence. The first three sins reflect different 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 three sins all involve distortion or inaccuracy. *Misattribution* involves attributing a recollection or idea to the wrong source, *suggestibility* refers to memories that are implanted as a result of leading questions or comments during attempts to recall past experiences, and *bias* involves retrospective distortions and unconscious influences that are related to current knowledge and beliefs. The seventh and final sin, *persistence*, refers to pathological remembrances: information or events that we cannot forget, even though we wish we could.

Like the biblical seven deadly sins—pride, anger, envy, greed, gluttony, lust, and sloth—the seven sins of memory occur frequently in human affairs. The biblical sins, however, can also be seen as exaggerations of human traits that are in many respects useful and even necessary for survival. So, too, is the case for the seven sins of memory. As annoying and occasionally dangerous as they may be, I suggest later in this article that memory's sins should not be viewed as flaws in system design or unfortunate errors made by Mother Nature during the course of evolution. Instead, the seven sins are more usefully conceptualized as by-products of otherwise desirable features of human memory (cf. J. R. Anderson & Schooler, 1991; Bjork & Bjork, 1988). Perhaps paradoxically, then, the seven sins can provide insights into the very operations of memory that make it such a valuable resource in numerous aspects of our everyday lives.

In the body of this article, I summarize two major types of evidence and ideas concerning each of the seven sins. First, much of what is known about the seven sins comes from work in cognitive, social, and clinical psychology; I summarize recent research from each of these domains. Second, I consider what we have learned about the seven sins from the perspective of contemporary cognitive neuroscience. During the past 20 years, cognitive neuroscience analyses of human memory have become increasingly influential (for general summaries, see Gabrieli, 1998; Gazzaniga, 1995; Schacter, 1992, 1996). The cognitive neuroscience approach has relied heavily on studies of patients with brain lesions that selectively affect particular forms of memory and, more recently, on studies using functional neuroimaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). PET and fMRI measure local changes in hemodynamic responses that are correlated with changes in neuronal activity: PET is sensitive to changes in blood flow, whereas fMRI is sensitive to oxygenation-level-dependent changes in the magnetic properties of blood, usually referred to as BOLD contrast. Both techniques allow relatively precise localization of the observed changes in hemodynamic response. To make inferences about the activation of particular brain regions during performance of behavioral tasks, investigators generally measure changes in blood flow or blood oxygenation level in one experimental condition relative to another condition. Estimates of blood flow or oxygenation level can then be subtracted from one another, or assessed with various other

analysis strategies (for further discussion of the nature and logic of neuroimaging approaches, see Posner & Raichle, 1994). The neuroimaging of human memory has progressed rapidly during the past five years (for reviews, see Buckner & Koutstaal, 1998; Cabeza & Nyberg, 1997; Schacter & Wagner, in press; Ungerleider, 1995).

In the sections that follow, I ask what (if anything) cognitive neuroscience approaches have taught us about each of the seven sins. I then conclude by considering the sense in which, and the extent to which, the seven sins reflect the operation of otherwise adaptive features of memory.

Understanding the Seven Sins: Evidence From Mind and Brain

Transience

Memory for facts and events typically becomes less accessible over time. Gradual forgetting was first documented in Ebbinghaus's (1885) well-known studies, where he attempted to learn and remember nonsense syllables. He assessed his own memory at various delays after initial learning and observed a rapid drop-off in retention at the early delays, followed by a more gradual drop-off at later delays. Cognitive psychologists continue to investigate and characterize the form of the forgetting function. Although the basic characteristics of the forgetting curve described by Ebbinghaus have been observed in numerous situations, recent evidence indicates that forgetting over time is best described mathematically with a power function: the rate of forgetting is slowed down by the passage of time (e.g., Wixted & Ebbesen, 1997).

Discussions about the cause of long-term forgetting have focused on whether forgetting is attributable to actual loss of information from memory storage, to retrieval failure that can be reversed by provision of appropriate cues, or both (e.g., Loftus & Loftus, 1980; Schacter, 1996; Squire, 1987). There is no doubt that retrieval failure plays an important role in forgetting. Some experiences may be rendered temporarily inaccessible because of interference from related experiences (Postman & Underwood, 1973), and it is well-established that cues and hints can elicit recall of seemingly forgotten memories (e.g., Tulving & Pearlstone, 1966; for a recent review, see Koutstaal & Schacter, 1997b). Nonetheless, such findings need not indicate that all forgetting is attributable to access failure. The view that experiences are recorded permanently, with all forgetting attributable to access failure, is surprisingly common—even among psychologists (Loftus & Loftus, 1980). However, it seems likely that information is also lost from storage over time (Schacter, 1996; Squire, 1987). Loss of information over time may be particularly likely to occur when people do not "use" a memory. It is known, for instance, that retrieving and rehearsing experiences plays an important role in determining whether those experiences will be remembered or forgotten (e.g., Bjork, 1988; Koutstaal, Schacter, Johnson, Angell, & Gross, 1998) and in determining what aspects of those

experiences will be retained (e.g., Suengas & Johnson, 1988). Memories that are not retrieved and rehearsed may slowly dissipate over time. Although there is no direct evidence for such dissipation in studies of humans, neurobiological evidence from invertebrate organisms has revealed loss of synaptic connectivity over time (e.g., Bailey & Chen, 1989).

It has also been established that forgetting can occur quite rapidly—on a time scale of seconds, rather than minutes, hours, or days. Beginning with the classic studies of J. Brown (1958) and Peterson and Peterson (1959), rapid forgetting has been attributed to the operation of a short-term or working memory system (Baddeley, 1986). Working memory is necessary for holding information "on-line," usually for brief periods of time, while other cognitive activities are carried out. The exact cause of rapid forgetting within working memory has long been debated (for a discussion of alternative views, see Crowder, 1989) but, as noted below, the evidence suggests that it involves different mechanisms than long-term forgetting.

Cognitive neuroscience analyses have been instrumental in providing insights into the underlying bases of both gradual (i.e., long-term) and rapid (i.e., short-term) transience. Beginning with the pioneering studies of Scoville and Milner (1957), studies of brain-damaged amnesic patients have shown that damage to the medial temporal lobes, including the hippocampus and related structures, produces profound long-term forgetting. Such patients perform reasonably well on tasks that tap short-term or working memory (e.g., digit span) and can maintain information in working memory if they are not distracted (Parkin & Leng, 1993; Squire, 1987). However, once distraction or delay are introduced, amnesic patients forget experiences rapidly (anterograde amnesia). They also exhibit varying degrees of forgetting for experiences that occurred prior to the injury (retrograde amnesia; for alternative perspectives, see Nadel & Moscovitch, 1997; Squire & Alvarez, 1995). However, studies with amnesic patients have not been highly successful in pinpointing the exact source of the pathological forgetting that patients exhibit. Thus, for instance, investigations of anterograde amnesia have not yet resolved whether forgetting is attributable specifically to problems in encoding, storage, or retrieval of information, or some combination of these processes (for a recent discussion, see Mayes & Downes, 1997).

Neuroimaging studies are also limited with respect to the kinds of insights they can provide concerning the neural bases of transience. Current neuroimaging techniques do not permit direct study of the storage or consolidation processes that intervene between encoding and retrieval and that are directly related to the occurrence of transience. However, neuroimaging techniques do allow a separation between encoding and retrieval processes. Thus, studies using fMRI and PET have provided some initial insights into the role of medial temporal lobes in encoding and retrieval processes that has not been possible to obtain in studies of amnesic patients (for review and discussion, see Lepage, Habib, & Tulving, 1998; Schacter & Wagner, 1999).

Two recent fMRI studies illuminate an important source of transience: initial encoding of information into memory. Both studies used "event-related" fMRI procedures, which make it possible to track encoding processes on a trial-by-trial basis. Responses can be sorted later according to whether an item is remembered or forgotten, much in the manner that data from studies using electrophysiological measures, such as event-related potentials, can be selectively sorted and averaged (for discussion of event-related fMRI methods, see Dale & Buckner, 1997).

Wagner, Schacter, et al. (1998) used event-related fMRI to determine whether responses to individual words during encoding predict subsequent remembering and forgetting of those words. During the scanning period, participants viewed a long list of words and decided whether each word was abstract or concrete. This encoding phase was followed by a nonscanned recognition test in which participants made old-new judgments indicating whether or not they remembered having encountered an item in the study phase and also indicated their degree of confidence in their judgment. Analysis of the fMRI data revealed that two regions of the brain were more active during the encoding phase of the experiment for words that were subsequently remembered with high confidence than for words that were subsequently forgotten. One of these regions was in the posterior (i.e., back) portions of the left temporal lobe (the left parahippocampal gyrus), and the other was in the lower portion of the left frontal lobe (the left inferior frontal gyrus). Thus, level of activity in these two regions at the time of encoding predicted whether an individual word was later remembered or forgotten.

