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Cognitive and Brain Mechanisms of False Memories and Beliefs

2

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This chapter describes some of the cognitive processes that give rise to false memories and beliefs and discusses possible underlying brain mechanisms. Cognitive studies of normal individuals, in combination with observations from neuropsychology and psychopathology, and with evidence from newer brain imaging techniques, permit a reasonably rich characterization of how distortion may come about. Such distortions include both everyday errors and the more profound constructions and fabrications categorized as confabulations and delusions.

Despite some differences in terminology, theoretical ideas about normal distortions of memory and belief (for example, Bartlett, 1932; Bransford and Johnson, 1973; Ceci and Bruck, 1993; Hasher, Goldstein, and Toppino, 1977; Johnson and Raye, 1981; Loftus, 1979; Roediger, 1996; Ross, 1989; Schacter, 1995; Zaragoza, Lane, Ackil, and Chambers, 1997) and about delusions and confabulation (Baddeley, Thornton, Chua, and McKenna, 1996; Burgess and Shallice, 1996; Conway, 1992; Dalla Barba, 1995; Frith, 1992; Johnson, 1988, 1991; Kopelman, 1987; Maher, 1974; Moscovitch, 1989, 1995; Norman and Schacter, 1996; Stuss, Alexander, Lieberman, and Levine, 1978), converge on a common set of themes—for example, the constructive and reconstructive nature of memory, the importance of retrieval cues, and the need for monitoring mechanisms. Our discussion is organized around the source monitoring framework (SMF) (Johnson, 1988, 1991; Johnson and Raye, 1981, 1988), an integrative approach that incorporates these central themes and also provides a developed description of the evaluation or monitoring functions that most theorists agree are critical to understanding confabulations and delusions.

False Memories and Beliefs

The phenomena in which we are interested include everyday distortions of memory (remembering that a conversation took place in a restaurant when it actually took place in a car) and erroneous beliefs (most people on welfare are black), as well as clinically significant phenomena such as confabulations (remembering a trip on a spacecraft) and delusions (believing that someone is controlling your thoughts). For present purposes, we will not make a sharp distinction between memory and belief in discussing normal cognition, or between confabulation and delusion in talking about abnormal cognition. We believe the cognitive processes described in this paper apply to both (see also Kopelman, Guinan, and Lewis, 1995). However, it should be emphasized that what people *call* memories and beliefs reflects the outcomes of these source monitoring processes. People tend to use the word "memory" when a mental experience or report of a mental experience is detailed, including information indicating that one experienced the event oneself, and they tend to use the word "belief" when it does not have contextual details and for a broad range of mental experiences or reports that seem to assert present or past general states of affairs which may or may not involve personally experienced events (including the events from which the belief was derived, such as reading the newspaper). Nevertheless, where veridicality is concerned, it is difficult to draw a sharp distinction between the concepts of memory and belief. Memories are beliefs about what happened, and beliefs are constructed from, and reinforced by, memories.

In the neuropsychological and clinical literatures, the term "confabulation" is often used to refer to a false memory and "delusion" to a false belief, but the usage is not consistent. It is equally likely to be driven by etiology: distortions of memory and belief that are associated with known or presumed *brain damage* tend to be called confabulations, and distortions of memory and belief associated with *psy-*

chopathology tend to be called delusions. As evidence accumulates that patients with psychotic delusions may have brain pathology in some of the same or related brain areas as do confabulating organic brain-damaged patients or abnormalities in one or more neurotransmitter systems (Frith, 1992; Gray, 1995), an etiology-based distinction between delusions and confabulations becomes questionable.

The Source Monitoring Framework (SMF)

Two earlier papers outlined an approach to understanding delusions (Johnson, 1988) and confabulations (Johnson, 1991) based on theoretical ideas derived from cognitive studies of reality monitoring and source monitoring. According to this view, false perceptions, false memories, and false beliefs can all be understood within a common source monitoring framework.

> The characteristics of mental experience that provide it with the quality of reality are similar for perception, event memories, and beliefs: sensory detail; embeddedness in spatial and temporal context; embeddedness in supporting memories, knowledge, and beliefs; and the absence of consciousness of or memory for the cognitive operations producing the event or belief. Reality testing of ongoing perception and reality monitoring of memories and beliefs are complex judgment processes that are subject to error and more difficult in some situations than others. (Johnson, 1988, p. 57)

A characterization of those judgment processes provided the background for suggestions about the various ways that distortions in memories and beliefs could come about through pathological operation of normal processes (such as rehearsal and embellishment) or disruption of normal processes as a consequence of brain damage (retrieval deficits or failure to access cognitive operations). Because much of the relevant evidence has been described elsewhere (Johnson, 1997a; Johnson, Hashtroudi, and Lindsay, 1993; Mitchell and Johnson, forthcoming), here we will highlight certain central ideas and further consider the brain mechanisms that are implicated (see also Johnson, 1997b).

The SMF assumes that memories consist of distributed features, more or less well bound together, that are a result of perceptual processing (identifying objects, locations and colors, and the like) and reflective processing (imagining a conversation, planning a meeting, ruminating on the past).[1] Errors can be introduced when a memory is first acquired and anytime thereafter when it is activated and when it is evaluated. That is, memories are initially constructed from perceptions, thoughts, beliefs, and goals active together at the time. Subsequently they are reconstructed, often differently, in the context of different goals and different activated information, with the result that they may be reactivated incompletely with different features active at different times, conflated with similar memories from other events, and embellished or otherwise changed by additional perceptual or reflective processing. Because of this indeterminacy about the origin of various aspects of mental experience, we need inferential processes to evaluate the veridicality or source of an activated "memory." The SMF proposes that we evaluate activated information and infer, from its phenomenal properties and/or its relation to other memories, beliefs and knowledge, that it is veridical or make other source attributions about it—for example, whether we did X or only thought about doing it, who said or did Y, where, and so on. Evaluation processes vary from relatively automatic (heuristic) to more deliberate or reflectively complex (systematic). The parameters of these evaluation (monitoring) processes—such as how different types of information are weighted in the decision, and whether we rely on a quick heuristic decision or engage systematic processes—vary as a function of the consequences of an error, social factors, and the like.

Distortions Arise from Normal Cognition

Knowing the source of information is an important element in judging the accuracy or veridicality of that information—it matters if we have seen something with our own eyes or heard it third hand, or dreamed it or fantasized it, or if we saw it on the nightly news or in a movie. But the source of information typically is not something stored as a propositional tag along with our memories, beliefs, and knowledge. Rather, we infer source. We use heuristic source monitoring processes to attribute a source to information based on an evaluation of various features of the information. If activated information from the memory being evaluated has qualities that we expect memories from a certain source to have, we attribute the information to that source (see Figure 2.1).

We are not always conscious of these processes. Heuristic source attributions take place constantly without notice, and are relatively automatic or effortless. In contrast, the systematic processes engaged in source monitoring (for example, extended retrieval and reasoning) require more of the reflective processes (Johnson and Hirst, 1993) that are likely to give rise to a sense of effort (Hasher and Zacks, 1979) or control (Posner and Snyder, 1975; Shallice, 1988).

As noted above, we believe aspects of an activated memory are evaluated with respect to our expectations or beliefs about the distinguishing qualities of different sources of memories (for example, how familiar we expect them to be or the kind of perceptual detail we expect them to have. Depending on the circumstances of the moment—our objectives, how important it is to be accurate, the particular subset of features of the target memory that is currently activated—we may be more or less specific in the information we use to evaluate the source, and therefore the accuracy, of a reactivated memory.

For example, suppose an advertisement for a movie triggers a vague memory that someone told us recently that they had seen a good movie. We may be very cursory in our *heuristic source evaluation*. We may decide that the movie in the ad is the movie someone told us about simply because its name seems familiar, as if someone might have mentioned it recently; that is, we may use very undifferentiated information. (And we may be wrong if we stop there, because we may have seen the movie title in another context or its title may be similar to that of another movie we have heard about.)

If veridicality is somewhat more important, we will likely require more specific (differentiated) information to make a particular source attribution. We may focus on (increase our weightings of) other features of the activated information. For example, if the activated information, although sketchy, includes a sense of a hallway conversation, we may conclude it is an accurate memory because it has some small degree of the detail that we would expect from a recent, possibly brief, casual event. If we have time to see only one movie this month, we

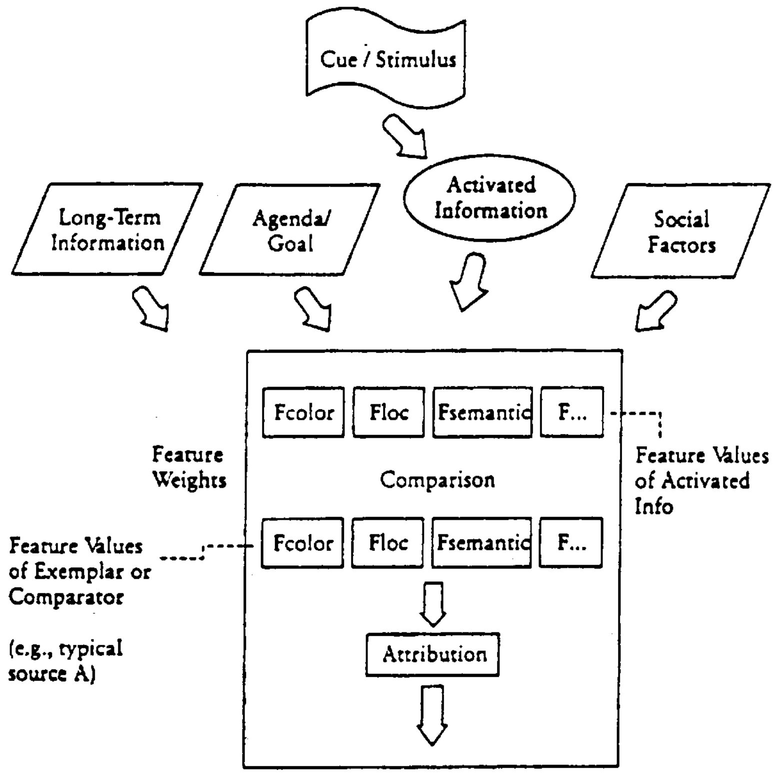

Figure 2.1 SMF heuristic processes.

may require yet more specific information and use systematic processes to retrieve additional candidate memories of recent social occasions until we find one that seems an appropriate match. It could be a recent dinner at a particular restaurant with two friends at which we talked about films—a highly detailed memory, which may in fact be accurate or inaccurate, but which we infer to be accurate based on its perceptual, temporal, semantic, and other features. Thus, depending on our motives, the types of information we expect or require to make a source decision will vary, whether we are engaging a heuristic process or systematic processes or both.

Qualitative Characteristics of Mental Experience

As we have described, heuristic source decision processes often are based on the phenomenal characteristics of activated information. Several lines of evidence support the idea that qualitative cues to source are evaluated in source attribution processes.

