Annu. Rev. Psychol. 1998. 49:289–318

THE COGNITIVE NEUROSCIENCE OF CONSTRUCTIVE MEMORY

Daniel L. Schacter, Kenneth A. Norman, and Wilma Koutstaal
Harvard University, Psychology Department, 33 Kirkland Street, Cambridge, Massachusetts 02138; e-mail: dls@wjh.harvard.edu

KEY WORDS: false recognition, confabulation, memory disorders, medial temporal lobes, frontal lobes

ABSTRACT

Numerous empirical and theoretical observations point to the constructive nature of human memory. This paper reviews contemporary research pertaining to two major types of memory distortions that illustrate such constructive processes: (*a*) false recognition and (*b*) intrusions and confabulations. A general integrative framework that outlines the types of problems that the human memory system must solve in order to produce mainly accurate representations of past experience is first described. This constructive memory framework (CMF) emphasizes processes that operate at encoding (initially binding distributed features of an episode together as a coherent trace; ensuring sufficient pattern separation of similar episodes) and also at retrieval (formation of a sufficiently focused retrieval description with which to query memory; postretrieval monitoring and verification). The framework is applied to findings from four different areas of research: cognitive studies of young adults, neuropsychological investigations of brain-damaged patients, neuroimaging studies, and studies of cognitive aging.

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0066-4308/98/0201-0289$08.00

INTRODUCTION

Beginning with the pioneering studies of Bartlett (1932), psychologists have recognized that memory is not a literal reproduction of the past but instead depends on constructive processes that are sometimes prone to errors, distortions, and illusions (for recent reviews, see Estes 1997; Johnson et al 1993; Roediger 1996; Schacter 1995, 1996). Contemporary cognitive psychologists have been especially concerned with constructive aspects of memory, in part as a result of real-world controversies concerning the suggestibility of children's memory (e.g. Ceci & Bruck 1995, Schacter et al 1995b) and the accuracy of memories recovered in psychotherapy (e.g. Lindsay & Read 1996, Loftus 1993, Schacter et al 1996c). In contrast, neuropsychologists and neuroscientists who have focused on brain substrates of remembering and learning have tended to pay less attention to memory errors, distortions, and related phenomena. During the past several years, however, cognitive neuroscientists have been increasingly interested in phenomena that illuminate constructive aspects of remembering, such as false recognition and confabulation (cf Moscovitch 1995, Schacter & Curran 1995, Squire 1995). This review attempts to integrate diverse empirical and theoretical observations concerning constructive memory phenomena from four different areas of research: cognitive studies of young adults, neuropsychological investigations of brain-damaged patients, studies of cognitive aging, and research using brain-imaging techniques.

We begin by sketching a general framework that places the study of constructive memory phenomena in a broader conceptual context. We then examine observations from relevant research domains concerning two major types of memory distortions: (*a*) false recognition and (*b*) intrusions and confabulations.

Constructive Memory: A General Framework

Our conceptualization of constructive memory functions, which we will refer to as the constructive memory framework (CMF), draws on notions put forward previously by Johnson et al (1993), McClelland et al (1995), Moscovitch (1994), Norman & Schacter (1996), and Squire (1992), among others. We begin by noting that representations of new experiences can be conceptualized as patterns of features, with different features representing different facets of the experience: the outputs of perceptual modules that analyze specific physical attributes of incoming information, interpretation and evaluation of these physical attributes by conceptual or semantic modules, and actions undertaken in response to incoming information (cf Johnson & Chalfonte 1994, Metcalfe 1990, Moscovitch 1994, Schacter 1989). Constituent features of a memory representation are distributed widely across different parts of the brain, such that no single location contains a complete record of the trace or engram of a specific experience (Damasio 1989, Squire 1992). Retrieval of a past experience involves a process of pattern completion (McClelland et al 1995), in which a subset of the features comprising a particular past experience are reactivated, and activation spreads to the rest of the constituent features of that experience.

A memory system that operates in such a manner must solve a number of problems if it is to produce mainly accurate representations of past experience. Features comprising an episode must be linked together at encoding to form a bound or "coherent" representation (Moscovitch 1994, Schacter 1989). Inadequate feature binding can result in source memory failure, where people retrieve fragments of an episode but are unable to recollect how or when the fragments were acquired (Johnson et al 1993, Schacter et al 1984, Squire 1995). As we shall see, source memory failure is an important contributor to various memory illusions and distortions. Source memory failures may also occur when binding processes are unimpaired, but not enough information that is diagnostic of the item's source is included in the bound representation. A closely related encoding process, sometimes referred to as pattern separation (McClelland et al 1995), is required to keep bound episodes separate from one another in memory. If episodes overlap extensively with one another, individuals may recall the general similarities (Hintzman & Curran 1994) or gist (Reyna & Brainerd 1995) common to many episodes, but fail to remember distinctive, item-specific information that distinguishes one episode from another.

Similar kinds of problems arise when retrieving information from memory. Retrieval cues can potentially match stored experiences other than the sought-after episode (Nystrom & McClelland 1992). Thus, retrieval often involves a preliminary stage in which the rememberer forms a more refined description of the characteristics of the episode to be retrieved (Burgess & Shallice 1996, Norman & Bobrow 1979). We have referred to this as a process of "focusing" (Norman & Schacter 1996). Poor retrieval focus can result in recollection of information that does not pertain to the target episode, or may produce impaired recall of an episode's details, insofar as activated information from non-target episodes interferes with recall of target information.

When the pattern completion process produces a match, a decision must be made about whether the information that is delivered to conscious awareness constitutes an episodic memory, as opposed to a generic image, fantasy, or thought. This phase of retrieval involves a criterion setting process in which the rememberer needs to consider the diagnostic value of perceptual vividness, semantic detail, and other kinds of information for determining the origin of the retrieved pattern (Johnson et al 1993). As Johnson et al point out, the use of lax source monitoring criteria increases the probability of accepting images, fantasies, or other internally generated information as evidence of external events that never happened. If retrieved information is accepted as an episodic memory, the rememberer must also determine whether the memory pertains to the sought-after episode or to some other stored episode.

A wide variety of brain regions are likely implicated in these and other aspects of constructive memory functions. For example, recent brain imaging studies, using such techniques as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), indicate that distributed networks of structures are involved in both episodic encoding and retrieval (for reviews, see Buckner & Tulving 1995, Ungerleider 1995). Nonetheless, two brain regions are especially relevant to phenomena of constructive memory: the medial temporal area, including the hippocampal formation, and the prefrontal cortex. It has long been known that the medial temporal region is implicated in memory functions, because damage to this area produces severe impairment of episodic memory for recent events (Squire 1992). Recent neuroimaging data indicate that the medial temporal area is involved in encoding novel events into episodic memory (Stern et al 1996, Tulving et al 1994b). Indeed, a consensus account has begun to emerge regarding how exactly the hippocampus implements feature binding and pattern separation (most recently expressed by McClelland et al 1995; see also Squire & Alvarez 1995, Treves & Rolls 1994). According to this account, distributed patterns of activity in the neocortex (corresponding to individual episodes) are linked to sparse neuronal representations in region CA3 of the hippocampus; essentially, each episode is assigned its own hippocampal "index." Pattern separation is achieved to the extent that the hippocampus is able to assign nonoverlapping CA3 representations to different episodes; some minimal amount of difference needs to exist between episodes, or else the pattern separation process will fail (O'Reilly & McClelland 1994). The hippocampal index corresponding to a particular episode may only need to last until the neocortex "consolidates" the episode (by directly linking all the constituent features of the episode to one another), at which point the index can be assigned to a new episode (Squire & Alvarez 1995; but see Nadel & Moscovitch 1997).