Brewer, Zhao, Desmond, Glover, and Gabrieli (1998) carried out a similar event-related fMRI encoding study, using pictures of everyday scenes instead of words. Their results converged nicely with those of Wagner, Schacter, et al. (1998). Brewer et al. found that degree of activity during encoding in parahippocampal regions of both the left and right hemispheres, and inferior frontal regions in the right hemisphere, predicted subsequent remembering and forgetting: There was greater parahippocampal and right prefrontal activity during encoding for subsequently remembered than forgotten pictures. The fact that right hemisphere regions predicted subsequent remembering and forgetting of pictures, whereas only left hemisphere regions predicted subsequent memory for words, fits with other neuroimaging data linking the left hemisphere with verbal encoding and the right hemisphere with nonverbal encoding (Kelley et al., 1998; Wagner, Poldrack, et al., 1998). Gradual forgetting of different types of information thus appears to be attributable, at least in part, to initial levels of activity in regions involved with encoding verbal and nonverbal experiences.

Turning from long-term to short-term transience, neuropsychological studies of brain-damaged patients have illuminated the nature of short-term forgetting by demonstrating a pattern opposite to that observed in amnesic patients. Specifically, a number of studies have described patients who show relatively intact long-term memory—they can remember the ongoing experiences of everyday

life and perform well on tests of memory that amnesic patients fail—but have severe problems with immediate retention (for a review, see Vallar & Shallice, 1990). Such patients may exhibit entirely normal performance on such long-term memory tasks as learning pairs of associated words, yet exhibit virtually instant forgetting on such immediate memory tasks as digit span.

These patients have problems within the working memory system. According to Baddeley (1986), this system contains a number of interrelated components. In many cases of short-term memory loss, the observed deficit can be attributed to a specific component of working memory known as the phonological loop (see Baddeley, Gathercole, & Papagno, 1998). The phonological loop is necessary for holding small amounts of speech-based information. It is the type of memory one would rely on when attempting to hold on to a telephone number as one races from the phone book to the telephone. Patients with damage to the phonological loop usually have a lesion in the lower part of the left parietal lobe, and they exhibit rapid forgetting of speech-based information. It is important to note that patients with damage to the phonological loop also have difficulty with long-term retention of phonological information, such as learning new vocabulary (Baddeley et al., 1998). Developmental studies have shown that performance on working memory tasks that require the phonological loop is closely associated with long-term vocabulary acquisition and related aspects of language learning (Gathercole & Baddeley, 1994). Thus, when the phonological loop does not operate normally (as in cases of left parietal damage or some children with developmental disabilities), problems with short-term forgetting arise that have important consequences for such fundamental abilities as language learning.

Neuroimaging studies have also begun to illuminate some of the neural systems that are relevant to short-term transience by revealing the component structures of working memory (for reviews, see Awh & Jonides, 1998; Schacter, Wagner, & Buckner, in press; E. E. Smith & Jonides, 1997). To take just one example, neuropsychological studies suggest that two key components of the phonological loop—a phonological store and a rehearsal mechanism that maintains the contents of this store—are based on distinct neural substrates, because storage and rehearsal processes can be impaired selectively (e.g., Vallar & Baddeley, 1984). Neuroimaging studies support this distinction: A number of studies suggest that regions within the left (posterior) parietal lobe subserve phonological storage, whereas portions of left (inferior) prefrontal cortex (Broca's area) are important for phonological rehearsal (e.g., Paulesu, Frith, & Frackowiak, 1993). Short-term forgetting can result from a failure of rehearsal processes, storage processes, or both.

Absent-Mindedness

Transience—forgetting over time—can occur even when an event or fact is initially well-encoded and remembered immediately and can occur even when we deliberately search memory in an attempt to recall a specific event or

fact. However, a good deal of forgetting likely occurs because insufficient attention is devoted to a stimulus at the time of encoding or retrieval or because attended information is processed superficially. Such incidents of forgetting associated with lapses of attention during encoding or during attempted retrieval can be described as errors of absent-mindedness (e.g., Reason & Mycielska, 1982).

Absent-mindedness during encoding is a likely source of common everyday memory failures, such as forgetting where one recently placed an object (e.g., car keys). Such absent-minded encoding failures occur when actions are carried out automatically and attention is focused elsewhere (Reason & Mycielska, 1982). Consistent with this observation, cognitive studies have established that dividing attention at the time of encoding results in poor subsequent memory for target information (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). Likewise, even when attention is nominally devoted to a target item, subsequent memory suffers when that item is initially encoded at a shallow level. This effect was firmly established in cognitive studies demonstrating the well-known "depth of processing" effect (Craik & Lockhart, 1972). When people are induced to carry out "shallow" encoding of target information by making judgments about low-level, nonsemantic features of target information (e.g., Is TABLE printed in upper- or lowercase letters?), they later have considerably worse memory for the target (TABLE) than when they are induced to carry out "deep" encoding by making judgments about semantic features of the target item (e.g., Is TABLE a type of furniture?; Craik & Tulving, 1975).

A form of shallow encoding also plays a role in recent demonstrations of an intriguing phenomenon termed "change blindness" (for a review, see Simons & Levin, 1997). In studies of change blindness, people observe objects or scenes in which various features are changed over time. Change blindness occurs when people fail to detect these changes. For example, Levin and Simons (1997) showed participants a movie in which an actor carried out a simple action. Unknown to the observers, the actor was replaced by a different person during the course of the scene. Only one third of observers noticed the change. Even more striking, Simons and Levin (1998) described a naturalistic study in which one of the experimenters asked a person on a college campus for directions. While they were talking, two men walked between them holding a door that hid the second experimenter. Behind the door, the two experimenters traded places, so that when the men carrying the door moved on, a different person was asking for directions than the one who had been there just a second or two earlier. Remarkably, only 7 of 15 participants reported noticing this change!

One explanation for change blindness is that people typically encode features of a scene at an extremely shallow level, recording the general gist of the scene but few of the specific details (Simons & Levin, 1997). As Simons and Levin (1998) noted, "successful change detection probably requires effortful encoding of precisely those features or properties that will distinguish the original from the

changed object" (p. 648). Support for this explanation is provided by a follow-up to the "door study." Simons and Levin (1998) noted that the people who failed to notice that a different person emerged from behind the door were middle-aged and older adults; college students tended to notice the change. They hypothesized that the older individuals might have encoded the initial (young) experimenter categorically as a "college student," whereas the college students (for whom the person asking directions was a peer) encoded the experimenter at a more specific level. To determine whether college students would be more susceptible to change blindness when induced to encode at a categorical or generic level, Simons and Levin repeated the "door study," but now attired as construction workers. They reasoned that college students now might tend to encode them categorically as "construction workers" and, hence, show higher levels of change blindness. Results supported the hypothesis: Only 4 of 12 students noticed when a different construction worker emerged from behind the door to ask instructions. Thus, shallow encoding that does not proceed beyond a categorical level results in poor recollection of the details of a scene and consequent vulnerability to change blindness.

Some of the neural bases of absent-minded encoding have been elucidated in neuroimaging studies that have compared "deep" and "shallow" encoding tasks. Several early studies revealed greater activation in the lower (i.e., inferior) regions of the left frontal cortex during semantic encoding trials than during nonsemantic encoding trials (e.g., Demb et al., 1995; Kapur et al., 1994), thereby indicating that level of left prefrontal activation is related to semantic encoding processes. More recent work has indicated that the left parahippocampal region discussed earlier also shows greater activation during semantic than nonsemantic encoding tasks (Wagner, Schacter, et al., 1998). Thus, we can tentatively infer that "absent-minded" encoding operations (at least within a verbal domain) are those that involve relatively little recruitment of left inferior prefrontal and parahippocampal regions. These observations are consistent with the previously discussed event-related fMRI data showing that level of activation in inferior prefrontal and parahippocampal regions predicts subsequent remembering and forgetting.

Absent-mindedness also occurs at the time of retrieval, when people may forget to carry out a particular task or function. Because such absent-minded lapses involve forgetting to execute a planned action at some point in the future, they are typically referred to as failures of prospective memory (e.g., Brandimonte, Einstein, & McDaniel, 1996; Cohen, 1989). Absent-minded errors of prospective memory can have important everyday consequences, as when elderly patients forget to take prescribed medications (Park & Kidder, 1996) or when air traffic controllers cannot execute a control action immediately and subsequently forget that they need to take deferred action in the near future (Vortac, Edwards, & Manning, 1995). Prospective memory researchers have found it useful to distinguish between "event-based" and "time-based" prospective memory tasks. Event-based tasks involve remembering

to perform a future action when a specified event occurs, such as remembering to deliver a message to a friend the next time you see her. Time-based tasks, in contrast, involve remembering to perform an action at a specified time, such as remembering to take one's medicine at 11:00 p.m. or remembering to turn off the burner on the stove five minutes from now. Event-based prospective memory tasks are externally cued, so forgetting tends to occur when a cue is not recognized. Time-based prospective memory tasks, in contrast, depend more on generating appropriate cues at the time an intended action needs to be carried out (McDaniel & Einstein, 1993; Vortac et al., 1995). Absent-minded forgetting in time-based tasks thus tends to occur because people fail to prospectively generate retrieval cues ahead of time, and then spontaneously fail to do so at the time the intended action needs to be performed. This distinction appears to be particularly relevant to studies of aging memory, which indicate that older adults often perform well on event-based prospective tasks and more poorly on time-based tasks (for a review, see Einstein & McDaniel, 1996; Maylor, 1996).