1. Source monitoring accuracy is influenced by manipulations that are specifically designed to vary the qualitative features of memories, such as perceptual detail, cognitive operations, and semantic information (Durso and Johnson, 1980; Lindsay, Johnson, and Kwon, 1991; Markham and Hynes, 1993). For example, if people imagine in another person's voice as opposed to their own voice, they are likely to claim later that that person said those words (Johnson, Foley, and Leach, 1988); and the more times people imagine an item, the more times they later think they saw it (Johnson, Raye, Wang, and Taylor, 1979). Visual imagery during reading leads people to say they saw in a picture what they only read about in text (Belli, Lindsay, Gales, and McCarthy, 1992; Intraub and Hoffman, 1992; Zaragoza et al., 1997), and hearing the sound an object makes (for instance, a barking dog) leads people to err and say they saw a picture of a dog (Henkel, Franklin, and Johnson, 1998). And increasing the *semantic* similarity between two speakers increases source errors (Lindsay, 1991).

2. People often offer specific details of a target memory as evidence that the remembered event really happened: "I can remember what the dentist's office looked like" or "I can remember how long it took" (Johnson, Foley, Suengas, and Raye, 1988).

3. When subjects rate the qualitative characteristics of their memories using, for example, a Memory Characteristics Questionnaire (MCQ), ratings typically are higher for perceived than for imagined events, and for correct than for incorrect source attributions (Henkel, Johnson, and De Leonardis, 1998; Johnson, Foley, Suengas, and Raye, 1988; Mather, Henkel, and Johnson, 1997; Norman and Schacter, 1997; see also Brewer, 1992; Conway and Dewhurst, 1995; Conway, Collins, Gathercole, and Anderson, 1996).

4. Confidence in source judgments tends to be associated with level of rated detail (Hashtroudi, Johnson, and Chrosniak, 1990) and confidence in autobiographical recall is related to amount of visual information recalled (Brewer, 1988).

5. The more differentiated the information required to make a source attribution, the more vulnerable the decision is to disruption from distraction or speeded responding (Johnson, Kounios, and Reeder, 1994; Jacoby, Woloshyn, and Kelley, 1989; see also Zaragoza et al. 1997).

Accessing and Weighting Information

According to the SMF, schemas and other prior knowledge (for example, about a particular person or about newsprint versus television as a news source) and categories constructed for the task (Barsalou, 1985; see also retrieval task processing in Burgess and Shallice, 1996) help define source-typical exemplars in heuristic source evaluation processes and in systematic evaluation of consistency and plausibility. Which features are weighted most heavily can be determined by long-term experience or by more immediate situational conditions (see Figure 2.1).

The MCQ rating procedure can be used to help identify what information is available for source discrimination and, together with performance data, to what extent that information is being used. For example, subjects who have heard sets of words in which all items within a set are related to a "theme" word that was not presented (*thread, sharp, haystack* are all related to *needle)* are very likely to falsely recall the theme word or recognize the theme word *(needle)* when it is presented as a lure (Deese, 1959; Roediger and McDermott, 1995). Using the MCQ, Mather, Henkel, and Johnson (1997) found that correctly recognized words had more perceptual detail than falsely recognized lure words, but did not have more associative information (see also Norman and Schacter, 1997). The high level of false memories typically found in this paradigm suggests that the weight given to perceptual information in this situation is less than that given to semantic, associative information or to familiarity.

People can flexibly access features or assign different weights to different features, as indicated by the fact that source accuracy varies with test conditions (Dodson and Johnson, 1993; Hasher and Griffin 1978; Raye, Johnson, and Taylor, 1980). For example, subjects are less likely to misattribute information suggested in a description to a previously seen picture if they are asked to indicate which of the possible sources the information came from (picture, description, both, neither) than if they are asked only to indicate whether it came from the picture or was new (Lindsay and Johnson, 1989; Zaragoza and Koshmider, 1989). One interpretation is that the source identification instructions induce subjects to more completely or more carefully assess the various qualitative characteristics of their memories in light of possible sources; thus, they are less likely to say "picture" if the item is simply familiar or exceeds some minimal threshold for perceptual detail. In the SMF, familiarity is treated as a phenomenal quality of memories that can serve as input to heuristic and systematic judgment processes. Even when subjects are making source judgments heuristically based on familiarity, as often occurs in old-new recognition, they adjust their criteria depending on expectations about the probability that an item is familiar and what familiarity signals (Dodson and Johnson, 1994; Skurnik, 1998).

The weight given to certain characteristics may also change as we grow older. Hashtroudi et al. (1990, reported in Johnson and Multhaup, 1992) found that although older and younger adults showed similar correlations between clarity (a factor derived from MCQ ratings) and confidence in the accuracy of a memory, older adults showed significantly higher correlations between emotion and confidence in accuracy. Johnson and Multhaup suggested that, compared to young adults, older individuals may give more weight to emotional aspects of memories in evaluating their veridicality.

In general, mental experiences are assessed according to certain expectations—that is, in light of the weights assigned to various types of information and the threshold amount or pattern (criteria) required for any particular attribution.[2] Both the qualitative and quantitative standards used to evaluate memories and beliefs may be adjusted in short-term, situational ways, as when test conditions induce subjects to look more carefully or to look at information they might have previously ignored (Lindsay and Johnson, 1989; Mather et al., 1997) or when subjects adjust to the relative proportions of types of items in a test set (Dodson and Johnson, 1996). Long-term changes may also occur in the habitual or default requirements. For example, older adults may come to require less perceptual information in order to attribute something to memory if they generally have less perceptual detail encoded, or come to weight emotional detail more heavily because they find the emotional aspects of events more interesting.

Features Binding

Features that are poorly bound to other features of an event during initial encoding or not consolidated afterward will be poor cues for those other features later (Johnson, 1992; Johnson and Chalfonte, 1994). Features of episodes may be poorly bound for any of a number of reasons, including distraction during encoding (Craik and Byrd, 1982; Jacoby, Woloshyn, and Kelley, 1989) or failure to think about the event subsequently (Suengas and Johnson, 1988).

Emotion is a particularly interesting factor that can affect the extent to which other features are bound together during encoding or during subsequent thinking or talking about events. Suengas and Johnson (1988) reported evidence that thinking about emotional aspects of prior events decreased the availability of perceptual information. Hashtroudi, Johnson, Vnek, and Ferguson (1994) had subjects act in a short play and then manipulated whether subjects thought about either the factual aspects of the play or their emotional reactions. Compared to young adults, older adults were less able to identify the origin (themselves or another person) of statements from the play when they had thought about emotional aspects, but did not differ significantly from young adults when they had thought about factual aspects. Johnson, Nolde, and De Leonardis (1996) had young adults listen to two speakers making various statements (such as "I support the death penalty;" "Interracial relations do not bother me") while subjects thought about either how they felt or how the speakers felt. Later, subjects were poorer at identifying the source of various statements if they had focused on how they themselves felt.

These studies suggest that when subjects are thinking about their feelings, they are less likely to be engaged in processes that bind perceptual detail with content than are subjects whose attention is focused on the factual aspects (Hashtroudi et al., 1994) or more external features of a situation (including other people's apparent emotion). Later these weakly bound features, if they are reactivated at all, are less likely to be sufficient for correctly identifying the source of statements. That is, a test probe statement is likely to reactivate only remembered emotion as a feature of the original event and not reactivate perceptual features of the speaker. Interestingly, Johnson, Nolde, and De Leonardis (1996) found that when subjects thought about how they felt, their old-new recognition was better than when they thought about how the speakers felt. Their reactivated emotional response was a cue for distinguishing experimental sentences from new sentences (which is a less specific, more general source decision) but not to distinguishing which speaker said an old item (which is a more specific source decision). Thus, emotional self-focus can yield memories that are "strong" but lack the features needed for some source decisions.

Effects of Thinking about Events

A fundamental premise of the SMF is that cognition is constructive; memories and beliefs are the joint product of perceptual inputs and the assumptions, knowledge, and motives we bring to them (Alba and Hasher, 1983; Bartlett, 1932; Bransford and Johnson, 1973; Johnson and Sherman, 1990; Ross, 1997). Such constructive processes import elements in the very acts of comprehension and remembering (Johnson, Bransford, and Solomon, 1973), elements that may later be attributed to the wrong source through the normal operation of imperfect source monitoring mechanisms (Johnson and Raye, 1981). For example, in simply understanding the sentence "John pounded the nail," one might infer a hammer and later claim to have heard it (Johnson et al., 1973) or in understanding the word "candy," concepts such as "sweet" might be activated and later falsely recognized (Deese, 1959; Underwood, 1965). Similarly, such constructive intrusions can happen during remembering, as associative and inferential processes fill in around incomplete memorial information.

An important dynamic in constructive memory is that we not only are able to think while we are experiencing events, but we also are able to think back on them (ruminate) after the fact. Suengas and Johnson (1988) showed that thinking about events maintains the vividness of memories, and that thinking about imagined events can have the same impact on vividness ratings as thinking about perceived events. They suggested that if one were to selectively rehearse imagined events, the vividness of these memories would begin to approximate that of memories of perceived events.

Suggestibility effects are a major case of thinking about events in which new information is introduced via a description or questions referring to a prior event, and the new information is later misattributed to the original event—for example, on the basis of perceptual or other details that were imagined when the suggestion was processed (Belli and Loftus, 1994; Hyman and Pentland, 1996; Loftus, 1979; Zaragoza and Lane, 1994). Furthermore, repeating suggestions increases the likelihood of false memory for the suggested events (Mitchell and Zaragoza, 1996).

Conflating Information

As discussed above, heuristic source attributions may rely on specific feature evidence (for example, auditory information if we are trying to decide if we heard something) or on less specific, more global assessments (perceptual information in general if we are deciding whether we imagined or whether we perceived something). For example, *hearing* something (say, a dog barking) increases the chances subjects will claim to have *seen* something (a *dog*) they only imagined (Henkel, Franklin, and Johnson, 1998). Also important is that normal memory distortion can arise through the combination of elements that have no obvious semantic or referential relation to each other. For example, Henkel and Franklin (1998) showed that seeing one object (for instance, a magnifying glass) increased the chances subjects claimed to have seen a perceptually similar item they had only imagined (a lollipop). Such false conjunctions of features (the semantic detail associated with a lollipop along with perceptual information about a round object) may be a consequence of poor binding as described above (see also Reinitz, Lammers, and Cochran, 1992).

More Systematic Processes

A number of investigators have noted that remembering can be an extended process involving systematic (or strategic) retrieval using self-presented cues, problem-solving strategies, and reasoning (Baddeley, 1982; Burgess and Shallice, 1996; Conway, 1992; Johnson and Raye, 1981; Reiser, 1986; Williams and Hollan, 1981). Source attributions are often made on the basis of evaluating an activated "memory" in relation to other knowledge, beliefs, and supporting memories related to the target. This additional information used to assess the veridicality of a memory is sometimes activated by cues that are self-generated. Such reflective (effortful, intentional) use of a retrieval strategy from a repertoire of strategic possibilities that help elaborate or constrain retrieval cues (as going through one's day to remember where one left some object) is a process that we include in the category of systematic source monitoring processes. It should be noted that we view the actual activation of memories and knowledge as an associative process that is directed by current goals or agendas; the existing associative relations among memories, knowledge, and beliefs; and active retrieval cues including self-generated cues and external cues (stimuli). Either or both systematic and heuristic evaluation processes may operate, in different ways, on the activated (retrieved) information.