The medial temporal region is also thought to play a role in pattern completion at retrieval (cf Moscovitch 1994). In the account of McClelland et al (1995), during retrieval of recent episodes (for which there is still a hippocampal index corresponding to the episode), cues activate the episode's index in region CA3 of the hippocampus, and activation spreads from the index to all the features comprising that episode. Once an episode has been consolidated in the neocortex, however, activation can spread directly between the episode's features, and the hippocampus no longer plays a crucial role in pattern completion. Although the neuroimaging data on medial temporal contributions to episodic retrieval are not entirely clear cut—many studies have failed to observe medial temporal activity during retrieval (for discussion, see Buckner et al 1995, Shallice et al 1994, Ungerleider 1995)—a number of brain imaging studies have implicated the medial temporal area in the successful recollection of recently acquired information (Nyberg et al 1996; Schacter et al 1995c, 1996a,e; Squire et al 1992).

Prefrontal cortex has also been implicated in episodic memory retrieval. Neuroimaging studies have consistently revealed evidence of prefrontal activity during episodic retrieval, especially in the right hemisphere (for reviews, see Buckner 1996, Nyberg et al 1996, Tulving et al 1994a), and recent data from electrophysiological studies using event-related potentials have provided converging evidence (Johnson et al 1996, Wilding & Rugg 1996). Although the exact nature of the functions indexed by these activations remains to be determined, they appear to tap effortful aspects of retrieval (Schacter et al 1996a) related to focusing or entering the "retrieval mode" (Nyberg et al 1995), post-retrieval monitoring and criterion setting (Johnson et al 1997, Rugg et al 1996), or both (Norman & Schacter 1996).

In summary, CMF emphasizes encoding processes of feature binding and pattern separation, and retrieval processes of focusing, pattern completion, and criterion setting. We have suggested further that medial temporal and prefrontal regions play important roles in various aspects of these component processes. We next consider phenomena of constructive memory in light of this general framework.

PHENOMENA OF CONSTRUCTIVE MEMORY

We have organized our review of recent studies by considering two major phenomena that are central to CMF: false recognition, where people claim that a novel word, object, or event is familiar, and intrusions and confabulations, where people produce nonstudied information in memory experiments (intrusions) or narrative descriptions of events that never happened (confabulations). We subdivide relevant research into four domains of investigation: cognitive experiments with intact individuals, neuropsychological studies of brain-damaged patients, research on aging memory, and brain imaging experiments.

False Recognition: Illusory Familiarity and Recollection

COGNITIVE STUDIES OF NORMAL SUBJECTS One of the most extensively studied examples of false recognition arises in investigations of the effects of misleading postevent suggestions, pioneered by Loftus and her colleagues (for a recent review, see Loftus et al 1995). Such studies typically involve two phases. Participants first view slides or a videotape depicting a sequence of events, and then they are asked questions about the events; some questions contain suggestions of incidents that never occurred. Loftus and colleagues have shown that people falsely recognize as “old” some of the suggested events. Although Loftus’s early claim that suggested information replaces or overwrites the initial event has been challenged (McCloskey & Zaragoza 1985), more recent studies indicate that false recognition in the misleading information paradigm is largely attributable to source monitoring confusions, with people failing to recollect whether the suggested information was originally presented in the videotape or slides, or occurred only in the postevent narrative (e.g. Belli et al 1994, Johnson et al 1993, Lindsay 1990, Zaragoza & Lane 1994). Insofar as thinking about an event frequently involves mentally picturing the event, mere contemplation of a suggested event can result in a vivid and detailed representation that is difficult to distinguish from stored representations of events that were actually perceived. This could sometimes lead individuals to mistakenly ascribe their recollections of an event to the original videotape even though they are also aware that references to the event occurred during postretrieval questioning (Zaragoza & Mitchell 1996; see also Fiedler et al 1996). In addition, participants may not always recognize the need for, or consistently implement, adequate source monitoring. Dodson & Johnson (1993) have shown that false recognition can be reduced by requiring participants to adopt strict source monitoring criteria: College students were less likely to claim that they had seen a picture of an object they had only read about when they were probed about source than when they were given a forced-choice recognition test.

Although studies of misleading suggestions provide a prominent example of false recognition, recent interest in the phenomenon is partly attributable to a demonstration of exceptionally high levels of false recognition by Roediger & McDermott (1995; see also Read 1996). They revived and modified a procedure originally described by Deese (1959) for producing large numbers of intrusions on a free recall test. College students studied a list of semantic associates (presented auditorily), all of which converged on a single nonpresented “theme” word; later, at test, participants frequently false alarmed to the nonpresented word (e.g. subjects who studied *drowsy, bed, tired, pillow, rest, pajamas,* and other associated words later claimed to remember having been exposed to the nonpresented theme word *sleep*). False alarm rates exceeded 70% in some conditions and were nearly as high as the hit rates. Participants expressed as much confidence in these false recognitions as they did in accurate recognitions of previously studied words. Moreover, when asked whether they possessed a specific recollection of having encountered the word (a “remember” response; cf Gardiner & Java 1993, Tulving 1985) or whether it just seemed familiar (a "know" response), subjects provided as many "remember" responses to nonstudied theme words as they did to studied words. (For an example of false "remembering" in the domain of autobiographical memory, see Conway et al 1996). Finally, the strength of the false recognition effect is a direct function of the number of associates presented during study (Robinson & Roediger 1997).

CMF provides two potential explanations for this false recognition effect. One possibility is that false recognition in the Deese/Roediger-McDermott paradigm results from a failure of pattern separation: Studying numerous semantically related words might result in unacceptably high levels of overlap between item representations. Pattern separation failure (i.e. assigning multiple similar items to the same hippocampal index) leads to excellent memory for what the items have in common ("gist" information) but impaired recall of distinctive, item-specific information. Because they lack specific recollection, participants are forced to rely on memory for gist, which does not discriminate well between studied items and nonstudied theme words. This idea is consistent with data from Mather et al (1997) and Norman & Schacter (1997), who examined the qualitative characteristics of subjects' memories and found that both true and false recognition were driven by retrieval of semantic associations (that is, participants typically claimed to "remember" nonpresented lures because they recalled associated items), and also that participants retrieved little item-specific information overall. The idea is also consistent with experiments by Israel & Schacter (1997) in which memory for item-specific information was increased by presenting, at the time of study, distinctive line drawings representing each associated word. Compared with a group that studied only lists of associated words, participants who also studied pictures showed greatly reduced false recognition of semantic associates.