Cognitive neuroscience has so far contributed relatively little to understanding absent-minded errors of prospective forgetting. Shallice and Burgess (1991) have demonstrated that failures to carry out future tasks in patients with frontal lobe lesions are associated with level of planning skills and executive functions. Cockburn (1995) investigated a variety of prospective memory tasks in a patient with bilateral frontal lobe damage. The patient performed well on each of five event-based prospective tasks, but performed poorly on several time-based prospective tasks, particularly those tasks that required interrupting one action to perform an unrelated one. In a recent PET study, Okuda et al. (1998) investigated the neural correlates of event-based prospective remembering. They required participants to perform a routine task (repeating spoken words) during scanning. In a condition that required prospective memory, participants were also required to retain a planned action (to tap when prespecified words were presented) while carrying out other activities. Prospective remembering was associated with activation in a number of brain regions, 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. Taken together, the patient studies and neuroimaging experiment implicate prefrontal cortex in aspects of both event-based and time-based prospective memory (note, however, that Cockburn's [1995] patient performed well on event-related prospective tasks; it would be important to determine whether this patient performed well on the exact task that produced prefrontal activation in the PET study). This apparent link between prospective memory and frontal lobe function makes sense in view of the role that frontal regions play in allowing "mental time travel" into both the past and the future (Wheeler, Stuss, & Tulving, 1997). Failure to activate appropriate frontal regions, either at the time of planning a future action or at the moment when it needs to be carried out, may be implicated in absent-minded errors of prospec-

tive memory, such as forgetting to keep an appointment or to take a prescribed medicine.

Blocking

Even when a fact or event has been encoded deeply, and has not been lost over time, it may sometimes be temporarily inaccessible (Koutstaal & Schacter, 1997b; Tulving & Pearlstone, 1966). When people are provided with cues that are related to a sought-after item, but are nonetheless unable to elicit it, a retrieval block has occurred (Roediger & Neely, 1982). Such blocks occur in both episodic memory (i.e., memory for specific personal experiences) and semantic memory (i.e., general knowledge of the world). Blocking constitutes one of the most subjectively compelling of memory's seven sins, in the sense that people are acutely aware of the block at the time it occurs. When blocking occurs at an inopportune moment under high stress—such as with actors who suddenly cannot recall their lines—the accompanying subjective awareness can be overwhelming (Reason & Mycielska, 1982).

The most thoroughly investigated example of blocking is the tip-of-the-tongue (TOT) state. In a TOT state, people are unable to produce a word or a name, but they have a powerful subjective conviction that the item is available in memory. Further, they can sometimes produce partial phonological or semantic information about the item (R. Brown & McNeil, 1966; for review, see A. S. Brown, 1991). TOT retrieval blocks are often resolved quickly: Several studies have shown that roughly half of the sought-after target items are retrieved within a minute or so after the onset of blocking, although some items may not be retrieved until days later (see A. S. Brown, 1991, pp. 211–213). TOT blocks appear to be partly attributable to the retrieval of similar but incorrect items that interfere with access to the target (see Harley & Brown, 1998, for other relevant factors). For example, in a diary study, Reason and Lucas (1984) found that over half of naturally occurring TOT states were characterized by the presence of what they termed "ugly sisters," referring to Cinderella's undesirable but dominating older sisters. Ugly sisters are incorrect items that are related to the sought-after target and that recur intrusively during the retrieval attempt. Consistent with this observation, when Jones and Langford (1987) induced TOT states by giving definitions of low frequency words, they found that providing phonologically or semantically related cues along with the definitions resulted in more TOT states than when unrelated words were given (see also Smith & Tindell, 1997).

Blocking appears to be especially pronounced in old age. The incidence of TOT states increases with aging (A. S. Brown & Nix, 1996; Maylor, 1990), although it remains unclear as to whether older adults are more susceptible to interference from "ugly sisters" than are younger adults (cf. Burke, MacKay, Worthley, & Wade, 1991; A. S. Brown & Nix, 1996). The age-related increase in TOT states may be particularly pronounced when people attempt to retrieve names (Maylor, 1990). This observation is consistent with other evidence indicating that name retrieval failure is a frequent subjective complaint by older

adults and that older adults exhibit difficulties retrieving proper names. However, it is unclear whether these problems are disproportionately worse than age-related retrieval problems for other kinds of information (for review and discussion, see Cohen & Burke, 1993; Maylor, 1997).

The foregoing observations concerning the role of "ugly sisters" in the TOT state resemble a curious phenomenon known as the "part-set cueing" effect, which has been documented in laboratory studies of episodic memory in which participants encode and retrieve lists of words. In part-set cueing, provision of some retrieval cues that are related to a previously studied word can block or inhibit, rather than enhance, retrieval of the target item (e.g., Roediger, 1974; Slamecka, 1968; Sloman, Bower, & Rohr, 1991). In a similar vein, several studies have shown that retrieving and reviewing an item or event is sometimes associated with decreased memory for related but nonretrieved items, perhaps because the nonretrieved items become inhibited as a result of retrieving related items (e.g., M. C. Anderson, Bjork, & Bjork, 1994; M. C. Anderson & Spellman, 1995). Although most such evidence comes from word-list learning studies, Shaw, Bjork, and Handal (1995) reported inhibitory effects of retrieval in an eyewitness memory paradigm involving more complex events. Participants first viewed color slides of a crime scene (a student's room where a theft had occurred). The experimenters then questioned them repeatedly about certain categories of objects in the scene (e.g., some of the college sweatshirts that were present), resulting in retrieval and review of these objects. No questions were asked about other categories of objects (e.g., college schoolbooks). Compared with objects about which no questions were asked (schoolbooks), participants recalled fewer of the nonretrieved and nonreviewed objects from the categories that had been repeatedly probed. Thus, access to these nonretrieved items seemed to be blocked by successful retrieval of related items (for similar results in a paradigm involving review of photographs depicting events that participants themselves had performed, see Koutstaal, Schacter, Johnson, & Galluccio, in press).

Cognitive neuroscience has so far provided some relevant observations concerning retrieval blocks in semantic memory and relatively little information concerning blocking in episodic memory. Within the domain of semantic memory, a variety of studies have examined amnesic patients who have difficulties with retrieval of common names of objects or with retrieval of proper names. Some patients have difficulty retrieving proper names but not common names, and still others exhibit a selective deficit in retrieving one type of proper name (e.g., names of people; for recent reviews, see Hanley & Kay, 1998; Semenza, Mondini, & Zettin, 1995). Semenza et al. (1995) observed that proper name retrieval deficits are typically associated with the most anterior regions of the left temporal lobe (temporal pole). Consistent with the neuropsychological evidence, a PET study by Damasio, Grabowski, Tranel, Hichwa, and Damasio (1996) revealed activation of the left temporal pole during proper name production. A more posterior temporal region showed increased activation dur-

ing animal naming, and an even more posterior region showed increased activation during naming of tools. These observations raise the intriguing possibility that retrieval blocks associated with attempts to name different kinds of items (e.g., individual persons, animals, tools) may reflect inhibition of slightly different left temporal regions. Although no neuroimaging studies of TOT states have yet been reported (and may be difficult to carry out because of the relative infrequency of the TOT phenomenon), such studies could provide novel insights into the neural correlates of retrieval blocking.

Numerous neuroimaging studies of episodic memory retrieval have been reported (for review and discussion, see Buckner & Koutstaal, 1998; Lepage et al., 1998; Schacter & Wagner, 1999), but none have specifically examined episodic retrieval blocks. Perhaps the most relevant data have been reported by Nyberg et al. (1996), who uncovered evidence of what they termed "ensemble inhibition." Nyberg et al. (1996) reported that regions that showed increased activity during a retrieval task appeared to actively inhibit other regions showing decreased activity. These observations suggest that, consistent with psychological observations (e.g., M. C. Anderson, Bjork, & Bjork, 1994; M. C. Anderson & Spellman, 1995), inhibitory processes may be a normal and perhaps necessary component of episodic retrieval. Whether and to what extent ensemble inhibition processes are related to retrieval blocks remains to be elucidated.

Misattribution

Transience, absent-mindedness, and blocking can all be thought of as sins of omission: At a moment when individuals need to remember, the desired information is inaccessible or unavailable. However, memory is also characterized by sins of commission: Situations in which some form of memory is present, but is misattributed to an incorrect time, place, or person (e.g., Jacoby, Kelley, & Dywan, 1989; Johnson, Hashtroudi, & Lindsay, 1993; Roediger, 1996; Schacter, Norman, et al., 1998). I find it useful to distinguish among three closely related forms of misattribution.

First, people may remember correctly an item or fact from a past experience but misattribute the fact to an incorrect source. For instance, individuals sometimes recall encountering a bit of trivia in the newspaper that, in fact, they acquired from an experimenter (Schacter, Harbluk, & McLachlan, 1984). Similarly, people may assert that they saw a face in one context when they encountered it in another (e.g., Read, 1994) or that they perceived an event that they only imagined (e.g., Garry, Manning, Loftus, & Sherman, 1996; Goff & Roediger, 1998; Johnson, Raye, Wang, & Taylor, 1979; for review, see Johnson et al., 1993). Source confusions of this kind can be particularly pronounced in older adults (McIntyre & Craik, 1987). In a recent study, for example, Schacter, Koutstaal, Johnson, Gross, and Angell (1997) found that older adults often confused whether they had seen an everyday action in a videotape or only in a photograph that they viewed several

days later, whereas younger adults had little difficulty remembering the correct source.