In addition to the self-generation of retrieval cues, a second important function of systematic source monitoring processes is another type of source evaluation process. We have sometimes referred to the systematic evaluation of additional source information as extended reasoning because, compared to heuristic processes, it often relies on a broader range of abstract relational knowledge as well as on event information and more complex comparisons of the two: noting the internal consistency or inconsistency in a memory, or between it and related memories; noting the reliability or unreliability in recall of an event at different times, noting the degree of consensus with other people's memories; or evaluating the plausibility of a memory based on general knowledge or beliefs (Johnson, 1988; Johnson and Raye, 1981) (see Table 2.1). For example, people may decide that a social event happened because they remember noting it on their calendar beforehand or talking about it later to others. Or they may decide that a dream about a scientific discovery did not happen because it is not consistent with what they know to be possible (Johnson et al., 1988). These more effortful or systematic processes are more likely to be observed in studies of autobiographical recall than in studies using simple laboratory materials because of the greater complexity of the memories and the longer retention intervals involved.

As with heuristic source processes, systematic processes may rely on less-differentiated information (for example, simply the fact that additional information is or is not retrieved; or the amount of infor-

Table 2.1 Systematic processes used in making source monitoring judgments

While heuristic source monitoring processes rely on a relatively nondeliberative comparison of phenomenal characteristics of an activated target memory to a set of expected or prototypic characteristics, systematic processes are responsible for a more reflective retrieval of additional knowledge, beliefs, and memories, and more deliberative reasoning about the target memory with respect to the additional information.

Examples of Systematic Processes

Reflective generation of retrieval cues—use of knowledge to generate retrieval cues to gain additional information relevant to the particular source question at hand, for instance:

- in trying to remember who told you a work-related fact, you might generate retrieval cues based on members of your department or recent phone calls and e-mails;
- to remember the source of a news item, you generate news sources, TV, radio, and so on.

Retrieving supporting memories—retrieving other memories related to the target, and the inability to retrieve additional information related to the target memory, for example:

- remembering a conversation about the event which took place soon before or after the event;
- "I know I said X because I remember my train of thought at the time";
- you decide you must be wrong in thinking that person X told you a particular fact a little while ago because you cannot recall any recent occasion when the two of you met or spoke.

Noting consistency or inconsistency in remembering from one time to another time (reliability), in remembering from person to person (consensus), or among the attributes of a specific memory (internal coherence), for instance:

- if in recounting a dinner party you realize that you recall Sam was there but recalled Phil was there the last time you described the party, you conclude you do not remember the event well;
- when your account and another's differ, you know one of you must be wrong;
- when you realize that some perceptual details in the memory reveal a perspective that you could not have, given other components of the memory (you did not go backstage at the play, yet you have vivid perceptual details of the dressing room).

Evaluating plausibility or likelihood of the target memory, given what is generally known or believed, for example:

- "It's not the kind of thing I would say, therefore I could not have said it";
- you remember seeing a politician give a speech at a park when you were young, but then you realize that you were not yet born at the time of the speech.

mation retrieved) or may require a more critical evaluation of specific information for coherence, plausibility, or consensus (Johnson, 1988; Ross, 1997). A new senator recently described his emotional response to a political speech that he had heard as a child in the park where it was given. If he had been more cautious and used a higher criterion to judge the veridicality of whatever he was about to say to the press, he might have invoked more systematic evaluation processes and realized, before the press pointed it out, that he was not born at the time of the speech.

Binding deficits operating when memories are encoded will, like strategic retrieval deficits, affect the success of retrieval cues and will affect the quality of related memories that are available to be retrieved. Like heuristic evaluation, systematic evaluation (plausibility and consistency checks) will suffer from polluted input, caused for example by rumination. *How* memories are thought about later will of course determine if veridicality is strengthened or weakened. As noted above, some types of emotional focus during or after an event potentially decrease the likelihood that perceptual features are bound together. In addition, emotional focus may produce memory deficits by increasing the chances that elaborations, interpretations, or constructions take place, thus increasing the chances for later source confusions. For example, Hashtroudi et al. (1994) found that both younger and older adults were more likely to include elaborations in their recall of a short play in which they had participated if they had thought about their affective reactions than if they had thought about factual details. Consistent with these findings, data recently collected by Mather (1998) suggest that subjects who focus on how they feel while reading a story are later more likely to show recall protocols that distort the story in ways that make it more consistent with their expectations than are subjects who focus on the factual aspects of the story. Again, both heuristic and systematic source attributions would be expected to be negatively affected by rumination that distorts the content of memories.

By capitalizing on the potential effects of rumination in creating the conditions for source monitoring errors (for example, increasing relative vividness of some features, elaboration and embedding in other memories and beliefs), some subjects can be induced to report constructed or fabricated complex autobiographical memories (Ceci, Crotteau Huffman, Smith, and Loftus, 1994; Ceci, Loftus, Leichtman, and Bruck, 1994; Hyman, Husband, and Billings, 1995). In these studies people are asked to think about long-past events, including some that they did not actually experience (going to the hospital with an ear infection or getting lost at a shopping mall). These tend to be events for which there is reasonably rich schematic or script knowledge (what hospitals and malls are like), which should make it relatively easy for subjects to imagine specific details of the situation. In a particularly compelling demonstration, Ceci and colleagues showed that with repeated tellings, some children came to produce vivid and coherent accounts of fictional events, and that clinicians and researchers who viewed videotapes of children describing events could not discriminate above chance between accounts of real and fictional events.

Interaction of Processes

Heuristic and systematic source monitoring processes often interact. Memories and other information may be revived via relatively effortless associative processes or via cues generated through the reflectively controlled use of systematic retrieval strategies. As shown schematically in Figure 2.2, the activated information may then be subject to heuristic evaluation, or may be more systematically evaluated for coherence or plausibility.

Figure 2.2 also illustrates that heuristic and systematic processes serve as checks on each other (Johnson, 1991; cf. Burgess and Shallice, 1996, and Norman and Bobrow, 1979). For example, the inappropriate heuristic use of familiarity can be countered by more systematic processing (Jacoby, 1991). If a memory has much detail, it may pass a heuristic check but fail a more systematic check for plausibility. Conversely, if a memory seems very plausible but has no specific detail, one might question whether it is, in fact, a veridical memory. A related point is that source information is not only useful when it appears to specify source unambiguously; when source monitoring processes are working normally, ambiguities and vagueness in mental experiences provide meaningful information as well. The lack of clear detail or of coherence signals "caution, this might not be an accurate memory of an actual event or defensible belief." If a memory or belief has inconsequential implications, it can be ignored or treated as a cu-

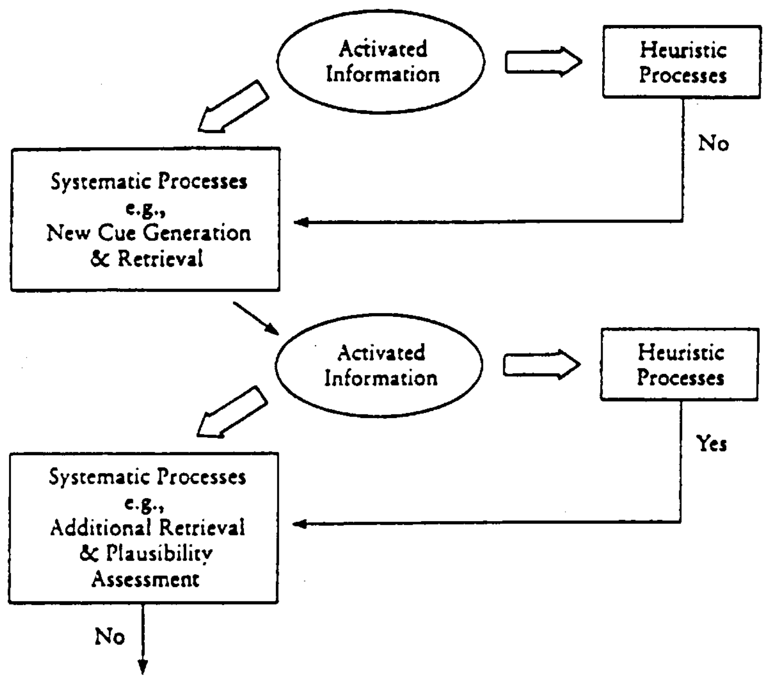

Figure 2.2 Interaction between systematic and SMF heuristic processes.

riosity. If it is important, additional efforts can be made to gather more information through further retrieval efforts, consulting records, documents, other people's memories and beliefs, and so forth. Without such confirming evidence, it may be better not to "act" on such a memory or belief.

One way that cognitive monitoring mechanisms could be disrupted is if such cautionary signals were ignored or misread. For example, it probably would be a mistake to assume that vague memories signal that something significant has been forgotten or repressed. Even supposing that one were especially likely to forget highly salient but unpleasant experiences, the quality of ambiguity or vagueness would not be a particularly reliable cue that a memory is meaningful. This is not to say that there are no important life events for which memories are dim or unavailable, only that there are a great many dim or unavailable memories that are not particularly important or accurate.

Both heuristic and systematic monitoring processes are embedded in an interindividual social context and a broader cultural context that influence the nature of the events we experience initially. They also affect how we interpret those events, what we subsequently think about them (including how we embellish memories), and the criteria we use (both what we focus on and the amount of evidence required) later in making attributions about their origin. For example, the impact that the social interaction between therapists and patients can have on the source monitoring of patients is at the heart of recent controversy over the recovery of repressed memories. Lindsay and Read (1994) draw on the SMF to discuss the potential for inducing false memories in a therapeutic situation.

Brain Mechanisms

Insofar as binding processes are crucial for creating event memories, and retrieval and evaluation processes are vital for monitoring them, it seems reasonable to suppose that those areas of the brain that have been identified as important for feature binding (medial-temporal structures—Cohen and Eichenbaum, 1993; Johnson and Chalfonte, 1994; Kroll, Knight, Metcalfe, Wolf, and Tulving, 1996; Squire and Knowlton, 1995) and strategic or executive functions (frontal areas—Daigneault, Braun, and Whitaker, 1992; Shallice, 1988; Stuss and Benson, 1986) are critical for veridical memories and beliefs (see Baddeley and Wilson, 1986; Johnson, 1991, 1997a, 1997b; Moscovitch, 1995). Indeed, confabulations and delusions have been associated with neuropathology in these regions (Baddeley and Wilson, 1986; Stuss, Alexander, Lieberman, and Levine, 1978).

Frontal Patients

Disrupted processes. Brain damage from head injuries, tumors, aneurysm of the anterior communicating artery (ACoA), and other diseases and traumas affecting frontal and adjacent subcortical brain regions have wide-ranging effects on cognition (Shimamura, 1995; Stuss, Eskes, and Foster, 1994). Of particular interest are those effects that would be expected to reduce the veridicality of memories and beliefs by affecting processes critical for source monitoring.