It is also possible to explain false recognition of semantically related lures by appealing to the notion of "implicit associative responses"—the idea that people overtly or covertly generate a nonpresented lure word at the time of study in response to an associate (Underwood 1965). From this perspective, false recognition is viewed as a kind of source confusion, where people fail to recollect whether they actually saw or heard a word at study or generated it themselves. Both of these ideas are consistent with the finding reported by Mather et al (1997) that false recognition effects were larger when semantic associates related to a particular theme word were all presented consecutively (in blocks) than when associates of different theme words were intermixed. Insofar as blocking increases the salience of list themes, it should result in increased generation of theme words, and it should also increase the likelihood that people will notice and encode commonalities between same-theme items, thereby decreasing pattern separation.

Both Mather et al and Norman & Schacter (1997) found that although participants recalled little specific information overall, veridical recognition of previously presented words was accompanied by recollection of more auditory detail from the study phase (i.e. what the word sounded like when it was initially presented) and related contextual information (e.g. reactions triggered by the item at study) than was false recognition. Importantly, however, people were not able to make use of these small qualitative differences to reject theme words; both studies found that requiring subjects to carefully scrutinize their memories during the recognition test, by asking them to indicate whether they could recollect various qualitative details of the items they designated as old, did not reduce the magnitude of the false recognition effect after blocked study (although increased scrutiny did result in diminished false recognition following randomly intermixed study in the Mather et al experiment).

Mather et al also found that, in a situation where different speakers read different study lists, participants were willing to assign a source to a majority of their false recognitions (see also Payne et al 1996). Furthermore, participants did better than chance at choosing the "correct" source for the lures they falsely recognized (i.e. the speaker who read words semantically related to the lure). However, Mather et al found that participants reported no greater vividness of auditory detail for "correct" than for "incorrect" source identifications.

In the Deese/Roediger-McDermott paradigm, it is extremely difficult to tease apart the "implicit associative response" and "pattern separation failure" accounts of false recognition. In other situations, however, interpretation is less ambiguous. The idea that false alarms can be driven by implicit associative responses is supported by studies by Wallace and colleagues (Wallace et al 1995a,b) on false recognition of spoken words. Participants heard a series of spoken sound stimuli in which a nonpresented target word (e.g. January) was disqualified as a candidate early in a nonword (e.g. Jatuary) or late (e.g. Januaty). On a subsequent test, false recognition rates were considerably higher for lure words that had been disqualified late during initial exposure than for those that had been disqualified early. Wallace et al argued that increased false recognition of late-disqualified words could be attributed to the increased probability that subjects internally generated the lure word as part of an activated cohort of physically similar words (Marslen-Wilson & Zwitserlood 1989).

Evidence consistent with false recognition driven by pattern separation failure is provided by Koutstaal & Schacter (1997), who showed people pictures from various categories (e.g. cars, footwear) intermixed with unrelated pictures that did not belong to any of the categories. After a three-day delay, they tested recognition of previously studied pictures, nonstudied pictures that were perceptually and conceptually similar to those previously studied, and new unrelated pictures. Despite the fact that recognition memory for pictures usually yields high hit rates and low false alarm rates, participants showed robust false recognition to similar pictures, particularly when many instances of a category had been presented during study. Koutstaal & Schacter reasoned that it is highly unlikely that participants generated the related picture during the study phase of the experiment, in the same sense that they might generate "sweet" when hearing a list of associates. Rather, false recognition in this experiment appears to be caused by high inter-item similarity, resulting in robust memory for "gist" information about perceptual or conceptual features of studied pictures, but poor memory for picture-specific details.

False recognition also occurs when people miscombine elements of words or other stimuli they have recently studied (e.g. Underwood et al 1976). Drawing on previous work concerning similar kinds of miscombinations in perception (Treisman & Schmidt 1982), Reinitz et al (1992) labeled such distortions "memory conjunction errors." Reinitz et al found significant numbers of memory conjunction errors with stimuli comprised of nonsense syllables; people claimed to have seen conjunction stimuli in which syllables from two previously studied stimuli were recombined. They also demonstrated similar conjunction errors during recognition of faces, when features from separate previously studied faces were conjoined in a single face. Furthermore, Reinitz et al (1994) found that requiring participants to divide their attention between tasks while they studied faces reduced the hit rate for actually studied faces to the same level as the false alarm rate for conjunction faces. Taken together, these results suggest that focal attention during encoding is critically important for binding facial features into a unified representation, and less important for encoding individual facial features.

NEUROPSYCHOLOGICAL STUDIES OF BRAIN-DAMAGED PATIENTS Although neuropsychological studies of memory disorders have long been concerned with the status of recognition memory after brain damage, it is only recently that systematic investigations of false recognition in patients with brain lesions have appeared. Delbecq-Derouesné et al (1990) described a patient (RW) who, after an operation to repair a ruptured anterior communicating artery aneurysm, made an abnormally large number of confident false recognitions. RW showed relatively more preserved free recall of studied items, although he did make many recall intrusions. A CT scan revealed bilateral areas of hypodensity in the medial aspects of the frontal lobes, as well as in the right temporal pole and the fusiform and parahippocampal gyri. Delbecq-Derouesné et al suggested that RW suffered from an impairment in a postretrieval verification or criterion setting process.

Parkin et al (1996) have recently described another patient (JB) who suffered a ruptured anterior communicating artery aneurysm; CT scans showed atrophy in the left frontal lobe. Like RW, JB made a large number of false recognitions that were accompanied by high confidence—he often said that he was “sure” that he had been exposed to target materials that had never been shown to him previously. When asked to make remember/know judgments about previously studied words and nonstudied words, all of JB’s false alarms to nonstudied words were accompanied by “know” responses—that is, JB felt that these items were familiar, and thus was certain that they had appeared in the study list, but he did not have a specific recollection of having encountered them. When JB studied and was tested on various kinds of visual patterns, Parkin et al found that JB did not make excessive numbers of false alarms when distractor items on a recognition test were perceptually dissimilar from studied items.

Schacter & Curran and their colleagues (Curran et al 1997, Schacter et al 1996b) have described a patient (BG) with an infarction of the posterior aspects of the right frontal lobe who in some respects resembles patients RW and JB. BG showed pathologically high rates of false recognition to a wide variety of experimental materials, including words, sounds and pictures, and pseudowords. This phenomenon is not limited to lures that are semantically related to studied items; for example, when BG studied a list of unrelated words, he false alarmed excessively to nonstudied unrelated words. However, as with patient JB, Schacter et al (1996b) found that BG’s pathological false recognition could be sharply reduced by testing him with items that differed substantially from those he had studied earlier (e.g. after studying pictures of inanimate objects from various categories, BG almost never made false recognition responses to pictures of animals). Unlike JB, when asked to make remember/know judgments about test items, most of BG’s false alarms were accompanied by “remember” responses.