Source confusions can have important implications in everyday life, as exemplified by cases of erroneous eyewitness identifications in which a person seen in one context is mistakenly "transferred" to another (D. F. Ross, Ceci, Dunning, & Toglia, 1994). A particularly dramatic example involved the psychologist Donald Thomson, a respected memory researcher who was accused of rape on the basis of the victim's detailed recollection of the rapist (Thomson, 1988). Fortunately for Thomson, he had an airtight alibi: He was giving a live television interview (ironically, concerning memory distortion) at the moment that the rape occurred. The victim had been watching that interview just prior to being raped. She had confused the source of her vivid memory of Thomson, misattributing the television image to the rapist. Thomson's alibi led to his immediate vindication, but others have not been so fortunate. Recent investigations into cases of wrongful imprisonment, where innocence was established by DNA evidence, provide sobering evidence. In a sample of 40 such cases, 36 (90%) involved false identification of the perpetrator by one or more eyewitnesses (Wells et al., in press; this finding is also relevant to the discussion of suggestibility in the next section).

In the foregoing examples of misattribution, recall of the item or fact is accompanied by a subjective experience of remembering a past event. A second type of misattribution is characterized by an absence of any subjective experience of remembering. People sometimes misattribute a spontaneous thought or idea to their own imagination, when in fact they are retrieving it—without awareness of doing so—from a specific prior experience (e.g., Schacter, 1987). This phenomenon of cryptomnesia is exemplified in everyday life by instances of unintentional plagiarism and has been studied recently in the laboratory (e.g., A. S. Brown & Murphy, 1989; Ceci, 1995; Marsh & Landau, 1995). A related type of misattribution has been dubbed the "false fame effect" by Jacoby and colleagues (e.g., Jacoby, Kelley, Brown, & Jasechko, 1989). In Jacoby et al.'s experiments, participants first studied lists including famous names (e.g., Ronald Reagan) and nonfamous names (e.g., Sebastian Weisdorf). Either immediately or one day after studying the names, participants were given a "fame judgment" task in which they made famous-nonfamous judgments about previously studied names and new names. On the one-day delayed test, participants frequently classified nonfamous names they had studied a day earlier as "famous," but they hardly ever made the false fame error on an immediate test. During the delayed test, having forgotten that they studied a nonfamous name such as "Sebastian Weisdorf," participants misattributed the familiarity of the name to the "fame" of the nonfamous individual. Older adults are sometimes more susceptible to the false fame effect than are younger adults (cf. Dywan & Jacoby, 1990; Multhaup, 1995).

A third type of misattribution occurs when individuals falsely recall or recognize items or events that never happened. During the 1960s and 1970s, a number of research-

ers produced laboratory demonstrations of false recall and recognition in which people claimed to have seen or heard sentences (Bransford & Franks, 1971), words (Underwood, 1965), or dot patterns (e.g., Posner & Keele, 1968) that had not been previously presented. Although a number of researchers have since produced impressive demonstrations of similar kinds of misattributions (e.g., Hintzman, 1988), the most striking such finding was reported recently by Roediger and McDermott (1995). They revived and modified a paradigm that was originally devised by Deese (1959). Deese had reported that when people studied lists of semantically associated words and later tried to recall them, they frequently intruded or falsely recalled a strongly associated word that had not been previously presented.

Roediger and McDermott (1995) replicated this false-recall effect and extended it to recognition. In Roediger and McDermott's extension of the Deese task, participants initially studied 15 semantic associates that were all related to a nonpresented "theme word." After studying a number of such 15-word sets, they were then asked to recall words from the list or to recognize them. For instance, participants might study a list containing the words candy, sour, sugar, bitter, good, taste, tooth, and other related words. They would later receive a recognition test that includes studied words (e.g., taste), nonstudied words that are unrelated to words that had appeared on the study list (e.g., point) and, most important, new theme words (e.g., sweet) that are associatively related to words from the study list. Roediger and McDermott (1995) reported that participants made false alarms to approximately 65%–80% of the nonpresented theme words in various conditions; indeed, false alarm rates to the theme words were indistinguishable from hit rates to words that were actually presented. Participants expressed as much confidence in these false memories as they did in accurate recollections of previously studied words. Roediger and McDermott also asked participants whether they possessed a specific, detailed recollection of having encountered a word on the list (a "remember" response; cf. Gardiner & Java, 1993; Tulving, 1985), or whether they thought it was on the list because it just seemed familiar to them (a "know" response). Participants provided as many "remember" responses to nonstudied theme words as they did to studied words. This striking false-recognition effect has been replicated and explored in a number of other laboratories (e.g., Mather, Henkel, & Johnson, 1997; Norman & Schacter, 1997; Payne, Elie, Blackwell, & Neuschatz, 1996; Seamon, Luo, & Gallo, 1998).

One explanation for this kind of misattribution is that participants are relying on their memory for the general semantic features or "gist" of the items that they studied (cf. Payne et al., 1996; Reyna & Brainerd, 1995; Schacter, Norman, et al., 1998). Participants may bind together studied items and generated associates, thereby forming and retaining a well-organized representation of the semantic gist of the study list (for discussion of alternative theoretical accounts of false recognition, see Roediger, McDermott, & Robinson, 1998; Schacter, Norman, et al., 1998). Theme words that match this semantic representation, such

as "sweet," are likely to be falsely recognized; unrelated words that do not match it are likely to be correctly rejected (for additional evidence on this point, see Mather et al., 1997; Norman & Schacter, 1997).

Consistent with this explanation, recent studies have shown that it is possible to reduce or suppress the false-recognition effect when study conditions are created that encourage participants to focus on distinctive properties of individual items. For example, Israel and Schacter (1997) reported that when participants study Roediger-McDermott (1995) lists along with pictures that represent each word, the false-recognition effect is reduced significantly compared with a word-only study condition. Schacter, Israel, and Racine (1999) have provided evidence that this reduction of false recognition involves the use of a "distinctiveness heuristic"—a mode of responding based on participants' expectation that recognition of studied items should be accompanied by recollection of distinctive details (i.e., pictorial information). After studying lists of words that are all accompanied by pictures, participants are less likely to rely solely on semantic gist when making a recognition decision. Instead, they demand access to distinctive perceptual information before they are willing to call an item "old" (for other studies on reducing false recognition of semantic associates, see Gallo, Roberts, & Seamon, 1997; McDermott & Roediger, 1998).

As with previous examples of source misattributions, older adults appear to be especially vulnerable to the kinds of misattributions involved in false recall and recognition. For example, several studies have demonstrated that older adults show disproportionately high levels of false recall and recognition in the Deese/Roediger-McDermott paradigm (Balota et al., in press; Kensinger & Schacter, in press; Norman & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998). Koutstaal and Schacter (1997a) provided a particularly striking demonstration of age differences in false recognition. In their paradigm, younger and older adults studied detailed colored pictures from various categories. When given a recognition test after a three-day delay, older adults showed considerably higher levels of false recognition to nonpresented pictures from studied categories than did younger adults. The age differences were most pronounced when participants studied large numbers of pictures (18) from a given category, with older adults showing approximately twice as many false alarms (60–70%) as younger adults (e.g., 25–35%). These observations contrast with other studies in which older adults exhibit high levels of picture recognition accuracy that do not differ substantially from that of younger adults (e.g., Park, Puglisi, & Smith, 1986). In Koutstaal and Schacter's (1997a) paradigm, 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 (for further relevant evidence and discussion, see Balota et al., in press; Kensinger & Schacter, in press; Norman & Schacter, 1997; Tun et al., 1998).

Cognitive neuroscience analyses have begun to explore aspects of misattribution. Studies of brain-injured

patients have revealed that damage to the frontal lobes is often associated with a selective increase in source memory errors (e.g., Janowsky, Shimamura, & Squire, 1989; Schacter et al., 1984). More recent experiments have also linked frontal lobe damage with increased susceptibility to false recognition (Parkin, Bindschaedler, Harsent, & Metzler, 1996; Rapcsak, Reminger, Glisky, Kaszniak, & Comer, in press; Schacter, Curran, Galluccio, Milberg, & Bates, 1996).

By contrast, several studies of amnesic patients with damage to the medial temporal lobes and related structures have revealed decreased susceptibility to certain forms of false recognition. For instance, several experiments using the Deese/Roediger-McDermott paradigm and similar procedures have shown that amnesic patients exhibit reduced levels of false recognition compared with nonamnesic controls (e.g., Koutstaal, Schacter, Verfaellie, Brenner, & Jackson, in press; Schacter, Verfaellie, & Pradere, 1996; Schacter, Verfaellie, Anes, & Racine, 1998). Balota et al. (in press) reported similar findings in patients with memory deficits attributable to Alzheimer's disease. Thus, false recognition in these paradigms depends on the same or similar brain regions that are usually associated with veridical recollection. Medial temporal regions appear to be involved in encoding and retrieving the kinds of semantic gist or similarity information that can support both true and false memories.