Frontal damage can result in various source memory deficits: remembering modality, visual versus auditory (Shoqeirat, 1989, cited in DeLuca and Diamond, 1995), speaker identification (Johnson, O'Connor, and Cantor, 1997), temporal judgments (Milner, 1971; Shimamura, Janowski and Squire, 1990), and identifying whether facts were learned in an experiment or known preexperimentally (Janowsky, Shimamura, and Squire, 1989; Schacter, Harbluk, and McLachlan, 1984). There is also evidence that systematic encoding and retrieval processes are likely to be disrupted. For example, Parkin, Leng, Stanhope, and Smith (1988) reported an ACoA patient, JB, who performed very poorly on a paired-associate learning task but improved dramatically when instructed to use imagery. This result suggests that frontal patients may fail to engage more systematic encoding processes that might be effective if they were engaged. And certainly some of the above judgments, especially temporal discriminations among autobiographical or historical events, may depend on systematic retrieval and extended reasoning processes.

Systematic retrieval deficits of frontal patients are especially apparent in their generally poor recall of autobiographical events (Baddeley and Wilson, 1986). For example, Johnson, O'Connor, and Cantor (1997) compared three patients with left frontal damage and three age-matched controls on autobiographical recall of preexperimental events (a vacation) and recall of complex experimental "minievents" (hammering a nail, imagining cutting out a paper snowflake). Relative to the controls, the frontal patients showed typically impoverished memories (they were less likely to recall an event and events, when recalled, had fewer details) and they tended to profit from additional cues.

Johnson and colleagues also found that although the amount of detail reported by the frontal patients was much lower than that reported by the normal controls, the distribution of characteristics (relative frequency of mention of actions, perceptual details, affect, spatial information) was about the same as for the normal controls. These results suggest that in these patients retrieval was not selectively disrupted for one or another type of information; rather, it was generally disrupted because the deficits were distributed across scoring categories. Such an unselective deficit argues for dysfunction of the processes that initiate and guide strategic retrieval, not of access to any particular type of information. Because additional cues did help autobiographical recall, at least some of the deficits appear to be related to poor self-initiated cueing (Baddeley and Wilson, 1986; Moscovitch, 1995; Norman and Schacter, 1996).

In future work with larger patient groups, a systematic comparison of the qualitative characteristics of autobiographical recall of right, left, and bilateral frontal patients would be quite interesting, to see if this unselective deficit pattern is general or is specific to left frontal patients.

In addition to their disrupted contextual and temporal memory, and strategic encoding and retrieval deficits, some frontal patients may use inappropriate feature weights and/or lax criteria in evaluating memories. Schacter, Curran, Galluccio, Milberg, and Bates (1996) reported a patient, BG, who had an infarction of the right frontal lobe and who showed an unusually high false recognition rate on old-new tests involving words, sounds, pronounceable nonwords, or pictures. When the distractors were drawn from a different semantic category than the studied items, this patient had a normal false recognition rate. It was as if he remembered that he had seen items of a given type, and then said "old" to any items of that type on the recognition test.

With the usual recognition test in which distractors are drawn from the same class(es) as studied items, this simple heuristic evaluation would lead to a high false recognition rate. If BG had only categorical information (as a consequence of poor feature binding or selective, schematic encoding), then the best heuristic he could adopt would be to give the greatest (or only) weight to categorical information. On the other hand, if he had additional potentially discriminating information, then category information would have been weighted inappropriately highly.

Given these various deficits in information or processes that have been shown to be important for normal source memory, it is not surprising that frontal patients may become confused about the origin of information, conflate elements from various sources (including, very likely, their own imaginations, television programs, dreams, and the like) and may produce quite bizarre and fantastic confabulations and delusions (Baddeley and Wilson, 1986; Damasio, Graff-Radford, Eslinger, Damasio, and Kassell, 1985; Luria, 1976; Moscovitch, 1995; Stuss, Alexander, Lieberman, and Levine, 1978).

Nevertheless, only some frontal patients confabulate, not all. The three frontal patients in Johnson, O'Connor, and Cantor (1997) illustrate that severe source deficits (including poor temporal information) and autobiographical recall deficits do not necessarily produce confabulation. Similarly, in spite of the high false recognition rate, the Schacter group's patient BG did not confabulate. However, the absence of confabulation in such patients is not difficult to understand from the perspective of the SMF.

According to the SMF, various mechanisms together constrain the extent to which memories and beliefs can get out of control or become distorted. Avoiding confabulations and delusions is not the specific responsibility of any one of these mechanisms. If, for example, certain pieces of temporal or spatial contextual information are missing, one might retrieve other related information that would allow the correct source to be identified based on plausibility. Or without retrieving additional related confirming or disconfirming information, one might remember some particular striking detail that would suggest the memory was veridical. If sufficient detail and supporting or disconfirming information are not available, an appropriate set of weights and criteria might indicate that one should remain in doubt. Recognition that one has poor memory or judgment processes (or feedback about this problem from others) might even cause one to adjust weights and tighten criteria in order to avoid mistakes. Thus, deficits in systematic retrieval alone, for example, would not necessarily produce confabulation.

Of course, the more of these "reality constraints" that break down, the more likely one should be to show confabulations and delusions. Consistent with this hypothesis, Fischer, Alexander, D'Esposito, and Otto (1995) found that clinical judgment of severity of confabulation was correlated with ***extent*** of lesion in ACoA patients. If we assume that various reality monitoring processes (such as assessing specific feature qualities, retrieving additional information, maintaining appropriate criteria) are mediated by different frontal regions (presumably in combination with more posterior projection areas), increased likelihood of confabulation with disruption of more frontal regions would be expected (see Johnson, Hayes, D'Esposito, and Raye, forthcoming).

The Johnson, O'Connor, and Cantor (1997) study included a fourth ACoA patient, GS, who had bilateral frontal damage and who confabulated. Like the nonconfabulating unilateral frontal patients, GS showed deficits on speaker identification. In addition, he showed a greater deficit than the other frontal patients on autobiographical recall—his ability to report specific autobiographical details was extremely impoverished. Bilateral damage may be especially disruptive to recursive retrieval or retrieval and evaluation processes; interhemispheric cooperation may be necessary to keep information refreshed while new cues are generated, new information is retrieved, or retrieved information is evaluated.

One finding suggests that GS had particular difficulty self-generating retrieval cues or sustaining a recursive retrieval strategy: when specific memories were cued, he did much better. In fact, he produced somewhat more detailed reports of the minievents than did the other frontal patients. In addition, when asked to recall a specific anniversary party several months earlier, his recall was quite detailed (but also included some confabulated elements). Another factor that may have been critical is that his reports of memories of events he had been asked to *imagine* in the lab (cutting out a paper snowflake) were more detailed than those of other frontal patients (cf. David and Howard, 1994). Thus, the combination of poor contextual memory, disrupted ability to self-initiate retrieval processes, and a propensity to vivid imagination may have combined to produce confabulations in this patient.

Qualitative characteristics of confabulations and delusions. In addition to comparing confabulators to nonconfabulating control patients, we can also try to compare the qualitative characteristics of a confabulating patient's veridical and nonveridical recall. Questions of interest include: Do confabulations have the same phenomenal characteristics as real memories, and hence seem real to the patient? Do they have the same coherence and embeddedness in supporting knowledge and beliefs as real memories? What is the relative importance of vividness and embeddedness in creating the sense of reality for a patient? (Johnson, 1988, 1991). A few studies provide preliminary evidence regarding such issues.

Dalla Barba (1995) tested whether a confabulating patient's real memories and confabulations differed in the phenomenal experience of "remembering" versus "knowing," or R/K (Tulving, 1985). In this technique, when a memory is recalled, individuals are typically asked to judge its qualities and answer "Remember" if they recollect specific characteristics of the event and "Know" if the memory is familiar but they cannot recall specific details (Gardiner and Java, 1993; Rajaram and Roediger, 1997). Dalla Barba emphasized "remembering" as the conscious experience of a particular episode of one's life (rather than recollecting detail) and found that a confabulating patient, MB, was as likely to indicate that he "remembered" a confabulated event as an actual event.

From our point of view, R/K judgments are based on an evaluation of features similar to source judgments, albeit perhaps with a different, lower criterion (see also Conway et al., 1996). If a confabulation is reasonably detailed and does not have strong cognitive-operations information associated with generating it, then it would be judged either "real" in a source monitoring judgment or R in an R/K judgment—and neither judgment alone might be sensitive enough to show qualitative differences between real and confabulated memories (see Mather et al., 1997). That is, it could be that confabulated memories have characteristically different details (features) but about the same number of details, or they may have less detail than true memories but still enough to qualify for a "remember" (or "perceived") response rather than a "know" response.

Johnson, O'Connor, and Cantor compared confabulated and real memory by asking two independent raters to use an MCQ to evaluate the qualitative characteristics of GS's confabulated memory for the circumstances of his aneurysm, and his real memory for a party that he had attended that same week. The confabulated memory had a level of qualitative detail similar to that of the veridical memory. However, this is just one case. It might be useful to see if confabulating patients could rate their own confabulations and real memories using an MCQ and compare subjective with objective MCQ ratings.

Damage in other brain regions. Right hemisphere damage in nonfrontal cortical regions appears to lead to perceptual and attentional deficits that can, especially in combination with frontal damage, produce confabulations and delusions of recognizable types. For example, quite bizarre or illogical confabulations and delusions sometimes center around misidentifications of place (right posterior temporoparietal lesions associated with reduplicative paramnesia), misidentification of persons (right inferior temporal lesions associated with Capgras syndrome), or somatic distortions (anterior right parietal lesions associated with infestation or somatic delusions) (Malloy and Duffy, 1994, p. 212); or they are associated with neglect (right inferior parietal lesions associated with anosognosia for hemiparalysis—Heilman, 1991; Ramachandran, 1995) and may represent responses to disrupted perceptual-attentional information (Maher, 1974).

These syndromes are generally consistent with a model such as the SMF in which (a) source attributions are made on the basis of qualitative features of experience and (b) either the input into, or the functioning of, evaluation/monitoring processes can be selectively disrupted for different types of information. Inasmuch as we assume the evaluation-monitoring processes to involve frontal systems, the neuropsychological findings suggest that disruption can occur in the information received by frontal regions from other cortical regions, or in the ability of frontal regions to either access or assess the information from various other regions, or both—thus resulting in a variety of confabulatory or delusional syndromes.

In summary, there is general consensus that confabulations and delusions shown by frontal patients involve disruptions in encoding, retrieval, and evaluation or monitoring processes (Baddeley and Wilson, 1986; Burgess and Shallice, 1996; Dalla Barba, 1993; Frith, 1992; Johnson, 1991; Moscovitch, 1989; Norman and Schacter, 1996; Stuss, Eskes, and Foster, 1994). Furthermore, neuropsychological studies of frontal patients find disruptions in various processes central for source monitoring (see also Schacter, Norman, and Koutstaal, 1998). Because of the multiple constraints arising from the multiple source monitoring factors outlined in the SMF, the kinds of severe confabulations and delusions seen in some patients may require a breakdown in more than one type of information or process. For example, poor contextual memory (especially, perhaps, poor temporal memory) in combination with other factors—such as strategic retrieval deficits, evaluation deficits (inappropriate feature weights or criteria), and a propensity for vivid imagery in some individuals—could contribute to false memories and beliefs through their effects on source monitoring attributions. The specific regions most frequently implicated in confabulation include the ventromedial frontal area, basal forebrain, and anterior cingulate (DeLuca, 1993; DeLuca and Diamond, 1995; Johnson, 1991; Johnson, Hayes, D'Esposito, and Raye, forthcoming; Moscovitch, 1995). These would be the most likely candidates or "regions of interest" in future attempts to sort out which brain systems are associated with which processes in the SMF.