Schacter et al (1996b) suggested that BG’s false recognition deficit stems from use of inappropriate decision criteria at test. According to this account, BG claimed to “remember” an item when that item matches the general characteristics of the study episode, whereas control subjects claimed to “remember” that a word or picture had appeared on a study list only when they retrieved specific information about that item’s presentation at study. This criterion-setting deficit might stem from an inability to form an appropriately focused description of the study episode. It is also possible that, in addition to (or instead of) faulty criterion-setting, BG’s false recognition deficit results from failure to encode distinctive item attributes at study. From the perspective of CMF, this would result in excessive feelings of familiarity for attributes common to multiple items at study (including new occurrences of those attributes in lure items), and poor memory for item-specific details.

Using signal detection analyses, Curran et al (1997) found that BG consistently used excessively liberal response criteria compared with matched controls, but there was also evidence of impaired sensitivity. When Curran et al (1997) increased BG's ability to recollect specific details about presented words by providing a semantic encoding task, BG assigned "remember" responses to more than 80% of studied items, but all of his false alarms were "know" responses. These observations suggest that BG can discriminate well between studied and nonstudied items when he has access to "high quality" recollective information about specific studied items; otherwise he relies on a signal that reflects the general similarity between study and test items.

Finally, Curran et al (1997) analyzed exactly what BG claims to recall when he makes a "remember" false alarm and found that he tends to provide associations to other words or sometimes to events in his life—specific information from an inappropriate context. In light of other evidence that frontal lobe damage is associated with impaired memory for source information (Butters et al 1994, Janowsky et al 1989, Milner et al 1991, Schacter et al 1984), it seems likely that deficient source monitoring (inability to assess whether an association triggered by an item at test is a memory from the study phase, or comes from some other episode, or is being generated for the first time at test) contributes to the character of BG's false recollections.

Excessive levels of false recognition of related lures have also been reported in studies of patients whose cerebral hemispheres have been surgically separated. Phelps & Gazzaniga (1992) showed two split-brain patients, JW and VP, slide sequences depicting everyday scenes (making cookies, bowling) and then tested yes/no recognition of previously studied slides, "schema-consistent" lures that had not been studied but that fit with the studied scene, and "schema-inconsistent" lures that were unrelated to the studied scene. Hits and false alarm rates to studied slides and unrelated lures did not differ as a function of hemisphere, but left hemisphere responses were associated with more false alarms to schema-consistent lures than right hemisphere responses. Metcalfe et al (1995) tested split-brain patient JW, and found that JW's left hemisphere made more false alarms than the right hemisphere to related words, faces, and visual patterns. The authors of both studies explain their findings in terms of hemispheric differences in encoding: The left hemisphere is thought to be biased toward "schematic" (categorical, gist) information, whereas the right hemisphere encodes more item-specific details and hence is better positioned to discriminate between studied and nonstudied schema-consistent items (cf. Chiarello & Beeman 1997).

The foregoing studies indicate that increased susceptibility to false recognition is associated with ventromedial and posterior frontal lobe damage, and with left hemisphere functioning in split-brain patients. More research is needed to pinpoint the exact kinds of frontal lobe damage that trigger increased false recognition. In any case, none of these patients exhibited the severe and pervasive memory loss observed in amnesic syndromes associated with damage to the medial temporal lobes, which have been the focus of extensive neuropsychological study (e.g. Parkin & Leng 1993, Squire 1992). Several recent experiments have begun to explore false recognition in amnesic patients, with sharply contrasting results emerging from different types of false recognition paradigms.

Two recent studies have examined memory conjunction errors using variants of the procedures introduced by Reinitz et al (1992). Reinitz et al (1996) found that normal controls made more "old" responses to studied compound words (e.g. *handstand* and *shotgun*) than to conjunction lures in which features of studied words were recombined (e.g. *handgun*), but amnesic patients failed to discriminate between studied words and conjunction lures (primarily because they made fewer "old" responses to studied words than controls). Kroll et al (1996) reported increased memory conjunction errors to recombined words in patients with left but not right hippocampal lesions, and increased conjunction errors to combined faces for both types of patients. Conjunction errors to words were more pronounced when items from which features were combined were separated by only a single item during the study phase than when they were separated by five items (lag was not manipulated for face stimuli). Kroll et al suggested that hippocampal lesions produce disinhibited binding, such that the damaged system binds features from different stimuli across an excessively broad temporal window.

In contrast to the aforementioned findings of normal or even increased levels of false recognition to conjunction lures in patients with medial temporal lobe damage, two recent experiments have revealed reduced levels of false recognition in these patients. Schacter et al (1996f), using a procedure similar to Roediger & McDermott (1995), found that amnesic patients showed reduced levels of false recognition to semantic associates of previously studied words. These findings imply that encoding, retention, and/or retrieval of the information that drives false recognition in this paradigm depend on the medial temporal and/or diencephalic brain regions that are damaged in amnesic patients. Schacter et al (1997b) replicated the Schacter et al (1996f) results with a different set of semantically related words (Shiffrin et al 1995) and extended them to the domain of perceptual false recognition: Amnesic patients made fewer false alarms than did matched controls to nonstudied words (e.g. *fate*) that were orthographically and phonologically similar to previously studied words (e.g. *lake, fake*). Conceptual false recognition in the control group was associated primarily with "remember" responses, whereas perceptual false recognition was associated primarily with "know" responses. The fact that amnesic patients showed similarly reduced levels of false recognition for both types of responses implies that structures that are damaged in amnesic patients are relevant to both of these forms of explicit memory (cf Knowlton & Squire 1995).

In all the foregoing neuropsychological investigations, false recognition occurred in the context of an episodic memory test: Participants were asked to make their old and new judgments with respect to a specific episode (the study phase). Rapcsak and colleagues (Rapcsak et al 1994, 1996) have recently described a different kind of false recognition in which patients, asked whether they have ever seen a particular face, claim that unfamiliar faces are familiar to them. These patients are characterized by damage to posterior regions of the right hemisphere and, in some instances, damage to the right frontal lobe. Rapcsak et al argue that in most patients, false recognition is attributable to impaired face perception; patients tend to rely on isolated facial features when making recognition decisions. However, one of these patients (with a right frontal lesion) did not suffer from obvious perceptual deficits. Rapcsak et al argue that this patient’s false recognition problem stems from an inability to engage strategic monitoring and criterion setting processes. Although the relationship between false recognition of this sort and false recognition on episodic memory tests (e.g. Curran et al 1997, Parkin et al 1996, Schacter et al 1996b) remains to be elucidated, the fact that both kinds of impairment can occur after right frontal lobe damage suggests that the relation between the two merits closer examination in future studies.