Several neuroimaging investigations of false recognition have also been reported. Using a modified version of the Deese/Roediger-McDermott paradigm, Schacter, Reiman, et al. (1996) investigated true and false recognition with PET, and Schacter, Buckner, Koutstaal, Dale, and Rosen (1997) did so with fMRI. The main finding from the two studies is that patterns of brain activity were highly similar during the two forms of recognition, including some evidence of medial temporal lobe activation during both true and false recognition. Differences in brain activity during true and false recognition were relatively small and appeared to depend on specific characteristics of recognition testing procedures (for a discussion, see Schacter, Buckner, et al., 1997; see also see Johnson et al., 1997). Frontal lobe activation was quite prominent in each of the PET and fMRI studies of false recognition. Indeed, both studies reported some evidence suggesting that frontal regions may be involved in strategic monitoring processes that are invoked as participants struggle to determine whether a related lure word was actually presented earlier in a study list (for elaboration and further relevant evidence, see Johnson et al., 1997). Such findings fit well with the previously mentioned observation that damage to regions within the frontal lobe is sometimes associated with heightened false recognition (Parkin et al., 1996; Rapcsak et al., in press; Schacter, Curran, et al., 1996). Thus, activity in the frontal lobes may signal an attempt to monitor or scrutinize the output of medial temporal lobe structures. As noted earlier, although medial temporal activity often provides a basis for accurate remembering, it is also implicated in the encoding and retrieval of the gist or general similar-

ity information that sometimes produces false recollections (for further discussion, see Schacter, Norman, et al., 1998).

Suggestibility

The foregoing material indicates that false memories can occur spontaneously when a current situation or test item is conceptually or perceptually similar to a previous one. But such illusory memories may also occur in response to suggestions that are made when one is attempting to recall an experience that may or may not have occurred. Suggestibility in memory refers to the tendency to incorporate information provided by others, such as misleading questions (Loftus, Miller, & Burns, 1978), into one's own recollections (note that this definition corresponds closely to Gudjonsson's [1992] notion of "interrogative suggestibility," which he distinguishes from various other forms of suggestibility). Suggestibility is closely related to misattribution in the sense that the conversion of suggestions into false recollections must involve misattribution. However, misattribution can occur in the absence of overt suggestion. Thus, suggestibility seems appropriately viewed as a distinct sin of memory.

Suggestion can influence memory in several different ways. Perhaps the most familiar example to experimental psychologists comes from the work of Loftus and colleagues concerning memory distortions produced by misleading postevent information (e.g., Loftus, Miller, & Burns, 1978). When people are asked suggestive and misleading questions about a previous event, their recollections of the original event may be altered by the provision of erroneous postevent information. In the classic studies of Loftus and colleagues (for a review see Loftus, Feldman, & Dashiell, 1995), experimental participants viewed a slide sequence involving an automobile accident in which a car stopped at a stop sign; some were later asked what the car did after it passed the yield sign. Compared with a control group that did not receive any misleading questions, participants in the misleading information group more often mistakenly claimed that they had seen a yield sign. Loftus et al. (1978) argued that misleading suggestions "overwrite" the original memory, but this interpretation has been convincingly challenged (e.g., Bekerian & Bowers, 1983; McCloskey & Zaragoza, 1985). Recent studies indicate that source misattributions—confusing whether target information had been previously perceived or only suggested—play an important role in misleading-information effects (e.g., Belli, Windschitl, McCarthy, & Winfrey, 1992; Lindsay, 1990; Zaragoza & Lane, 1994).

The work of Loftus et al. (1978) on misleading information was motivated initially by concerns about the potentially damaging effects of suggestion on eyewitness testimony. Wells and Bradfield (1998) have recently provided a dramatic example of a form of suggestion involving misleading feedback to eyewitnesses. In their experiments, participants viewed a videotape of a crime and were later asked to identify the gunman from a set of photos. The actual gunman was not present in the photos. After making their choice, some participants were given confirming feedback (i.e., they were told that they were correct), whereas

others were given no feedback. All participants were later asked to remember various aspects of the crime. Compared with those given no feedback, participants who were given the confirming feedback indicated higher confidence and trust in their recollection, a clearer view of the gunman, and increased memory for facial details.

Suggestibility is also closely related to the controversy concerning false and recovered memories of childhood sexual abuse. Some of this work has been conducted with young children, inspired by concerns about suggestive procedures used in investigations of alleged abuses in day care settings (Ceci & Bruck, 1995). A growing body of evidence from controlled studies with preschoolers indicates that although their memories are often accurate, suggestive procedures can lead to the creation of subjectively compelling false recollections of autobiographical episodes in a substantial proportion of preschool children (for a review, see Ceci, 1995; Ceci & Bruck, 1995).

In studies of adults, the idea that many recovered memories are the products of suggestion during psychotherapy (e.g., Lindsay & Read, 1994; Loftus, 1993) has spurred controlled research investigating whether it is possible to implant false memories of entire autobiographical episodes by using various kinds of suggestive procedures. A number of studies using hypnosis have shown that sizeable proportions (e.g., 50%) of highly hypnotizable individuals will sometimes claim, following hypnotic suggestions, to remember such illusory events as hearing loud noises at night (e.g., Laurence & Perry, 1983). However, hypnotic "pseudomemories" of this kind are determined by a complex interaction of social, situational, and subject variables (for thorough reviews, see Lynn & Nash, 1994; McConkey, Barnier, & Sheehan, 1998) and may have limited relevance to questions concerning false memory creation outside of the hypnotic context.

Loftus (1993, p. 532) described preliminary observations from what has since come to be known as the "lost in the mall" study. Loftus focused on the case of 14-year-old Chris, who had been asked by his older brother, Jim, to try to remember an event that, according to Jim and other family members, had never occurred: The time Chris had been lost in a shopping mall at age five. He initially recalled nothing, but after several days of attempted recall, Chris produced a detailed recollection of an event that had never occurred. Loftus and Pickrell (1995) reported a more extensive study of 24 participants who were asked to respond to descriptions by close relatives of four different events. Three of the events were actual episodes from the individual's past, and one was the "false episode" of being lost in a shopping mall or similar public place. Participants were given booklets containing the descriptions, were told to write down what they recalled from the event, and were also instructed that if they did not remember the event described they should indicate so. Two additional interviews were conducted to further probe participants' recall of both the true and false events. Results from the three sessions were highly consistent: Participants remembered some details from 68% of the true events in each session, whereas 29% (7 of 24) of the participants initially "re-

called" something about the false event (25% of these participants recalled the false event in the two follow-up interviews).

Although these results indicate that false memories of being lost as a child are not unique to Chris, they do not address the generalizability of the phenomenon to other kinds of experiences. A series of experiments by Hyman and colleagues speaks to this issue (Hyman & Billings, 1998; Hyman, Husband, & Billings, 1995; Hyman & Pentland, 1996). They studied college undergraduates whose parents had agreed to complete a childhood events questionnaire. On the basis of parents' responses, Hyman and colleagues asked students about various childhood experiences that, according to their parents, had actually happened. In addition, however, they asked students about a false event that, parents confirmed, had never happened. For instance, Hyman and Pentland (1996) inquired about the following false event: "When you were 5 you were at the wedding reception of some friends of the family and you were running around with some other kids, when you bumped into the table and spilled the punch bowl on the parents of the bride" (p. 105).

Participants were asked about both true and false events in a series of interviews, usually separated from each other by one day. In general, participants accurately remembered 80–90% of the true events. During the initial interview, almost no participants reported any memory for the false events. However, depending on experimental conditions, approximately 20–40% of participants came to describe some memory of the false event in later interviews. For example, in an experiment by Hyman and Billings (1998), only 2 of 66 (3%) participants described any memory of the false event in an initial interview, whereas 18 of 66 (27%) did so in a second interview. Ten of these 18 participants reported "clear" false memories, which included specific details of the central event (e.g., spilling the punch), whereas eight participants reported "partial" false memories, which included some details but no specific memory of the central event.

Hyman and Billings (1998) also found that the tendency to report memories of the false events was positively correlated (.48) with scores on the Dissociative Experiences Scale (Bernstein & Putnam, 1986), which measures self-reported lapses in cognitive and memory functioning and was also positively correlated (.36) with scores on the Creative Imagination Scale (Wilson & Barber, 1978), which measures vividness of mental imagery. This latter finding is consistent with findings from Hyman and Pentland (1996), who manipulated mental imagery experimentally. Participants who were assigned to the imagery condition were given instructions that when they failed to recall either a true or false event, they should try to form detailed images of the event. Participants in the control condition, by contrast, were instructed to sit quietly and think about the event. Participants in the imagery condition recalled more true events than they had initially failed to remember than did participants in the control condition. It is important, however, that mental imagery also produced a significant increase in memories of false events. By the

third interview, 38% of participants in the imagery condition reported either a clear or partial false memory, compared with only 12% of participants in the control condition (for related evidence showing that mental imagery can contribute to false memories, see Garry et al., 1996; Goff & Roediger, 1998; Johnson et al., 1979).

Mazzoni and Loftus (1998) have recently described another kind of suggestive procedure that can produce false memories of life events—dream interpretation. Mazzoni and Loftus asked participants to indicate their confidence that various kinds of experiences had or had not ever happened to them. One group then participated in an ostensibly unrelated task 10–15 days later in which a clinical psychologist interpreted their dreams. The psychologist suggested to them that their dreams included repressed memories of events that had happened to them before the age of three—difficult experiences such as being abandoned by parents, getting lost in a public place, or being lonely and lost in an unfamiliar place. The participants had previously indicated on the life events inventory that such events had never happened to them. Nonetheless, when they completed the life events inventory again in an unrelated context 10–15 days later, the majority of these individuals now claimed to remember one or more of the three suggested experiences for which they had previously denied any memory. No such effects were observed in a control group that did not receive any suggestions regarding their dreams.