Schizophrenic Patients

Neuropathological, neuropharmacological, neuroimaging, and neuropsychological approaches to determining the brain correlates of schizophrenia have not produced a consensus (see, for example, Andreasen, 1997; David and Cutting, 1994; Frith, 1996; Weinberger, 1988). Nevertheless, the brain areas that tend to be implicated (frontal and temporal cortex, hippocampal formation, basal ganglia, and other basal forebrain structures) overlap with areas of brain damage associated with confabulation and delusions in cases of documented brain damage. Furthermore, damage in more posterior brain regions, especially in combination with frontal dysfunction, can produce a range of exotic delusions such as reduplicative paramnesia and Capgras syndrome. Such disruptions in experience could provide the grain of sand around which more complex delusional syndromes form (Maher, 1974), perhaps through selective rumination (Johnson, 1988). For example, the fact that Capgras syndrome is common in schizophrenia (Cutting, 1994) implicates underlying brain pathology in at least some cases of schizophrenia (Ellis and De Pauw, 1994; Fleminger, 1994). Insofar as perceptions of (and memory for) qualitative characteristics of experience provide the inputs for evaluation and source attribution, distorted inputs may lead to false perceptions, memories, and beliefs.

The most prevalent hypotheses today relative to a neural basis for schizophrenia focus on possible defects in neurotransmitter (dopamine) systems (Andreasen, 1997; Fibiger, 1997; Gray, 1995). So-called positive and negative symptoms of schizophrenia respond to different drug therapies and differ by other assessments of brain correlates as well. For example, negative symptoms (apathy, lack of initiative) seem more likely to be associated with neuropsychological tests of frontal function (Frith, 1996). Positive symptoms of schizophrenia (hallucinations, delusions) do not show strong associations with neuropsychological tests of frontal function, nor with neuroimaging evidence of frontal pathology. However, positive symptoms appear to respond to neuroleptics that block dopamine, especially in the lateral septal nucleus and nucleus accumbens (Fibiger, 1997). Notably, these two structures are in the basal forebrain area, which is also generally implicated in confabulation resulting from brain damage (DeLuca and Diamond, 1995).

Positive symptoms of schizophrenia, like the confabulations and delusions of frontal patients, can be viewed as a product of normal source monitoring processes applied to unusual input (for example, vivid perceptual or strong affective features from imaginations) or dysfunctional processes applied to usual input (for example, lower criteria) or both. According to the SMF, source monitoring processes not only assess information about visual, auditory, semantic, affective, and other features, they also assess information about cognitive operations associated, for example, with imagery in various modalities, inference, or reflective initiation and manipulation of images and thoughts (Johnson and Raye, 1981).

Cognitive operations (self-generated or reflective processes) are important for identifying oneself as the origin of thoughts or actions (see also Johnson and Reeder, 1997). Disruptions in either the quality of the cognitive operations information available, or in the ability to evaluate it, lead to self-generated experiences that one would not have the sense of having initiated or controlled. For example, the disruption of brain regions associated with either the cognitive control of or the initial phenomenal experience of cognitive operations, or with the evaluation of cognitive operations features associated with a mental experience, could lead to a variety of psychotic experiences such as hallucinations, beliefs about thought insertion, and delusions of external control.

Consistent with this idea, Bentall, Baker and Havers (1991) proposed a reality monitoring deficit specific to cognitive operations to account for hallucination in schizophrenia patients. They found that hallucinating patients, compared to psychiatric controls and normals, were more likely to attribute self-generated items to the experimenter. This effect was especially noticeable on items that required more effort to generate and that should have had the most cognitive operations information, suggesting that the hallucinators did not store or were less able to access information about cognitive operations in making source attributions.

Frith's (1992) suggestion that first-rank symptoms of schizophrenia result from disorders of self-monitoring of willed intentions is similar to the SMF idea that deficits can occur selectively in monitoring cognitive operations (Bentall et al., 1991; Johnson, 1988, 1991). This theme is also present in Gray's (1995) proposal that positive symptoms may result from a limbic-basal ganglia-based system that compares expected and actual outcomes, and in which a disruption could make self-initiated events appear novel or unexpected.

Based on the SMF, deficits can occur in different ways in monitoring cognitive operations. One possibility is that little or no cognitive operations information may be associated with hallucinatory or delusional phenomenal experiences. Of course, normally, some thoughts seem to occur spontaneously, without conscious effort or intention, much as dreams do or as images may arise while reading a novel. Nevertheless, in most waking thought, the modulating influence of goals and agendas typically restrict conscious cognitive activity to relevant information (Shallice, 1988).

Spontaneous thoughts may occur more frequently in schizophrenia for several reasons. For example, reduced inhibition of weak or unintentional mental experiences (Hasher and Zacks, 1988) or a reduced ability to maintain the task-relevant context, and thus less goal-directed modulation of cognitive activity (Cohen and Serven-Schreiber, 1992), could render conscious that which ordinarily would not be conscious. Thus source evaluation processes may be presented with many more candidates than normal that have no cognitive operations features and hence are more likely to be attributed to other agents or sources—for example, aliens or a radio transmitter implanted in the head. If these ordinarily inhibited ideas were to include vivid perceptual or affective detail as well, they might seem especially compelling. An increase in the frequency of spontaneous mental experiences would not necessarily be accompanied by a decrease in the cognitive operations information associated with deliberate goal-directed thoughts. Thus, schizophrenic patients may show greater deficits in identifying themselves as the origin of unintentional thoughts than as the origin of intentional thoughts.

Another possibility is that information about the cognitive operations that produced a delusion or hallucination is present but is unavailable to or not used in reality-monitoring evaluation processes. For example, Johnson (1991) proposed that two reflective subsystems (R-1 and R-2) ordinarily cooperate (monitor each other), but their ability to communicate could be disrupted, thereby reducing access of one subsystem to the cognitive operations information from the other.

Insofar as initiating and later reactivating reflective operations such as those involved in agenda-controlled thoughts and actions are frontally based (Shallice, 1988), and monitoring (evaluation) processes also are frontally based, an inability to access or use cognitive operations information might be expected to result from disruption of frontal functioning, particularly if two or more cooperative processes or systems underlie these functions. If R-1 and R-2 processes are disproportionately represented in the right and left hemispheres respectively (Johnson, 1997), deficits in the interaction of the two systems would be consistent with characterizations of schizophrenia that emphasize some kind of hemispheric imbalance or disconnection (Cutting, 1990). Alternatively, systematic R-2 processes important for source monitoring may require interhemispheric cooperation (Nolde, Johnson, and Raye, 1998).

Although a reality-monitoring deficit specific to cognitive operations information could lead to experiences of sensory hallucinations and delusions of external control, more complex delusions, such as delusions of persecution, are likely to involve additional factors. Especially important, we believe, in more complex delusions and other psychotic syndromes is the role of repetition and rumination. Thinking about events (both real and fantasized) can make them more vivid, make them come to mind more readily, and embed them in related thoughts and beliefs that will then be taken as evidence of their veridicality (Johnson, 1988).

David and Howard (1994) addressed such issues in a study of the phenomenal experiences of four patients with delusional memories (three late paraphrenia cases and one person diagnosed with schizoaffective psychosis). These researchers compared patients' MCQ ratings for their delusional memories with their ratings for nondelusional memories from the same period. Delusional memories had higher ratings on aspects such as clarity, contextual information, and feelings. High ratings on these attributes were correlated with ratings of frequency of rehearsal, and patients indicated that they had rehearsed the delusional memories more frequently than the real memories. Of course, delusional ideas may be rehearsed because they are vivid rather than the reverse, but David and Howard's findings are at least consistent with laboratory findings on the effects of rehearsal (Suengas and Johnson, 1988).

One's worldviews, schemas, and chronic anxieties are likely to influence one's rumination, as well as the way various features of experience, including memories, are likely to be weighted in any monitoring process. Thus a number of cognitive, social, and motivational mechanisms exist by which clinically significant confabulations and delusions can occur in the absence of or in combination with specific brain damage (Kopelman, Guinan, and Lewis, 1995; O'Connor, Walbridge, Sandson, and Alexander, 1996).

Aging and Memory Distortion

Because normal aging is likely to be accompanied by neuropathology in medial temporal and frontal regions, studies of older adults provide one way of investigating the brain mechanisms underlying disruption of source monitoring processes. There are many more people older than age sixty-five than there are amnesics, frontal patients, or schizophrenics. Furthermore, healthy older individuals can engage in a wider range of tasks, so they constitute a promising population for studying the processes involved in true and false memories and beliefs.

Numerous studies show that older adults have deficits in source memory. For example, older adults are less likely to accurately remember contextual features of events such as the speaker (Bayen and Murnane, 1996; Ferguson, Hashtroudi, and Johnson, 1992), the color or font of the stimuli (Kausler and Puckett, 1980; Park and Puglisi, 1985), the location of items (Light and Zelinski, 1983; Pezdek, 1983), the origin of trivia facts (Craik, Morris, Morris, and Loewen, 1990), whether something was seen in a video or a photograph (Schacter, Koustaal, Johnson, Gross, and Angell, 1997), and the orienting task performed (De Leonardis and Johnson, 1997).

Chalfonte and Johnson (1996) found that even when older and younger adults had apparently equivalent information about individual features (item and color), the older adults were less likely to bind those features to each other. Chalfonte and Johnson suggested that such binding deficits might be related to neuropathology in the medial-temporal regions associated with aging (Ivy, MacLeod, Petit, and Markus, 1992), but their study provided no direct evidence for such a link.

Henkel, Johnson, and De Leonardis (1998) explored the potential link between source memory and age-related deficits in medial-temporal and frontal-lobe function.

The subjects in their study viewed some pictures and imagined others, and then were given a source monitoring test (older adults were tested after a fifteen-minute retention interval and younger adults after a two-day interval, to equate groups on old-new recognition). Whereas older adults were no more likely than young adults to claim to have seen imagined items that were unrelated to any other items, they were much more likely to claim to have seen imagined items (for example, *lollipop* or *banana*) that were perceptually (or conceptually) related to perceived items, for example, *magnifying glass* or *apple*. Thus, older adults were not simply more confused in general, but suffered in particular from similarity among features of candidate memories. Henkel and colleagues suggested that such memory distortions arise because certain memory records of features (for example, round shape) are not tightly bound to the context of their occurrence, which can affect judgment about the source of another memory. As would be expected based on the likelihood of age-related neuropathology in medial-temporal regions, source memory scores of older adults were correlated with their scores on a neuropsychological battery of tests often used to assess medial-temporal function (Glisky, Polster, and Routhieaux, 1995).