AGING MEMORY Early studies of aging memory reported that elderly adults show increased false recognition of semantically related distractors in paradigms, where young adults show relatively small false recognition effects (Hess 1984, Rankin & Kausler 1979, Smith 1975). More recent studies have replicated these findings (Isingrini et al 1995) and extended them to paradigms that produce high levels of false recognition even in younger adults (see Schacter et al 1997c).

Norman & Schacter (1997) reported that older adults show increased susceptibility to false recognition of semantic associates in the Deese/Roediger-McDermott converging associates paradigm (discussed above). Like younger adults, elderly individuals expressed high confidence in their false memories, frequently claimed to “remember” nonpresented words, and, when asked to rate various qualitative features of their memories, indicated that false recognitions were based primarily on recollection of semantically associated items. However, memory for auditory details of the initial presentation discriminated less well between true and false recollections in older than in younger adults, suggesting that failure to retrieve specific sensory details is related to age-related increases in false recognition (although it is unclear whether sensory details are not encoded in the first place, or whether they are encoded but not recalled due to interference from similar studied items). Because older adults showed increased susceptibility to false recognition even when they were instructed to rate the qualitative characteristics of their memories (Experiment 2) or to provide explanations of what they remembered (Experiment 1), the age effect is probably not attributable to a failure to consider relevant memorial attributes (cf Multhaup 1995). Tun et al (1996) have reported additional evidence of age-related increases in false recognition with a similar paradigm, using both accuracy and latency measures.

Although the foregoing experiments all used verbal materials, two recent studies examined whether older adults show increased false recognition after studying scenes or pictures. Schacter et al (1997b) exposed participants to videotaped scenes of everyday events and later showed them photographs of some previously viewed actions, together with actions that had not been seen previously. On a subsequent recognition test, participants were given brief verbal descriptions of individual objects or actions and instructed to respond “old” only when they specifically remembered seeing the object or action in the videotape; participants were explicitly warned that some of the items on the recognition test occurred only in photographs. Older adults showed greater false recognition of objects and actions that had appeared only in photographs than did younger adults.

The false recognition effect observed by Schacter et al (1997a) is clearly attributable to source confusion on the part of elderly adults; participants had actually seen photographs of the falsely recognized actions earlier. This observation fits with other evidence indicating that older adults often exhibit disproportionately impaired source memory compared with younger adults (e.g. Brown et al 1995, Johnson et al 1995, Schacter et al 1994). Additional analyses conducted by Schacter, Koutstaal, and colleagues (on data from their Experiment 2) showed that, as with the results described earlier from the Deese converging associates paradigm, elderly subjects were not successful at retrieving perceptual and contextual details that could be used to differentiate sources. Therefore, in this paradigm, source confusions are not simply a matter of recollecting useful contextual information and then failing to make use of it.

Koutstaal & Schacter (1997) compared older and younger adults using their picture recognition paradigm (discussed above), in which participants study exemplars of pictures from various categories intermixed with unrelated pictures, and later make old/new recognition judgments about previously studied pictures, related lure pictures, and unrelated lure pictures. Older adults consistently exhibited higher levels of false recognition of related pictures than did younger adults; older adults also showed normal hit rates to studied pictures from large categories and impaired hit rates to unrelated pictures. Overall, this pattern of results indicates age-related preservation of access to general similarity information (driving both hits and false alarms to items from studied categories) together with age-related impairment of access to item-specific, distinctive information (thereby explaining impaired hit rates to unrelated pictures).

Although the exact mechanisms remain to be elucidated, within CMF such effects could be attributable to impaired pattern separation in older adults, caused either by generally indistinct encoding or by specific impairment of the hippocampal mechanisms involved in pattern separation and binding. This latter idea is consistent with PET evidence indicating decreased hippocampal activation during encoding of novel faces in the elderly (Grady et al 1995). Alternatively, the effects described above could be attributable to a failure to engage in effortful focusing processes that facilitate retrieval of item-specific information. This idea is consistent with PET evidence showing abnormal frontal lobe activations in the elderly in test conditions that require effortful retrieval (Schacter et al 1996e). One final possibility is that elderly adults do successfully recollect item-specific information but fail to use this information when making their recognition decisions (i.e. a criterion-setting deficit).

BRAIN IMAGING STUDIES Despite the recent surge of brain imaging studies of memory noted earlier, only a handful of recent studies have examined false recognition. In a PET study, Schacter et al (1996d) adapted procedures from Deese (1959) and Roediger & McDermott (1995) to examine brain activity of healthy young individuals during true versus false recognition. Compared with a control condition in which participants fixated on a crosshair, a variety of brain regions showed significant blood flow increases for both true and false recognition, including several areas previously implicated in episodic retrieval: anterior prefrontal cortex, medial parietal cortex, left middle temporal gyrus, cerebellum, and left parahippocampal gyrus. Although direct comparison between true and false recognition yielded little evidence of significant blood flow differences, two suggestive trends were evident in this comparison. First, there was evidence of increased left superior temporal activity during veridical recognition; the activity may reflect memory for auditory rehearsal at study, which presumably occurred more for studied items than nonstudied associates. Second, there was a trend toward increased right anterior prefrontal activity during false recognition. This trend was replicated and extended in an fMRI study conducted by Schacter et al (1997a). In addition, using new fMRI procedures that allow analysis of the time course of blood flow increases (Buckner et al 1996), they documented a late onset of anterior prefrontal activations relative to other brain areas. This latter finding suggests that anterior prefrontal activations during false recognition reflect processes that operate on the output of the memory system, such as postretrieval monitoring or criterion setting (cf Rugg et al 1996, Schacter et al 1996d).

Johnson et al (1997) used ERPs to investigate true and false recognition of semantically related words. They found that when studied words, nonstudied semantic associates, and nonstudied unrelated words were tested for recognition in separate blocks (as required by PET), ERP differences between true and false recognition were observed at frontal and left parietal electrode sites, providing a good fit with the PET data. However, when the word types were randomly intermixed during recognition testing (as is usually done in purely cognitive experiments), differences were greatly attenuated (cf Düzel et al 1997). Johnson et al (1997) noted that, in the randomly intermixed testing condition, participants could do reasonably well by relying on semantic similarity information alone (i.e. they could reject nonstudied unrelated items). However, with blocked testing, semantic similarity information does not discriminate well between items of a particular type, and hence participants may have used stricter criteria (e.g. trying to recall perceptual details) in this condition.

Intrusions and Confabulations

Evidence concerning false recognition leaves open the question of whether people recall on their own nonpresented items or events that never happened. This question is addressed by research concerning recall intrusions, where nonstudied information is produced together with previously studied information, and confabulation, where people provide narrative accounts of events that did not occur.