Overall, then, the studies of Loftus and Hyman and their colleagues (Hyman & Billings, 1998; Hyman et al., 1995; Hyman & Pentland, 1996; Loftus, 1993; Loftus & Pickrell, 1995; Mazzoni & Loftus, 1998) have established that it is possible to implant false memories of several different types of childhood experiences in a significant number of experimental participants. However, there may be limits to the kinds of memories that can be implanted in such studies. For example, Pezdek, Finger, and Hodge (1997) reported that whereas 15% of participants generated false recollections of being lost in a shopping mall, none generated false memories of a childhood rectal enema.

Although studies demonstrating false memories of everyday experiences are striking and important, they are characterized by a clear methodological limitation: Experimenters cannot determine definitively whether a target event actually occurred and, hence, whether and to what extent a particular memory is "true" or "false." Though not a trivial problem, this concern should not be overblown, for at least two reasons. First, reports of parents and other relatives provide reasonably convincing evidence that the kinds of highly salient target events used in these studies did or did not occur. Second, internal evidence from within an experiment, such as manipulations that increase or decrease the probability that false memories are reported, or individual-difference variables that correlate with the tendency to produce false memories, provide evidence consistent with the psychological reality of the effect.

A related domain in which suggestions contribute to the creation of false memories also has important social and legal consequences—false confessions. False confessions

occur for numerous reasons (some having little to do with suggestibility and memory), but they occasionally are based on illusory recollections generated in response to highly suggestive interrogations from police (Gudjonsson, 1992; Kassir, 1997). Perhaps the best known case in recent years involved sheriff's deputy Paul Ingram, who was accused of raping his daughters and confessed to this abuse as well as to satanic rituals and murders. He later retracted the confession. No evidence for the rituals or murders was ever uncovered despite massive efforts by police, and the rape charges rested on the dubious recovered memories of his daughters (Wright, 1994).

Kassin and Kiechel (1996) have recently reported a compelling experimental analogue of false confession. Participants performed either a fast-paced or slow-paced reaction time task; all had been instructed not to press the "ALT" key because it would cause the program to crash. Although none of the participants actually hit the ALT key, the experimenter falsely accused them of doing so. After participants denied the charge, one group heard a confederate "witness" say that she saw the error; there was no witness for the other group. Overall, nearly 70% of the participants eventually signed a false confession that they had hit the ALT key. The effect was particularly pronounced in the witness-fast-paced group, where all participants signed the confession and 35% confabulated a detailed false recollection of how they made the error.

The foregoing studies clearly indicate that suggestions made at the time of memory retrieval can lead to the creation of false memories of autobiographical episodes. Perhaps it is surprising, however, that despite the theoretical and applied importance of suggestibility, cognitive neuroscience approaches have contributed little or nothing to understanding its nature and basis—or at least nothing beyond prior contributions to understanding related processes such as source misattributions. As seen in the preceding section, the cognitive neuroscience approach has begun to illuminate the neural correlates of misattributions underlying specific types of false-recall and false-recognition effects. It would therefore be desirable to carry out neuropsychological and neuroimaging studies that specifically examine forms of false-memory effects that fall under the rubric of suggestibility.

Bias

Memory encoding and retrieval are highly dependent on, and influenced by, preexisting knowledge and beliefs. Dating at least to the pioneering studies of Bartlett (1932), cognitive psychologists have known that memories can be influenced and even distorted by current knowledge, beliefs, and expectations (i.e., schemas; for a review, see Alba & Hasher, 1983). Likewise, memories of past experiences may be colored by present mood and emotional state (Bower, 1992; Ochsner & Schacter, in press). Bias refers to the distorting influences of present knowledge, beliefs, and feelings on recollection of previous experiences.

Biases of recollection have been observed in several domains (for reviews, see Dawes, 1988; M. Ross, 1989; M. Ross & Wilson, in press). A number of studies have pro-

vided evidence for the operation of a consistency bias in retrospection: People's recollections tend to exaggerate the consistency between their past and present attitudes, beliefs, and feelings. For instance, Marcus (1986) asked people in 1973 to rate their attitudes toward a variety of important social issues, including legalization of marijuana, equality of women, and aid to minorities. When asked to make the same rating again in 1982, and asked also to indicate what their attitudes had been in 1973, participants' recollections of their 1973 attitudes were more closely related to their 1982 attitudes than to what they had actually indicated in 1973. In a more recent study, Levine (1997) examined emotional reactions—hope, anger, and sadness—in supporters of candidate Ross Perot when he withdrew from the 1992 presidential campaign in July and after the election in November (following Perot's return to the campaign in early October). On this second assessment, Levine examined current feelings about Perot's candidacy and also asked the supporters to recall how they had initially felt about Perot's withdrawal in July. Although accurate in many respects, memory for past feelings was nonetheless influenced by current circumstances, showing a strong consistency bias. Thus, "returning" supporters—those who initially switched their support to another candidate when Perot withdrew but later supported him again—recalled their initial reactions as less angry than they actually were. "Loyal" supporters—those who never wavered from Perot—underestimated how sad they felt when Perot withdrew. And "deserting" supporters—those who switched to another candidate and never returned—underestimated how sad and how hopeful they felt when Perot withdrew in July.

Consistency biases have also been observed in studies of memories of people involved in romantic relationships (for reviews, see Acitelli & Holmberg, 1993; Holmberg & Homes, 1994). In a study of dating couples, McFarland and Ross (1987) asked participants to evaluate themselves, their dating partner, and their relationship in an initial session and again in a second session conducted two months later. During the second session, participants were also asked to recall their earlier evaluation. McFarland and Ross found that participants whose evaluations of their partners became more negative over time recalled their initial evaluations as more negative than they actually were. In contrast, when participants reported liking or loving a partner more over time, they also tended to recall having felt more liking or loving in the past.

In a more recent study, Scharfe and Bartholomew (1998) reported similar evidence for consistency bias in a study of three kinds of couples involved in romantic relationships (i.e., dating, cohabitating, married). Each member of the couple completed a self-report attachment questionnaire in an initial session and again eight months later. During the second session, they were also asked to remember their initial attachment evaluations. Scharfe and Bartholomew (1998) found that most of the participants who inaccurately remembered their initial attachment evaluation erred by recalling their past assessment as more congruent with their present one (see also Kirkpatrick &

Hazan, 1994). The consistency bias was observed in both men and women, although it was slightly more pronounced in men. Regression analyses revealed that for women, initial (past) attachment ratings accounted for about 34% of the variance in recall of those ratings, whereas present attachment ratings contributed an additional 24% of the variance. For men, past attachment ratings contributed 23% of the variance, and present attachment ratings contributed an additional 32% of the variance. Overall, then, present attachment ratings accounted for about as much of the variance in recall as did past attachment ratings.

M. Ross (1989) has argued that the specific form that retrospective bias assumes is influenced by individuals' implicit theories of whether or not they have changed over time with respect to what they are asked to remember. When individuals believe it is likely that they have been stable over time, they will tend to overestimate the consistency between past attitudes and current ones. In the foregoing examples of consistency bias, people had no particular reason to believe that their attitudes or feelings had changed over time and, hence, they relied on their current attitudes and feelings to guide reconstruction of past events. By contrast, when individuals have reason to believe that they have changed over time, they may be biased to overestimate differences between current and past attitudes. For example, Conway and Ross (1984) attempted to invoke expectancy for change by assigning a group of participants to a study-skills training group. Participants in this group diligently worked at enhancing their study skills in order to improve their grades. A second group was assigned to a waiting list control condition. When asked to remember their initial skill level, participants in the study skills group exaggerated how poor their study skills had been prior to training (compared with the assessments they had provided at the time). No such bias was observed in the control group.

In the foregoing studies, retrospective bias was observed when people attempted to recall very general features of past beliefs, attitudes, and feelings. However, similar effects have been documented when people are asked to remember specific incidents. For example, Spiro (1980) instructed participants to read a story about a man, Bob, who dearly wanted to marry his girlfriend, Margie. However, he did not want to have children and was anxious about how Margie would react to this disclosure. In one version of the story, Margie was thrilled to hear that Bob wished to remain childless because this fit well with her career plans; in another version she was horrified because she desperately wanted children. After reading the story, some participants in each condition were informed either that Bob and Margie married or that they ended their relationship. When later asked to recall the story, memory biases were observed, but only in those participants who were given poststory information that was incongruent with what they would have expected to happen, based on general knowledge of relationships. Thus, participants who read that Margie was horrified, and then learned that Bob and Margie married, incorrectly recalled various incidents that helped to explain why this would be so. For instance,

one participant recalled incorrectly that "they separated but realized after discussing the matter that their love mattered more," and another misremembered that "they discussed it and decided that they could agree on a compromise: adoption." By contrast, participants who read that Margie was thrilled, and later were told that the couple split, incorrectly recalled such incidents as "there was a hassle with one or the other's parents" or that "they disagreed about having children." The fact that no such errors were made by participants who read that Margie was horrified and the couple split, or read that Maggie was thrilled and that the couple married, indicates that preexisting knowledge and beliefs influenced memory retrieval only when the conclusion of the story violated schema-based expectancies.