A second group of older adults were tested after a two-day delay. In addition to a correlation between source accuracy and medial-temporal scores, a correlation was found between source accuracy and scores on a neuropsychological battery of tests often used to assess frontal function (Glisky et al., 1995). Henkel, Johnson, and De Leonardis suggested that this correlation reflects the greater importance of systematic retrieval and evaluation processes after a delay, and is consistent with evidence for age-related neuroanatomic and neurochemical changes in frontal-lobe regions (Kemper, 1984; West, 1996) and with other observations of correlations between source memory and frontal measures in older adults (Craik, Morris, Morris, and Loewen, 1990; see also Mather, Johnson, and De Leonardis, in press).

These results are consistent with the idea that medial-temporal and frontal regions play somewhat different roles in source memory, with medial-temporal regions more important for binding features into complex memories and frontal regions more important for evaluation and systematic retrieval (Johnson et al., 1993; Moscovitch, 1995). Of course, this is an oversimplification because frontal and medial-temporal regions typically work together. Thus frontal damage can interfere with binding processes by disrupting the agendas that affect binding—for instance, reflectively controlled agendas that promote rehearsal and elaborative encoding. Similarly, medial-temporal damage can decrease the effectiveness of elaborative frontal processes at encoding and self-cuing at retrieval because fewer features are bound together.

In any event, the combination of medial-temporal and frontal damage should be particularly devastating because of the combined effects of poor binding of features and disrupted reflective processes that maintain agendas and retrieve and evaluate information. In fact, some of the most severe cases of confabulation come from patients with both medial-temporal and frontal damage (Baddeley and Wilson, 1986; DeLuca and Diamond, 1995).

Brain Activity and Source Memory Processes

Techniques for recording metabolic (positron emission tomography or PET; and functional magnetic reasonance imaging, or fMRI) and electrical (event-related potentials, or ERPs) brain activity offer an opportunity to bridge the gap between evidence and theoretical ideas derived from the study of normal individuals in cognitive tasks, and those derived from the neuropsychological study of brain-damaged patients and from clinical studies of psychiatric patients (for reviews of brain imaging research see Buckner and Tulving, 1995; McCarthy, 1995; Nolde, Johnson, and Raye, 1998; Rugg, 1995; Ungerleider, 1995). Evidence suggests that these techniques will be useful in exploring the heuristic and systematic processes that go into the construction and reconstruction of memories and beliefs, including the agenda-driven selective probing for and weighting of memory features and their evaluation in light of task goals.

Selective access and weighting. Johnson, Kounios, and Nolde (1996) reported a study in which subjects saw pictures (line drawings) and words under one of two orienting tasks. Subjects in the Function task rated the number of functions they could think of for each item on a scale from 1 to 3 or more, and subjects in the Artist task rated how difficult a picture would be to draw (for picture items), or they imagined a picture (for word items) and rated how difficult that would be to draw on a scale from 1 (easy) to 3 (difficult). Subsequently, ERPs were recorded while subjects were shown words and for each one indicated whether it corresponded to an item previously presented as a picture, previously presented as a word, or was new.

Johnson and colleagues found marked negativities at about 400 milliseconds following the onset of the test stimulus that appeared at occipital sites in the Function group and at frontal sites in the Artist group. They suggested that this different topographical pattern was consistent with the idea that different attributes of memory are distributed in different regions of the neocortex (Damasio, 1989; see also Martin et al., 1995), and that the two groups differentially probed or weighted different types of information in their judgments. It appears that Function subjects were making picture/word judgments largely on the basis of the amount of visual detail evoked by the stimulus, hence the large occipital negativity. In contrast, although Artist subjects presumably encoded as much (and probably more) visual detail about the stimuli, the amount of remembered visual detail was not a particularly diagnostic cue for source because the test subjects generated visual details (imaged line drawings) for objects represented by word stimuli as well. Artist subjects were thus more likely to probe for information about the cognitive operations engaged at encoding rather than the visual detail stored as a result of that encoding, hence the frontal negativity.

A subsequent study by Nolde (1997) supported this interpretation that the observed negativities reflected selective access and/or weighting of different attributes. Subjects at acquisition engaged in the Function task for some items and the Artist task for other items, then were given the same source monitoring task as in the previous study. If our interpretation of the earlier study is accurate, the ERP data in the Nolde study should not show a difference in information probed as a function of acquisition task, since in that study it was not possible for subjects to adopt a selective strategy at test (any individual test item might have been in the Function or the Artist condition). Our prediction was correct; test trial ERPs for Artist and Function items did not differ in topographical distribution of activation. For both Artist and Function items, both occipital and frontal negativities occurred, suggesting that subjects were using the two types of information. Also, response latencies were slower in this more complex decision situation, as would be expected if subjects were considering both types of information. Taken together, the two studies suggest that people adjust the information that they probe or evaluate to fit the particular conditions of the source discrimination task (see also Johnson, Nolde, Mather, et al., 1997).

Retrieval versus evaluation. Recent brain imaging studies have yielded hemispheric asymmetries, with the right frontal areas more active than the left in episodic memory tasks (Buckner, 1996). Such asymmetries have led to the suggestion that retrieval is a right frontal function (Shallice, Fletcher, Frith, Grasby, et al., 1994; Tulving, Kapur, Markowitcsch, Craik, Habib, and Houle, 1994). One possibility is that this right lateralized activity represents a "retrieval mode" that is engaged during the test stage of episodic tasks (Nyberg, Cabeza, and Tulving, 1996). Or the right frontal activity may represent the amount of retrieval effort required by a task (Schacter, Alpert, Savage, et al., 1996). Still a third possibility is that the right frontal activity represents not retrieval processes per se, but evaluation or monitoring of the output of activation and retrieval processes (Shallice et al., 1994). Sorting out these possibilities is a challenge because every episodic memory study is a source monitoring study, just as every episodic memory study is a retrieval study; that is, every memory that is attributed to some particular past event is so ascribed on the basis of source attribution processes.

The ERP study by Johnson, Kounios, and Nolde (1996) provides some evidence that the right lateralized activity seen in PET and fMRI studies may not reflect either a retrieval mode or retrieval per se, but perhaps some component(s) of postretrieval evaluation of the activated information. In addition to the subjects who made source monitoring judgments at test, other subjects had the same acquisition conditions (Function or Artist task) and then received an old-new recognition test. In that test, all old items (pictures and words) and new items were presented as words, and subjects were asked to identify items as "old" (from the previous list) or "new."

Collapsed across subjects who were given old-new and those given source identification tests, test-trial ERPs showed a frontal, right-lateralized asymmetry. However, this frontal asymmetry was greater in the later interval of individual trials, suggesting it did not reflect an overall retrieval mode adopted for the task. Also, the asymmetry was larger starting at a point past where critical access probes for specific information evidently took place (around 400 milliseconds, as discussed above). Further, the degree of hemispheric asymmetry did not interact with whether subjects were making old-new judgments or more specific source judgments (picture, word, new). Because this lateralized activity did not vary between test tasks, we believe it may represent commonalities in the evaluation processes of old-new recognition and source identification. Nevertheless, despite commonalities, these processes are not necessarily identical (Johnson and Raye, 1981; Raye, 1976). Is there further evidence that reflects differences in old-new and source decision processes?

Although the frontal, right-lateralized effect was not different for old-new and source monitoring conditions, Johnson, Kounios, and Nolde (1996) did find a marked difference in ERP waves (superimposed on the right-lateralized effect mentioned above) between old-new recognition and source identification groups that was frontally, but bilaterally, distributed (see also Senkfor and Van Petten, 1998). Source identification typically is a more difficult source monitoring task than is old-new recognition—that is, it requires more differentiated information, or a closer inspection of the nature of the activated information, or the attempted retrieval of additional information (Johnson et al., 1994). Thus, this late frontal, bilateral difference between recognition and source identification suggests that difficult source monitoring tasks require the activation and perhaps cooperation of both hemispheres (for relevant evidence see Nolde, Johnson, and D'Esposito, 1998; Nolde, Johnson, and Raye, 1998).

In short, these ERP studies are consistent with the behavioral evidence suggesting that not all information in memory is equally accessed or weighted during remembering (Lindsay and Johnson, 1989; Hashtroudi et al., cited in Johnson and Multhaup, 1992; Mather et al., 1997). Brain imaging in combination with ERPs can provide converging evidence about where in the brain and when in the processing (during memory access, during evaluation) agendas are having their impact.

We speculate that the right-frontal effect in episodic memory tests seen with brain imaging may index a common component of heuristic evaluation processes that operates on activated information in light of whatever task agenda has been set. For example, a target representation in perceptual cortical sites (say P-2 in MEM; Johnson, 1992) might be evaluated by frontal heuristic reflective processes (R-1 in MEM) for familiarity in old-new recognition, or for amount of perceptual detail in source identification. (In fact, there is some evidence that the right hemisphere may be better than the left in discriminating at test between old items and similar items—Metcalfe, Funnell, and Gazzaniga, 1995; Phelps and Gazzaniga, 1992).

We further speculate that the bilateral frontal effect we observed represents interhemispheric cooperation or coordination. We would expect more systematic R-2 type processing (or processing that requires coordination between R-1 and R-2 subsystems) to be necessary more often in source identification than in old-new recognition tasks. This expectation is not specific to source monitoring, of course. Other reflectively demanding tasks, such as recall, should require interaction between hemispheres as well (see Phelps, Hirst, and Gazzaniga, 1991).

The example of heuristic processing above illustrates "metaprocessing" in MEM, whereby one representation (in this case a P-2 target) is taken as the object of another (in this case a reflective R-1 agenda) (Johnson and Reeder, 1997; cf. Nelson and Narens, 1990). (Similar ideas are Jacoby and Kelley's 1987 notion of memory as "object," and Frith's 1992 concept of "metarepresentation.")

Our example of bilateral systematic processing also illustrates metaprocessing. Again assume that a target representation is activated in a P-2 representation system. If a decision cannot be made quickly (heuristically), the activated information will need to be kept refreshed while, perhaps, other recent items are systematically retrieved in order to make a judgment that is consistent with other recent judgments. One hemisphere may be needed to keep the activated information refreshed while the other is retrieving additional information. Or one hemisphere may represent and keep refreshed information (such as perceptual detail) while the other hemisphere retrieves other information (perhaps semantic interpretations or elaborations; see Metcalfe et al., 1995). According to the SMF, information represented in or retrieved by the two hemispheres would be weighted and evaluated in order to yield a source attribution.

We further speculate that certain types of reasoning, problem solving, or cyclical retrieval (that is, activities involving subgoals) involved in autobiographical recall and in evaluating memories for plausibility or coherence with other memories would also involve cooperation between hemispheres. Thus, we expect that these complex (reflective R-2) retrieval and evaluation processes are more likely to require interhemispheric cooperation. They should therefore be particularly likely to be disrupted by bilateral frontal damage (as in the case of GS described above, Johnson, O'Connor, and Cantor, 1997) or by disruption in the communication between the two hemispheres as in split-brain patients (Metcalfe et al., 1995). That is, if interhemispheric cooperation is central to more difficult source judgments, or those that depend on the retrieval and integration of various sources of information, that fact would explain why bilateral frontal damage can produce severe confabulation. Hemispheric imbalance and disrupted communication have also been proposed as basic deficits in schizophrenia (Cutting, 1994).