COGNITIVE STUDIES OF NORMAL SUBJECTS It is known that people sometimes produce incorrect items on free recall tests, but such recall intrusions are usually infrequent. In contrast, using the lists of semantic associates described earlier with respect to false recognition, Deese (1959) demonstrated that participants often intrude nonpresented false targets that are strong associates of previously presented words. A large number of recent studies, beginning with Roediger & McDermott (1995), have explored the parameters of this false recall effect. In general, manipulations that affect false recognition of semantic associates in the Deese/Roediger-McDermott paradigm affect false recall in a similar fashion. For example, McDermott (1996) found that false recall occurs more frequently when semantic associates of a particular theme word are studied in a block, as opposed to being randomly intermixed with associates of other theme words.

An important observation is that false recall appears to be more enduring than recall of studied items: McDermott (1996) found that when participants were tested two days after study, false recall of critical lures exceeded correct recall of studied words (see Payne et al 1996, for a similar finding with false recognition). Moreover, Robinson & Roediger (1997) found that while veridical recall is reduced by adding unrelated filler items to the study list, false recall is unaffected by this manipulation. McDermott (1996) also found that false recall persisted even when associate lists were repeatedly presented and tested, thereby providing multiple opportunities for participants to notice that lure words were not actually presented. There was some reduction of false recall across repeated trials, implying that people could make use of increasingly available item-specific information to suppress false recalls (cf Brainerd et al 1995, Hintzman et al 1992), but even after five trials participants still produced over 30% of the critical lure words.

Although it may seem paradoxical for false recall to be more robust than accurate recall, this follows from the fact that semantic features of the nonpresented theme word occur multiple times at study (insofar as they are shared and activated by several individual list items), whereas the features that distinguish a specific list item from other items occur less frequently (unless study lists are presented repeatedly). Payne et al (1996) found that providing repeated recall tests (without any intervening study trials) resulted in consistent but small increases in false recall across trials, whereas veridical recall showed little evidence of across-test increases; this may occur because list items cue the critical lure but do not cue each other.

False recall in the Deese/Roediger-McDermott paradigm (like false recognition in this paradigm) could result from subjects having generated the lure at study (and then making a source monitoring error), or simply from the semantic features of the lure having been strongly activated at study. As such, it belongs to a large class of intrusion phenomena in which the intruding information was either activated or generated earlier in the experiment. Along these lines, Roediger et al (1996) reported that subjects in post-event misinformation experiments will intrude misleading post-event suggestions on free recall tests. Another relevant example is the memory distortion known as “boundary extension”: After having viewed a partial photograph of a scene, people tend to recall having seen a larger expanse of the scene than they actually did; the boundaries of the scene are “extended” in memory (Intraub et al 1992, 1996). Intraub et al argue that boundary extension reflects the fact that during scene perception, information about the expected layout of a scene is automatically activated.

From the perspective of CMF, recall distortion can also occur when people fail to construct a retrieval cue that is fully consistent with information in the target trace. Insofar as recall is a pattern completion process that seamlessly merges the retrieval cue with retrieved information, any inaccuracies in the cue might be carried over to the output of the pattern completion process. For example, during the phase of retrieval we have called "focusing," people may use schematic knowledge (information that is easily accessed because it has been encountered on multiple occasions) and information that is present in the test environment to construct cues, which in turn are used to access specific past episodes. Normally, this process produces reasonably accurate memory, but distortions of recall can arise when schematic knowledge or physical retrieval cues fail to accurately describe a particular episode. For example, Bahrick et al (1996) found that students with high grade-point averages tended to inflate their grades in classes where they did not get As, in keeping with the general idea that they received As most of the time (for another example of schema-driven recall errors, see Vicente & Brewer 1993). Also relevant here are studies of retrospective bias: distorted recollection of past perceptions and attitudes that is driven by present knowledge and beliefs (cf Dawes 1988, Ross 1989). For example, when supporters of Ross Perot recalled after the November 1992 election how they felt when Perot temporarily dropped out of the race in July 1992, their recollections were systematically biased by their present feelings toward Perot (Levine 1997). Retrospective bias can be thought of as a special case of the general principle that recall distortion will occur when the retrieval target (e.g. what one thought of Ross Perot in June 1992) is inconsistent with presently available knowledge (e.g. what one thinks of Ross Perot now).

Ochsner et al (1997) have reported a somewhat different, but related, type of recall bias. College students studied faces while listening to a corresponding voice speaking in an angry or happy tone. Ochsner et al reported that participants later tended to recall that faces with slightly positive expressions had been accompanied by a happier tone of voice than faces with slightly negative expressions, even though there was no relation between facial expression and tone of voice. This is yet another situation in which information present in the retrieval cue overshadows information present in the target trace. Although contemporary models allow for such effects (e.g. McClelland 1995), there has been little attempt thus far to consider them from a cognitive neuroscience perspective.

The studies of intrusions and retrospective biases reviewed thus far do not address whether normal adults can be induced to recall entire events that never happened. In a well-known study by Loftus (1993), young adults were asked by their relatives to try to remember a childhood event that had never occurred—being lost in a shopping mall. After repeated questioning, four of five participants in an initial study developed detailed recollections of the false event. Studying a larger sample, Loftus & Pickrell (1995) reported that approximately 25% of participants developed detailed false recollections. One limitation of such a procedure is that the experimenter has no way of knowing whether the suggested event did, in fact, occur. Since most people presumably have been lost at least sometime in their lives, it is possible that such veridical experiences may provide the basis for the false recollection. Using a slightly different procedure, Hyman and colleagues queried college students about actual events from their childhood, as well as fabricated but exceedingly improbable events, such as causing an accident by releasing a parking brake when left alone in a car. Hyman et al (1995) reported that none of their sample provided false memories when initially queried about such events, but after being repeatedly questioned, about 25% falsely recalled at least one of the fabricated events. In follow-up studies, Hyman & Pentland (1996) found that the probability of false event recall was increased significantly by instructions to imagine the suggested event. Imagery has also been implicated in the related phenomenon of "imagination inflation," where simply imagining an event leads to increases in subjective estimates of the likelihood that the event actually occurred (cf Garry et al 1996).

Although the mechanisms of these "confabulatory" false recall effects remain poorly understood, source confusions may play a role: As people repeatedly think about or imagine an event, they may retrieve fragments of other actual events, without recognizing them as such. Furthermore, the more that a person thinks about an event, the easier it becomes to retrieve details pertaining to that event; numerous studies have shown that retrieval fluency is a key determinant of whether a particular conscious experience is interpreted as a memory (cf Jacoby et al 1989, Lindsay & Kelley 1996; see also Rankin & O'Carroll 1995). In addition, a PET study conducted by Kosslyn et al (1993) found that visual imagery activated some of the same brain regions as visual perception. These results suggest that visual imagery may enhance the subjective reality of falsely recalled events because it draws on some of the same neural circuitry as does veridical perception (see also Silbersweig et al 1995).