The studies reviewed here indicate that retrospective biases have been well-established in studies by cognitive and social psychologists. Despite the pervasiveness of the phenomenon, however, it remains largely unexplored from a cognitive neuroscience perspective: I am not aware of any neuropsychological or neuroimaging studies that have specifically examined recollective biases of the kind reviewed in this section.

Bias may also take the form of subtle influences of past experiences on current judgments about other people and groups. These kinds of biases are well-illustrated by recent studies in implicit social cognition, where various kinds of gender, racial, and related biases have been revealed by indirect or implicit tests of social judgments and beliefs (see Greenwald & Banaji, 1995). Consider, for instance, an experiment that used the previously discussed false fame paradigm (Jacoby, Kelley, Brown, et al., 1989). Banaji and Greenwald (1995) exposed participants to famous and nonfamous male and female names. On a later fame judgment task, participants were more likely to make "false fame" errors—judge incorrectly that a previously studied nonfamous name is famous—for male than for female names. Walsh, Banaji, and Greenwald (cited in Banaji & Bhaskar, in press) reported a related racial biasing effect of past experiences. Participants were shown lists of male names that were either European American (e.g., Adam McCarthy) or African American (e.g., Tyrone Washington) and were asked to indicate which were the names of criminals (they were told that the names might seem familiar because they had appeared in the media). None of the individuals were in fact criminals, but across a series of experiments participants "recognized" significantly more Black than White names as those of criminals. Participants claimed that they were basing their judgments on memory and not race, but the results clearly revealed a nonconscious biasing effect of prior knowledge and experience.

As with retrospective biases, the biases revealed in studies of implicit social cognition remain unexplored from a cognitive neuroscience perspective. However, a possible model for the investigation of such biases may be provided by the numerous neuropsychological and neuroimaging studies that have explored aspects of nonconscious or implicit memory (for recent reviews, see Schacter & Buckner, 1998; Wiggs & Martin, 1998). The wealth of data from

cognitive neuroscience studies of implicit memory could provide a useful foundation for studies of bias in implicit social cognition.

Persistence

The first three of memory's sins—transience, absent-mindedness, and blocking—all entail forgetting a fact or event that one wants to remember. The final sin—persistence—involves remembering a fact or event that one would prefer to forget. Persistence is revealed by intrusive recollections of traumatic events, rumination over negative symptoms and events, and even by chronic fears and phobias.

Studies of traumatic memories reveal that failures to forget can sometimes be even more disabling than forgetting itself. Traumatic events are typically remembered repetitively and intrusively (e.g., Herman, 1992; Krystal, Southwick, & Charney, 1995). Although traumatized individuals may engage in a variety of strategies to avoid or suppress unwanted recollections, such strategies often have little or no impact on the frequency and vividness of intrusive memories (for a review, see Koutstaal & Schacter, 1997c). Relevant experimental evidence has been provided by McNally, Metzger, Lasko, Clancy, and Pitman (1998), who examined "directed forgetting" of traumatic and non-traumatic words in women with post-traumatic stress disorder (PTSD) resulting from documented sexual abuse and matched controls who had a sexual abuse history but no PTSD. In directed-forgetting procedures, individuals are instructed to try to remember some target items and to forget others. Control participants remembered fewer of the trauma-related words they had been instructed to forget than those they had been instructed to remember. However, the trauma patients showed no such directed-forgetting effect, indicating a loss of cognitive control over the encoding and retrieval of trauma-related content.

Persistence also occurs in less extreme situations than PTSD. Disturbing emotional events that are not necessarily traumatic, such as pictures that elicit negative affect, are sometimes remembered in greater detail than are positive pictures (see Ochsner & Schacter, in press). Studies by Wegner and associates have shown that instructing people not to think about a particular item or object (e.g., don't think about white bears) can produce a rebound effect. The initially suppressed item is subsequently produced at higher levels than are items for which no suppression instructions were given (e.g., Wegner & Erber, 1992).

Persistence can be influenced by aspects of current mood and emotion. Just as current feelings can distort recollections of past emotions, they can also increase the accessibility of memories whose affective tone is congruent with a current mood state (Bower, 1992; Mineka & Nugent, 1995). For example, a variety of studies have shown that depressed individuals tend to show increased memory for negative autobiographical events and experimentally presented items compared with positive events and items (for a review, see Mineka & Nugent, 1995). In the present terminology, such effects may reflect an interaction between persistence and bias. Similar considerations apply to phenomena of rumination and regret, in which individuals

dwell on current and past events related to current negative mood states, generating alternative or counterfactual scenarios of what might have been (e.g., Gilovich & Medvec, 1995; Roesse, 1994). Excessive rumination over depressive symptoms is associated with, and can contribute to, increased duration of depressive episodes (Nolen-Hoeksema, 1991).

Recent evidence indicates that the persistence of negative memories can be enhanced by ruminative tendencies in individuals with dysphoric moods. Lyubomirsky, Caldwell, and Nolen-Hoeksema (1998) examined recall of autobiographical memories in college students experiencing depressed and nondepressed moods. Participants engaged in a rumination task that required them to focus on self and mood (i.e., current energy level, why they turned out this way, and so forth) or they performed a distraction task that turned attention away from self and mood (e.g., thinking about the face of the Mona Lisa, clouds forming in the sky). Participants then engaged in an autobiographical memory task that required recall of specific events from their pasts. In each of four experiments using different variants of the autobiographical memory task, the rumination task resulted in increased access to negative autobiographical memories for students experiencing depressed mood, but not for students experiencing a positive mood.

Related processes occur in cases of suicidal depression. Studies by Williams and colleagues (for a review, see Williams, 1997) have shown that depressed individuals are often plagued by the persistence of "overgeneral" memories that represent the past in a nonspecific and highly negative manner. These persisting overgeneral memories can be amplified by and also contribute to depressed mood, leading to a downward spiral that may culminate in suicide.

Cognitive neuroscience analyses have increased our understanding of persistence by illuminating neurobiological factors that contribute to enduring emotional memories. A good deal of this research has followed from animal studies showing that persisting emotional memories (especially fear) depend to a large extent on a specific structure in the limbic system (the amygdala) and are promoted by a particular type of modulatory influence (stress hormones; Cahill & McGaugh, 1998; LeDoux, 1996). During the past few years, converging evidence from neuroimaging, pharmacological, and neuropsychological studies has revealed a similar picture in humans. For example, Cahill et al. (1996) carried out two PET scans: One while participants viewed emotional films and the other while participants viewed nonemotional films. Amygdala activity during viewing of the emotional films was remarkably highly correlated (.93) with subsequent recall of the emotional films three weeks later. No such correlation was observed for the nonemotional films.

Convergent with this result, studies of patients with selective damage to the amygdala have examined recall of emotional and nonemotional information about recently presented stories. Amygdala damage was associated with specific impairments in recalling emotional elements of stories, together with normal retention of nonemotional information (Cahill, Babinsky, Markowitsch, & McGaugh,

1995). Drug studies suggest that release of stress hormones that influence activity within the amygdala contribute importantly to persisting emotional memories. For example, based on prior animal studies showing that administration of beta-adrenergic antagonists ("beta blockers") interfere with the influence of stress-related hormones, Cahill, Prins, Weber, and McGaugh (1994) examined whether administration of a beta blocker (propranolol) would interfere with emotional memory. Consistent with this hypothesis, Cahill et al. (1994) found that propranolol interfered with retention of emotional but not nonemotional aspects of a story (for further review and discussion, see Cahill & McGaugh, 1998; LeDoux, 1996; Ochsner & Schacter, in press).

Conditioning studies in experimental animals have highlighted the persisting quality of certain kinds of emotional memories. For example, conditioned fear responses that depend on the amygdala, once acquired, may be resistant to erasure over time and thus are in some sense indelible (LeDoux, Romanski, & Xagoraris, 1989). In a study using brain-damaged patients, Bechara et al. (1995) reported that amygdala damage interferes with the acquisition of conditioned fear, whereas hippocampal damage does not. These kinds of persisting influences have been implicated in the development and maintenance of powerful and sometimes disabling fears and phobias (e.g., Jacobs & Nadel, 1985). Recent PET studies of patients with PTSD have revealed activation in a variety of brain regions previously implicated in fear and anxiety, including the amygdala, when patients recall the traumatic experiences that in everyday life come to mind persistently and intrusively (e.g., Rauch et al., 1996; Shin et al., 1997).

The Seven Sins: Costs of an Adaptive System?

Considering together the seven sins of memory could easily lead one to question the wisdom of Mother Nature in building such a seemingly flawed system: It is sobering—and perhaps even depressing—to contemplate all the ways in which memory can land us in trouble. J. R. Anderson and Milson (1989) summarized the prevailing perception that memory's sins reflect poorly on its fundamental design:

Human memory is typically viewed by lay people as quite a defective system. For instance, over the years we have participated in many talks with artificial intelligence researchers about the prospects of using human models to guide the development of artificial intelligence programs. Invariably, the remark is made, "Well, of course, we would not want our system to have something so unreliable as human memory." (p. 703)

Bjork and Bjork (1988) have noted that a similar view prevails among memory researchers: "According to the modal view of human memory among today's theorists, loss of retrieval access is a central weakness of the system" (p. 283).