SMF functions and brain regions. The broad outlines of a model relating brain mechanisms to the cognitive processes involved in remembering can be described and would have reasonable consensus (see Table 2.2). Memories result from a complex balance between medial-temporal and frontal brain regions, in interaction with other cortical and subcortical regions that encode information about visual, auditory, spatial, affective, and other features of events. The accuracy of memories and beliefs is determined by feature-binding processes mediated by medial-temporal regions, often in the service of frontally mediated agendas, and by frontally mediated strategic retrieval and evaluation processes, themselves dependent on medial-temporal reactivation of bound features. Thus this delicate system can be disturbed by the disruption of brain regions supporting any of these processes or perceptual processing or their interaction, as indicated by studies of aging and of brain-damaged patients. Confabulations and delusions seem particularly likely when damage to more than one part occurs, especially when damage includes the basal forebrain region and increases in frontal regions. Similarly, drugs that target neurotransmitter systems critical to these regions, especially dopamine circuits, have therapeutic effects on positive symptoms of schizophrenia.

We can also begin to propose some more specific aspects of a cognitive model of these processes (Figures 2.1 and 2.2) and of their neural mapping. Processes mediated by frontal systems adjust weights for possible types of evidence—for features such as visual or auditory detail, location, and so forth. Confidence in the accuracy of a memory is especially related to the amount of evidence in the most heavily weighted features. Decision criteria determine how discrete judgments or attributions are mapped onto the weighted evidence. Consistent with these ideas, ERP studies show differential brain activation related to the presumably differential weighting of features in memory source decisions (Johnson, Kounios, and Nolde, 1996; Johnson, Nolde, Mather, et al., 1997).

Among the various types of information available during perceiving, remembering, and thinking, we have suggested that evidence from

Table 2.2 Brain regions and cognitive functions important in evaluating veridicality

Brain area	Cognitive functions	Evidence cited
Cerebral cortex (various cortical areas)	Feature perception Distributed feature representation in memory	Clinical syndromes caused by brain damage (e.g., Capgras, neglect) Brain damage, PET, ERP studies
Medial-temporal area (e.g., hippocampal formation)	Feature binding, reactivation (nondeliberative)	Brain damage (amnesia patients), aging
Frontal regions	Reflective processing (e.g., self-generated cognition)	Brain damage (Korsakoff, frontal patients), aging, schizophrenia (positive symptoms)
Right frontal cortex	Heuristic evaluation processes (e.g., heuristic source monitoring attributions)	ERP, PET studies, brain damage
Bilateral frontal cortex	Systematic processes (e.g., cue generation, strategic retrieval, evaluating consistency or plausibility)	ERP, PET, fMRI studies, brain damage

reflective cognitive operations is especially important in distinguishing real from imagined events, memories, and beliefs (Johnson, 1992; Johnson and Raye, 1981). Disruptions in the deliberative control of mental operations or in the ability to evaluate this information as evidence of source of an experience or memory could produce hallucinations, delusions, or confabulations. ERP data showed frontal brain activation when individuals attempted to use information about past cognitive operations to make source decisions, and activation in posterior brain regions when decisions could be based on remembered visual information (Johnson et al., 1996). These data could indicate that stored cognitive operations are represented frontally.

Frontally maintained agendas not only modulate feature weights and criteria, they initiate further processing if the task goals are not met. The further processing that might be needed—for example, strategic retrieval or comparing the relative amounts of evidence contained in mental experiences on the current trial with those from past trials—also requires a frontally maintained agenda. Processing is said to be heuristic when a relatively simple agenda or a single reflective subsystem is sufficient for the task. Processing is said to be systematic when two or more synchronously interacting agendas or reflective subsystems are required. ERP, fMRI, and PET data suggest that right prefrontal regions are disproportionately involved in heuristic processing during source monitoring and other memory tasks, and that left and right prefrontal regions coordinate when more complex or systematic processing is required (Nolde, Johnson, and D'Esposito, 1998; Nolde, Johnson, and Raye, 1998).

Conclusion

A common set of themes has arisen from neuropsychological and clinical studies of confabulations and delusions. A number of these are similar to ideas that have arisen in the study of normal cognition and have been proposed as mechanisms by which false memories and beliefs come about. The source monitoring framework provides a way of integrating these two traditions. The SMF points to the importance of encoding and consolidation processes, cognitive events and experiences that happen after events (such as rumination), and cue conditions and agendas (schemas, plans, and the like) that are active at both encoding and test. These factors determine which information will receive selective processing, how much additional strategic processing takes place, and how elements of mental experiences are evaluated. Normal distortions in perceptions, memories, and beliefs arise because these processes are not perfect and because they are subject to the influence of cognitive contexts and motivational and social factors. Clinically significant confabulations and delusions arise when these imperfect processes are further disrupted by brain damage and functional abnormalities. Such clinical findings have provided valuable information identifying general brain regions implicated in remembering and believing.

As additional data become available from brain imaging and ERP studies designed to isolate various components of critical cognitive processes underlying memories and beliefs, the exact nature and location of the transactions or brain circuits required for binding, reactivating, retrieving, and evaluating information of various types should become more apparent. We will then come closer to characterizing the brain activity associated with the phenomenal experiences of remembering and believing.

References

Alba, J. W., and Hasher, L. (1983). Is memory schematic? *Psychological Bulletin, 93*, 203–231.

Andreasen, N. C. (1997). Linking mind and brain in the study of mental illnesses: A project for a scientific psychopathology. *Science, 275*, 1586–93.

Baddeley, A. (1986). *Working memory*, Vol. 2. New York: Oxford University Press.

Baddeley, A., Thornton, A., Chua, S. E., and McKenna, P. (1996). Schizophrenic delusions and the construction of autobiographical memory. In D. C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 384–428). New York: Cambridge University Press.

Baddeley, A. D., and Wilson, B. (1986). Amnesia, autobiographical memory and confabulation. In D. C. Rubin (Ed.), *Autobiographical memory* (pp. 225–252). New York: Cambridge University Press.

Barsalou, L. W. (1985). Ideals, central tendency, and frequency of instantiation as determinants of graded structure in categories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*, 629–654.

Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge: Cambridge University Press.

Bayen, U. J., and Murnane, K. (1996). Aging and the use of perceptual and temporal information in source memory tasks. *Psychology and Aging, 11*, 293–303.

Belli, R., and Loftus, E. (1994). Recovered memories of childhood abuse: A source monitoring perspective. In S. J. Lynn and J. W. Rhue (Eds.), *Dissociation: Clinical and theoretical perspectives* (pp. 415–433). New York: Guilford Press.

Bentall, R. P., Baker, G. A., and Havers, S. (1991). Reality monitoring and psychotic hallucinations. *British Journal of Clinical Psychology, 30*, 213–222.

Bransford, J. D., and Johnson, M. K. (1973). Considerations of some problems of comprehension. In W. Chase (Ed.), *Visual information processing* (pp. 383–438). New York: Academic Press.

Brewer, W. F. (1988). Memory for randomly sampled autobiographical events. In U. Neisser and E. Winograd (Eds.), *Remembering reconsidered: Ecological and traditional approaches to the study of memory. Emory symposia in cognition*, Vol. 2 (pp. 21–90). New York: Cambridge University Press.

Brewer, W. F. (1992). Phenomenal experience in laboratory and autobiographical memory tasks. In M. A. Conway, D. C. Rubin, H. Spinnler, and W. A. Wagenaar (Eds.), *Theoretical perspectives on autobiographical memory* (pp. 31–51). Boston: Kluwer Academic Publishers.

Buckner, R. L. (1996). Beyond HERA: Contributions of specific prefrontal brain areas to long-term memory retrieval. *Psychonomic Bulletin and Review, 3*, 149–158.

Buckner, R. L., and Tulving, E. (1995). Neuroimaging studies of memory: Theory and recent PET results. In F. Boller and J. Grafman (Eds.), *Handbook of neuropsychology*, Vol. 10 (pp. 439–46). New York: Elsevier.

Burgess, P. W., and Shallice, T. (1996). Bizarre responses, rule detection and frontal lobe lesions. *Cortex, 32*(2), 241–259.

Ceci, S. J., and Bruck M. (1993). Suggestibility of the child witness: A historical review and synthesis. *Psychological Bulletin, 113*, 403–439.

Ceci, S. J., Crotteau Huffman, M. L., Smith, E., and Loftus, E. F. (1994). Repeatedly thinking about a non-event: Source misattributions among preschoolers. *Consciousness and Cognition, 3*(3/4), 388–407.

Ceci, S. J., Loftus, E., Leichtman, M., and Bruck, M. (1994). The possible role of source misattributions in the creation of false beliefs among preschoolers. *International Journal of Clinical and Experimental Hypnosis, 42*(4), 304–320.

Chalfonte, B. L., and Johnson, M. K. (1996). Feature memory and binding in young and older adults. *Memory and Cognition, 24*(4), 403–416.

Cohen, J. D., and Servan-Schreiber, D. (1992). Context, cortex, and dopamine: A connectionist approach to behavior and biology in schizophrenia. *Psychological Review, 99*, 45–77.

Cohen, N. J., and Eichenbaum, H. (1993). *Memory, amnesia, and the hippocampal system*. Cambridge, MA: MIT Press.

Conway, M. A. (1992). A structural model of autobiographical memory. In M. A. Conway, D. C. Rubin, H. Spinnler, and W. Wagenaar (Eds.), *Theoretical perspectives on autobiographical memory* (pp. 167–193). Boston: Kluwer Academic Publishers.

Conway, M. A. (1996). Autobiographical knowledge and autobiographical memories. In D. C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 67–93). New York: Cambridge University Press.

Conway, M. A., Collins, A. F., Gathercole, S. E., and Anderson, S. J. (1996). Recollections of true and false autobiographical memories. *Journal of Experimental Psychology: General, 125*, 69–95.

Conway, M. A., and Dewhurst, S. A. (1995). Remembering, familiarity, and source monitoring. *Quarterly Journal of Experimental Psychology, 48A*(1), 125–140.

Craik, F. I. M., and Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik and S. E. Treehub (Eds.), *Aging and cognitive processes* (pp. 191–211). New York: Plenum Press.

Craik, F. I. M., Morris, L. W., Morris, R. G., and Loewen, E. R. (1990). Relations between source amnesia and frontal lobe functioning in older adults. *Psychology and Aging, 5,* 148–151.

Cutting, J. (1990). *The right cerebral hemisphere and psychiatric disorders.* Oxford: Oxford University Press.

Cutting, J. C. (1994). Evidence for right hemisphere dysfunction in schizophrenia. In A. S. David and J. C. Cutting (Eds.), *The neuropsychology of schizophrenia* (pp. 231–242). Hove, England: Lawrence Erlbaum.

Daigneault, S., Braun, C. M. J., and Whitaker, H. A. (1992). An empirical test of two opposing theoretical models of prefrontal function. *Brain and Cognition, 19,* 48–71.

Dalla Barba, G. (1993). Confabulation: Knowledge and recollective experience. *Cognitive Neuropsychology, 10,* 1–20.