NEUROPSYCHOLOGICAL STUDIES OF BRAIN-DAMAGED PATIENTS Confabulatory responses in brain-damaged patients—spontaneous narrative reports of events that never happened—have been known to neurologists and neuropsychologists for decades (for reviews, see Johnson 1991, Moscovitch 1995). In addition, more recent experimental studies have examined intrusions on free recall tests in various patient populations. Although confabulations and intrusions are sometimes treated synonymously (e.g. Kern et al 1992), we prefer to examine them separately and leave open questions about the nature of their relations. We first summarize recent studies of intrusions and then consider confabulatory phenomena.

Schacter et al (1996f) examined false recall of semantically related lures in amnesic patients using the previously described procedures developed by

Deese (1959) and Roediger & McDermott (1995). They found that, while both veridical and false recall were impaired in amnesics, false recall was relatively more preserved. The robustness of false recall can be explained in terms of the fact, discussed above, that the constituent semantic features of nonpresented theme words were activated multiple times at study (presumably resulting in increased trace strength). Overall, the results from this experiment suggest that amnesics' free recall consists entirely of degraded semantic gist information, whereas normal controls recall both gist information and specific information about individual items.

Dalla Barba & Wong (1995) found that both amnesic patients and patients with memory deficits attributable to Alzheimer's disease (AD) made an abnormally large number of intrusions when they studied items from various categories and were cued with category names. Neither patient group showed an excessive number of intrusions on a free recall test. From this, we can conclude that intrusions are likely to occur when subjects are faced with strong retrieval cues ("strong" in the sense that it is easy to think of specific fruits in response to the category cue "fruit"), but memory traces are degraded. Studying items along with category names helped alleviate cued-recall intrusions in patients with intact semantic memory but not in patients with impaired semantic memory.

A major focus in recent studies of intrusion errors concerns whether and to what extent the tendency to make intrusion errors is related to frontal lobe damage. Two of the frontally lesioned patients discussed earlier who showed robust false recognition (JB, studied by Parkin et al 1996, and RW, described by Delbecq-Derouesné et al 1990) also made an abnormally high number of intrusion errors on free recall tests. These patients both suffered damage to the ventromedial regions of the frontal lobes (and possibly adjoining brain regions), brought on by ruptured anterior communicating artery aneurysms. Interestingly, patient BG (Curran et al 1997, Schacter et al 1996b), whose lesion is limited to the posterior lateral frontal lobe (and does not include ventromedial frontal cortex), is extremely susceptible to false recognition errors but does not show abnormally high levels of intrusion errors on free recall tests (KA Norman, W Koutstaal, DL Schacter & L Galluccio, unpublished data).

Group studies of recall intrusions in frontal-damaged patients have found mixed results, which is not surprising in light of the heterogeneity of lesion sites and etiologies in these patients (as well as the heterogeneity of recall paradigms used in these studies). Stuss et al (1994) failed to find abnormally high intrusion rates in patients with unilateral and bilateral frontal lobe damage on immediate free recall of categorized and unrelated word lists. By contrast, I Daum, A Mayes, Y Schwarz & R Lutgehetman (manuscript in preparation) found that patients with unilateral frontal lobe lesions made more intrusion errors than patients with posterior cortical lesions and normal controls on delayed recall of stories, categorized word lists, and dot patterns. Kern et al (1992) found that intrusion errors on story recall, design recall, and object recall tests were slightly (nonsignificantly) greater in Alzheimer's disease (AD) patients with relatively impaired frontal functioning than in AD patients with relatively intact frontal functioning. However, it is unclear whether this association is specifically related to frontal lobe dysfunction or whether it simply reflects global severity of deficit.

Following up on Dalla Barba & Wong's (1995) findings, Dalla Barba et al (1995) also used a category-cued recall test to examine the relation between intrusion errors, performance on neuropsychological tests of frontal lobe dysfunction, and awareness of memory deficit (anosognosia; McGlynn & Schacter 1989) in AD patients. Dalla Barba et al found a strong relationship between intrusion errors and degree of anosognosia, such that patients who were unaware of their memory deficits made more intrusion errors than those who exhibited awareness of deficit. Since anosognosia is often associated with frontal lobe impairment (McGlynn & Schacter 1989, Stuss 1991), this relationship indirectly suggests a link between intrusion errors and frontal impairment. The only "frontal" measure that correlated with intrusion errors and awareness of deficit was verbal fluency; intrusion errors and awareness of deficit were uncorrelated with performance on tests thought to tap (primarily dorsolateral) frontal functioning, including card sorting, sequencing, and cognitive estimation.

Questions concerning the role of frontal lobe damage have also assumed paramount importance in discussions of confabulation. The general features of confabulation are well summarized by Johnson (1991), Moscovitch (1995), and Burgess & Shallice (1996). Confabulations are typically false narrative accounts of personal experiences, although under some conditions patients may confabulate about factual knowledge (cf Dalla Barba 1993, Moscovitch 1995, Moscovitch & Melo 1997). Confabulations usually draw upon bits and pieces of the patient's actual past experiences, with episodes confused in time and place, but confabulated autobiographical memories may sometimes incorporate knowledge acquired from other sources. Confabulations are typically not intentionally produced and do not appear to be measured attempts to attract attention or compensate for memory loss (though also see Conway & Tacchi 1997). Patients typically present confabulations without awareness that their memories are false, and are more generally unaware of their own memory deficits (e.g. McGlynn & Schacter 1989). Confabulation usually occurs together with anterograde amnesia (i.e. poor memory for recent events). Finally, confabulations may sometimes contain bizarre or "fantastic" content (Kopelman 1987, Talland 1965) that patients nonetheless accept as veridical.

A number of early case reports of confabulation described patients with damage to the ventromedial aspects of the frontal lobes (e.g. Stuss et al 1978), particularly on the right (e.g. Joseph 1986). Damage limited to dorsolateral frontal regions does not appear to produce confabulation; conversely, confabulating patients frequently perform well on tasks that are sensitive to dorsolateral frontal damage, such as cognitive estimation and card sorting (Dalla Barba 1993, Dalla Barba et al 1990). More recently, Benson et al (1996) described a case of alcohol-induced Korsakoff amnesia in which the patient exhibited spontaneous confabulation together with severe memory loss during the early phases of the disorder. Single photon emission (SPECT) scanning at this time revealed hypoperfusion (low blood flow) in the medial diencephalic brain region typically associated with memory loss in Korsakoff patients, as well as hypoperfusion in the orbitomedial frontal lobe. When the patient was assessed again four months later, amnesia persisted but confabulation had disappeared. Repeat SPECT scanning revealed continuing hypoperfusion in the medial diencephalic region but normal perfusion in the frontal regions that had previously shown abnormal blood flow (see also Conway & Tacchi 1997).