As tempting as such views may be, I suggest that it is a mistake to view the seven sins as flaws in system design that ought to have been corrected during the course of evolution. Instead, building on the analyses of J. R. Ander-

son and Bjork and their colleagues, the seven sins can be usefully viewed as by-products of otherwise adaptive features of memory. Bjork (Bjork, 1989; Bjork & Bjork, 1988) and J. R. Anderson and colleagues (J. R. Anderson, 1990; J. R. Anderson & Milson, 1989; J. R. Anderson & Schooler, 1991; L. Schooler & Anderson, 1997) have already applied this idea to transience (i.e., forgetting over time). Thus, in their discussion of adaptive forgetting, Bjork and Bjork (1988) emphasized that it is often useful and even necessary to forget information that is no longer current, such as old phone numbers or where we parked the car yesterday. Information that is no longer needed will tend not to be retrieved and rehearsed, thereby losing out on the strengthening effects of postevent retrieval and becoming gradually less accessible over time. J. R. Anderson and Schooler (1991; L. Schooler & Anderson, 1997) have argued that forgetting over time reflects an adaptation to the structure of the environment. By their view, an adapted system retains the kind of information that is most likely to be needed in the environment in which the system operates. L. Schooler and Anderson (1997) argued that "memory's sensitivity to statistical structure in the environment allows it to optimally estimate the odds that a memory trace will be needed" (p. 219). To support this claim, they provided evidence consistent with the idea that traces of more recent and more frequently retrieved events are more likely to be needed than are traces of less recent and less frequently retrieved events. Thus, a system that exhibits gradual forgetting of the kind documented for human memory is adapted to the demands of its informational environment (for extension of this notion to animal memory, see Kraemer & Golding, 1997).

A similar analysis can be applied to blocking. As noted earlier, blocking reflects the operation of inhibitory processes in memory. Consider what might result without the operation of inhibition: A system in which all information that is potentially relevant to a retrieval cue invariably and rapidly springs to mind (Bjork, 1989). Although such a system might be free of the occasionally annoying episodes of blocking that plague human rememberers, it would likely result in mass confusion produced by an incessant coming to mind of numerous competing traces.

The third of the forgetting-related sins—absent-mindedness—involves similar considerations on the "front end" of memory. Absent-minded errors occur in part because establishment of a rich memory representation that can later be recollected voluntarily requires attentive, elaborate encoding; events that receive minimal attention have little chance of being recollected subsequently. But what if all events were registered in elaborate detail, regardless of the level or type of processing to which they were subjected? The result would be a potentially overwhelming clutter of useless details, as happened in the famous case of Shereshevski, the mnemonist studied by Luria (1968). Shereshevski was unable to function at an abstract level because he was inundated with unimportant details of his experiences—details that are best denied entry to the system in the first place. An elaboration-dependent system ensures that only those events that are important enough to warrant

extensive encoding have a high likelihood of subsequent recollection. Such a system allows us to enjoy the considerable benefits of operating on "automatic pilot," without having memory cluttered by unnecessary information about routine activities.

Similar ideas can be applied to the three sins that involve distortion of prior experiences: misattribution, suggestibility, and bias. These sins are rooted, to a large extent, in three fundamental features of memory. First, many instances of misattribution, and at least some instances of suggestibility, reflect poor memory for the source of an experience—the precise details of who told us a particular fact, where we saw a familiar face, or whether we witnessed an event ourselves or only heard about it later. When such details are not initially well-encoded, or become inaccessible over time, individuals become quite vulnerable to making the kinds of misattributions associated with false recognition or cryptomnesia, and may also be vulnerable to incorporating postevent suggestions regarding the nature of specific details that are remembered only vaguely. But what would be the consequences and costs of retaining the myriad of contextual details that define our numerous daily experiences? Consider again J. R. Anderson and Schooler's (1991) notion that memory is adapted to retain information that is most likely to be needed in the environment in which it operates. How often do we need to remember all the precise, source-specifying details of our experiences? Would an adapted system routinely record all such details as a default option, or would it record such details only when circumstances dictate?

A second and related factor that contributes to misattributions involving false recall and recognition concerns the distinction between memory for gist and verbatim or specific information (Reyna & Brainerd, 1995). False recall and recognition often occur when people remember the semantic or perceptual gist of an experience but do not recall specific details. However, memory for gist may also be fundamental to such abilities as categorization and comprehension and may facilitate the development of transfer and generalization across tasks. In a neural network analysis of memory distortions, McClelland (1995, p. 84) noted that generalization often results from gist-like, accumulated effects of prior experiences. Noting that such generalization "is central to our ability to act intelligently" and constitutes a foundation for cognitive development, McClelland further observed that "such generalization gives rise to distortions as an inherent by-product."

A third factor that is particularly relevant to many instances of bias concerns the influences of preexisting knowledge and schemas. Although they can sometimes contribute to distorted recollections of past events, schemas also perform important organizing functions in our cognitive lives (Mandler, 1979). Schemas are especially important in guiding memory retrieval, promoting memory for schema-relevant information, and allowing us to develop accurate expectations of events that are likely to unfold in familiar settings on the basis of past experiences in those settings (Alba & Hasher, 1983). In a somewhat different vein, as discussed earlier, retrospective biases frequently

involve memory distortions that exaggerate consistency or change between present and past attitudes and beliefs. M. Ross and Wilson (in press) have argued that such distortions often serve to enhance appraisals of one's current self and thus in some sense contribute to life satisfaction (see also Singer & Salovey, 1993; Strack, Schwarz, & Gschneidinger, 1985; Taylor, 1991).

Of all the seven sins, it is perhaps easiest to see the positive or adaptive side of persistence. Although intrusive recollections of trauma can be disabling, it is critically important that emotionally arousing experiences, which may occur in response to dangers that can be life threatening, persist over time and provide a basis for long-lasting memories (cf. LeDoux, 1996; McGaugh, 1995). The fact that the amygdala and related structures help to increase the persistence of such experiences by modulating memory formation may sometimes result in memories we wish we could forget. But it also provides us with a mechanism that increases the likelihood that we will retain information about arousing or traumatic events whose recollection may be crucial for survival.

The idea that the seven sins of memory are by-products of otherwise adaptive features of memory requires some cautions and clarifications. As noted recently by Buss, Haselton, Shackelford, Bleske, and Wakefield (1998), psychologists use the term "adaptation" or "adaptive features" in at least two different ways. One comes from evolutionary theory and involves a highly specific, technical definition of an adaptation as a feature of a species that came into existence through the operation of natural selection because it in some way increased reproductive fitness. The other is a more colloquial, nontechnical sense of the term that refers to a feature of an organism that has generally beneficial consequences, whether or not it arose directly in response to natural selection during the course of evolution. As discussed by Buss et al. (1998), many generally useful or "adaptive" features of humans and other animals are not, strictly speaking, adaptations. Sometimes termed "exaptations" (Gould & Vrba, 1982), these useful functions arise as a consequence of other related features that are adaptations in the technical sense. Such adaptations are sometimes co-opted to perform functions other than the one for which they were originally selected. In an evolutionary analysis of memory systems, Sherry and Schacter (1987) emphasized the possible role of exaptations in human memory:

few of the current functions that memory serves can be genuine adaptations of memory. Human memory is clearly not an adaptation for remembering telephone numbers, though it performs these functions fairly well, nor is it an adaptation for learning to drive a car, though it handles this rather different function effectively, too. The idea of exaptation emphasizes the difference between the current functions memory systems perform and their evolutionary histories. (p. 449)

In view of these considerations, we must be cautious about making any strong claims for the evolutionary status of the adaptive features of memory considered here; they might be adaptations, exaptations, or both. As far as the

sevens sins go, it seems possible that some are genuine adaptations, whereas others are clearly by-products of adaptations or exaptations. For example, J. R. Anderson and colleagues' analysis of forgetting (J. R. Anderson, 1990; J. R. Anderson & Milson, 1989; J. R. Anderson & Schooler, 1991; L. Schooler & Anderson, 1997) would lead us to view transience as a genuine adaptation to the structure of the environment. By contrast, misattributions involved in source memory confusions are clearly not adaptations, but are more likely by-products of adaptations and exaptations that have yielded a memory system that does not routinely preserve all the details required to specify the exact source of an experience. Similarly, false recall and recognition may be by-products of gist-based memory processes that themselves could have arisen either as adaptations or exaptations.

These kinds of by-products resemble what Gould and Lewontin (1979) called "spandrels." A spandrel is a type of exaptation that is a side consequence of a particular function. The term spandrel is used in architecture to designate the left-over spaces between structural elements in a building. As an example, Gould and Lewontin described the four spandrels in the central dome of Venice's Cathedral of San Marco: leftover spaces between arches and walls that were subsequently decorated with four evangelists and four Biblical rivers. The spandrels were not built in order to house these paintings, although they do so very well (for further discussion of spandrels, see Buss et al., 1998; Gould, 1991). Architectural spandrels generally have benign consequences. Perhaps some of the seven sins discussed here can be thought of as spandrels gone awry—side consequences of a generally adaptive architecture that sometimes get us into trouble. Future research in psychology and cognitive neuroscience that incorporates an evolutionary perspective should help to increase our understanding of the nature and source of the seven sins of memory.

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