Importantly, observations of patients with ruptured aneurysms of the anterior communicating artery (ACoA) suggest that ventromedial frontal lesions are not sufficient to produce confabulation. Ruptured ACoA aneurysms can result in damage to a wide range of structures in the general region of the ventromedial frontal lobes, including (but not limited to) the basal forebrain and the head of the caudate nucleus. The basal forebrain is closely linked to the hippocampus, and ACoA patients with basal forebrain damage show a form of amnesia (for a review of the neuropsychological consequences of ACoA damage, see DeLuca & Diamond 1995; Moscovitch & Melo 1997). Confabulation is reasonably common following ruptured ACoA aneurysms (especially during the acute phase that immediately follows rupture), and a number of recent studies have examined groups of ACoA patients with the goal of relating confabulatory symptoms to underlying neuroanatomical damage. These studies have established that both ventromedial frontal lobe damage and amnesia subsequent to basal forebrain damage must be present in order for lasting confabulation to occur; neither kind of damage on its own seems to suffice (DeLuca 1993).

While some progress has been made in understanding the brain regions associated with confabulation, and the domains of confabulation are beginning to be specified (e.g. episodic vs semantic memory; cf Dalla Barba 1993, Moscovitch 1995), there has been relatively little experimental work that allows firm conclusions about the nature of the memory processes that are compromised in patients who confabulate and/or show robust free recall intrusions. In general, theoretical attention has focused on impaired criterion setting and monitoring processes (e.g. Burgess & Shallice 1996, Conway & Tacchi 1997, Johnson 1991, Moscovitch 1995). Norman & Schacter (1996) point out that theories of confabulation need to explain why incorrect information comes to mind in the first place (in addition to why subjects fail to reject this incorrect information). From the perspective of CMF, one possibility is that focusing processes are impaired in confabulating patients (i.e. they submit vague cues to memory, or cues that are inordinately biased by the individual's present internal and external environment). Another possibility is that the process of pattern completion is itself dysfunctional. Regarding this latter possibility, the basal forebrain (which is damaged in ACoA patients who confabulate) is a major source of the neurotransmitter acetylcholine, and Hasselmo (1995) has argued that acetylcholine plays a key role in regulating the dynamics of pattern completion processes in the hippocampus and other brain structures.

One final unresolved issue is the relationship between intrusions, confabulation, and false recognition. Neuroanatomically, all three deficits appear to require damage to either posterior or ventromedial prefrontal cortex. Functionally, this damage probably relates to monitoring and criterion-setting deficits that are present, to some extent, in all three syndromes (if these processes were unimpaired, patients would be able to reject nontarget information). Based on data from patient BG (whose lesion is limited to posterior prefrontal cortex), it appears that frontal damage by itself is sufficient to cause false recognition. However, at least in ACoA patients, both ventromedial frontal and basal forebrain damage must be present in order for confabulations or robust free-recall intrusions to occur. The fact that the critical lesion for intrusions and confabulations extends outside of prefrontal cortex is consistent with the claim that poor monitoring (resulting from frontal lobe damage), in and of itself, is not sufficient to explain retrieval of incorrect information; some other functional deficit has to be present. Finally, it appears that free-recall intrusions can occur in the absence of confabulation (e.g. Parkin's patient JB shows a strong tendency to make free-recall intrusions despite the fact that he no longer confabulates spontaneously), suggesting that confabulation involves additional functional deficits or that confabulation is a more extreme manifestation of the same functional deficits that are responsible for free-recall intrusions.

AGING MEMORY There has been comparatively little systematic investigation of false recall in normal aging. Two recent studies have shown that older adults are more susceptible to false recall of semantic associates in the Deese (1959) paradigm than are younger adults. In each of two experiments, Norman & Schacter (1997) found that older adults recalled fewer previously studied items and intruded more related false targets than did younger adults. In Norman & Schacter's experiments, associate lists were presented together in blocks, as in Roediger & McDermott (1995). Tun et al (1996) randomly intermixed the associate lists during presentation and found that whereas older adults recalled fewer studied items than younger adults, they produced just as many semantically related lures. As with false recognition, these age-related increases in false recall (relative to correct recall) could be attributable to source confusions, over-reliance on gist information, or both.

CONCLUDING COMMENTS

Cognitive neuroscience has embraced the strategy of attempting to understand how a particular process works by studying how it malfunctions. In memory research, this strategy has led to productive investigations of amnesic syndromes in which patients recall little new information, either correct or incorrect. This research has yielded a rich body of knowledge specifying which neural circuits are responsible for storing and retrieving episodic memories. However, this focus on "absent" memory has diverted researchers from studying situations where memory is present but wrong; that is, situations in which people claim to remember past episodes that did not actually occur (cf Koriat & Goldsmith 1996). In this review, we have examined evidence concerning memory inaccuracies from the perspective of CMF.

A large part of CMF is concerned with the need for pattern separation at encoding, and focusing at retrieval. That is, episodes need to be stored in a manner that allows them to be accessed separately at test, and retrieval cues need to be specific enough to activate only a single episode. If either of these conditions is not met, then multiple episodes will be accessed at test; when this occurs, details that differ from episode to episode will compete, resulting in poor memory for differentiating or "source specifying" (Johnson et al 1993) details. However, between-episode competition should not adversely affect features that are common to many episodes—the gist or general similarity information that is often implicated in memory distortions and that has been the focus of theoretical interest (Hintzman & Curran 1994, Reyna & Brainerd 1995).

Once information has been retrieved, decision-making or criterion-setting processes need to be engaged, to evaluate whether it pertains to the target episode. Decision making/criterion setting is logically distinct from the retrieval process we have called focusing, but we should note that postretrieval monitoring processes require a focused description of the target episode (otherwise, there would be no way of assessing whether or not retrieved information is accurate; for additional discussion, see Norman & Schacter 1996). An important area for future research, particularly with brain imaging techniques, will be to examine the relation between processes involved in focusing and postretrieval monitoring/verification.

We have found CMF to be useful in classifying and thinking about different kinds of memory distortions. However, the vast majority of extant data on memory distortions cannot be classified or understood unambiguously. For example, false recognition of nonstudied pictures from studied categories can, at first pass, be explained by either pattern separation failure at encoding or lax criterion-setting or poor focusing at retrieval. Clearly, these are quite different (although not mutually exclusive) claims about the nature of the underlying deficit. We hope that by articulating different ideas regarding how and why different memory distortions occur, we will spur researchers to generate experiments that disentangle and specifically test such alternative hypotheses.

In conclusion, the problems inherent in retrieving accurate, episode-specific information from a system with the biological and functional properties of human memory are complex. Our attempts to understand how the brain accomplishes this difficult task are still in their infancy, and much theoretical and empirical work remains to be done. Fortunately, the neurobiology of memory has progressed to the point where this is a reasonable and even promising enterprise; we see in the research reviewed here the seeds of a cognitive neuroscience of constructive memory that should bear much fruit in the years to come.

ACKNOWLEDGMENTS

Preparation of this paper was supported by the National Institute on Aging grant AG08441 and by a grant to the second author from the Sackler Scholar Programme on Psychobiology. We would also like to thank Lissa Galluccio for her assistance.

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