Dalla Barba, G. (1995). Consciousness and confabulation: Remembering "another" past. In R. Campbell and M. A. Conway (Eds.), *Broken memories: Case studies in memory impairment* (pp. 101–114). Oxford: Blackwell.

Damasio, A. R. (1989). Time-locked multiregional retroactivation: A systems-level proposal for the neural substrates of recall and recognition. *Cognition, 33,* 25–62.

Damasio, A. R., Graff-Radford, N. R., Eslinger, P. J., Damasio, H., and Kassell, N. (1985). Amnesia following basal forebrain lesions. *Archives of Neurology, 42,* 263–271.

David, A. S., and Cutting, J. C. (1994). The neuropsychology of schizophrenia—introduction and overview. In A. S. David and J. C. Cutting (Eds.), *The neuropsychology of schizophrenia* (pp. 231–242). Hove, England: Lawrence Erlbaum.

David, A. S., and Howard, R. (1994). An experimental phenomenological approach to delusional memory in schizophrenia and late paraphrenia. *Psychological Medicine, 24,* 515–524.

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

De Leonardis, D. M., and Johnson, M. K. (1997). *Aging and source monitoring: The relation between cognitive operations and perceptual information.* Manuscript.

DeLuca, J. (1993). Predicting neurobehavioral patterns following anterior communicating artery aneurysm. *Cortex, 29,* 639–647.

DeLuca, J., and Diamond, B. J. (1995). Aneurysm of the anterior communicating artery: A review of neuronanatomical and neuropsychological sequelae. *Journal of Clinical and Experimental Neuropsychology, 17*(1), 100–121.

Dodson, C. S., and Johnson, M. K. (1993). Rate of false source attributions depends on how questions are asked. *American Journal of Psychology, 106*(4), 541–557.

Dodson, C. S., and Johnson, M. K. (1996). Some problems with the process dissociation approach to memory. *Journal of Experimental Psychology: General, 125*(2), 181–194.

Durso, F. T., and Johnson, M. K. (1980). The effects of orienting tasks on recognition, recall, and modality confusion of pictures and words. *Journal of Verbal Learning and Verbal Behavior, 19,* 416–429.

Ellis, H. D., and de Pauw, K. W. (1994). The cognitive neuropsychiatric origins of the Capgras delusion. In A. S. David and J. C. Cutting (Eds.), *The neuropsychology of schizophrenia* (pp. 317–335). Hove, England: Lawrence Erlbaum.

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

Fibiger, H. C. (1997). Anti-psychotic drugs: Insights provided by immediate early genes. Paper presented at the Langfeld Conference on Current Issues in Comparative and Developmental Psychobiology, Princeton.

Fischer, R. S., Alexander, M. P., D'Esposito, M., and Otto, R. (1995). Neuropsychological and neuroanatomical correlates of confabulation. *Journal of Clinical and Experimental Neuropsychology, 17*(1), 20–28.

Fleminger, S. (1994). Delusional misidentification: An exemplary symptom illustrating an interaction between organic brain disease and psychological processes. First International Conference on Delusional Misidentification Syndromes (1993), Paris. *Psychopathology, 27*(3–5), 161–167.

Frith, C. D. (1992). *The cognitive neuropsychology of schizophrenia.* Hove, England: Lawrence Erlbaum.

Frith, C. D. (1996). Neuropsychology of schizophrenia: What are the implications of intellectual and experiential abnormalities for the neurobiology of schizophrenia? *British Medical Bulletin, 52*(3), 618–626.

Gardiner, J. M., and Java, R. I. (1993). Recognising and remembering. In A. E. Collins, S. E. Gathercole, M. A. Conway, and P. E. Morris (Eds.), *Theories of memory* (pp. 163–188). Hove, England: Lawrence Erlbaum.

Glisky, E. L., Polster, M. R., and Routhieaux, B. C. (1995). Double dissociation between item and source memory. *Neuropsychology, 9*(2), 229–235.

Gray, J. A. (1995). A model of the limbic system and basal ganglia: Applications to anxiety and schizophrenia. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1165–76). Cambridge, MA: MIT Press.

Hasher, L., Goldstein, D., and Toppino, T. (1977). Frequency and the conference of referential validity. *Journal of Verbal Learning and Verbal Behavior, 16*(1), 107–112.

Hasher, L., and Griffin, M. (1978). Reconstructive and reproductive processes in memory. *Journal of Experimental Psychology: Human Learning and Memory, 4,* 318–330.

Hasher, L., and Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108,* 356–388.

Hasher, L., and Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *Psychology of Learning and Motivation, 22,* 193–225.

Hashtroudi, S., Johnson, M. K., and Chrosniak, L. D. (1990). Aging and qualitative characteristics of memories for perceived and imagined complex events. *Psychology and Aging, 5,* 119–126.

Hashtroudi, S., Johnson, M. K., Vnek, N., and Ferguson, S. A. (1994). Aging and the effects of affective and factual focus on source monitoring and recall. *Psychology and Aging, 9*(1), 160–170.

Heilman, K. M. (1991). Anosognosia: Possible neuropsychological mechanisms. In G. P. Prigatano and D. L. Schacter (Eds.), *Awareness of deficit after brain injury: Clinical and theoretical issues* (pp. 53–62). New York: Oxford University Press.

Henkel, L., and Franklin, N. (1998). Reality monitoring of physically similar and conceptually related objects. *Memory and Cognition, 26,* 659–673.

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

Henkel, L. A., Franklin, N., and Johnson, M. K. (1998). Cross-modal source monitoring confusions between perceived and imagined events. Manuscript.

Hyman, I. E., Jr., Husband, T. H., and Billings, F. J. (1995). False memories of childhood experiences. *Applied Cognitive Psychology, 9,* 181–197.

Hyman, I. E., and Pentland, J. (1996). The role of mental imagery in the creation of false childhood memories. *Journal of Memory and Language, 35,* 101–117.

Intraub, H., and Hoffman, J. E. (1992). Reading and visual memory: Remembering scenes that were never seen. *American Journal of Psychology, 105,* 101–114.

Ivy, G. O., MacLeod, C. M., Petit, T. L., and Markus, E. J. (1992). A physiological framework for perceptual and cognitive changes in aging. In F. I. M. Craik and T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 273–314). Hillsdale, NJ: Lawrence Erlbaum.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30,* 513–541.

Jacoby, L. L., and Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*(3), 306–340.

Jacoby, L. L., and Kelley, C. M. (1987). Unconscious influences of memory for a prior event. *Personality and Social Psychology Bulletin, 13,* 314–336.

Jacoby, L. L., Woloshyn, V., and Kelley, C. M. (1989). Becoming famous without being recognized: Unconscious influences of memory produced by dividing attention. *Journal of Experimental Psychology: General, 118*(2), 115–125.

Janowsky, J. S. Shimamura, A. P., and Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia, 27,* 1043–56.

Johnson, M. K. (1988). Discriminating the origin of information. In T. F. Oltmanns and B. A. Maher (Eds.), *Delusional beliefs* (pp. 34–65). New York: John Wiley.

Johnson, M. K. (1991). Reality monitoring: Evidence from confabulation in organic brain disease patients. In G. P. Prigatano and D. L. Schacter (Eds.), *Awareness of deficit after brain injury: Clinical and theoretical issues* (pp. 176–197). New York: Oxford University Press.

Johnson, M. K. (1992). MEM: Mechanisms of recollection. *Journal of Cognitive Neuroscience, 4*(3), 268–280.

Johnson, M. K. (1997a). Identifying the origin of mental experience. In M. S. Myslobodsky (Ed.), *The mythomanias: The nature of deception and self-deception* (pp. 133–180). Mahwah, NJ: Lawrence Erlbaum.

Johnson, M. K. (1997b). Source monitoring and memory distortion. *Philosophical Transactions of the Royal Society of London, 352,* 1733–45.

Johnson, M. K., Bransford, J. D., and Solomon, S. K. (1973). Memory for tacit implications of sentences. *Journal of Experimental Psychology, 98,* 203–205.

Johnson, M. K., and Chalfonte, B. L. (1994). Binding complex memories: The role of reactivation and the hippocampus. In D. L. Schacter and E. Tulving (Eds.), *Memory systems 1994* (pp. 311–350). Cambridge, MA: MIT Press.

Johnson, M. K., Foley, M. A., and Leach, K. (1988). The consequences for memory of imagining in another person's voice. *Memory and Cognition, 16,* 337–342.

Johnson, M. K., Foley, M. A., Suengas, A. G., and Raye, C. L. (1988). Phenomenal characteristics of memories for perceived and imagined autobiographical events. *Journal of Experimental Psychology: General, 117,* 371–376.

Johnson, M. K., Hashtroudi, S., and Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin, 114*(1), 3–28.

Johnson, M. K., Hayes, S. M., D'Esposito, M., and Raye, C. L. (Forthcoming). Confabulation. In L. Cermak (Ed.). Title to be determined.

Johnson, M. K., and Hirst, W. (1993). MEM: Memory subsystems as processes. In A. F. Collins, S. E. Gathercole, M. A. Conway, and P. E. Morris (Eds.), *Theories of memory* (pp. 241–286). Hove, England: Lawrence Erlbaum.

Johnson, M. K., Kounios, J., and Nolde, S. F. (1996). Electrophysiological brain activity and memory source monitoring. *NeuroReport, 7*, 2929–32.

Johnson, M. K., Kounios, J., and Reeder, J. A. (1994). Time-course studies of reality monitoring and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(6), 1409–19.

Johnson, M. K., and Multhaup, K. S. (1992). Emotion and MEM. In S.-A. Christianson (Ed.), *The handbook of emotion and memory: Research and theory* (pp. 33–66). Hillsdale, NJ: Lawrence Erlbaum.

Johnson, M. K., Nolde, S. F., and De Leonardis, D. M. (1996). Emotional focus and source monitoring. *Journal of Memory and Language, 35*(2), 135–156.

Johnson, M. K., Nolde, S. F., Mather, M., Kounios, J., Schacter, D. L., and Curran, T. (1997). The similarity of brain activity associated with true and false recognition memory depends on test format. *Psychological Science, 8*, 250–257.

Johnson, M. K., O'Connor, M., and Cantor, J. (1997). Confabulation, memory deficits, and frontal dysfunction. *Brain and Cognition, 34*, 189–206.

Johnson, M. K., and Raye, C. L. (1981). Reality monitoring. *Psychological Review, 88*, 67–85.

Johnson, M. K., and Raye, C. L. (1998). False memories and confabulation. *Trends in Cognitive Science, 2*, 137–145.

Johnson, M. K., Raye, C. L., Wang, A. Y., and Taylor, T. H. (1979). Fact and fantasy: The roles of accuracy and variability in confusing imaginations with perceptual experiences. *Journal of Experimental Psychology: Human Learning and Memory, 5*, 229–240.

Johnson, M. K., and Reeder, J. A. (1997). Consciousness as meta-processing. In J. D. Cohen and J. W. Schooler (Eds.), *Scientific approaches to consciousness* (pp. 261–293). Mahwah, NJ: Lawrence Erlbaum.

Johnson, M. K., and Sherman, S. J. (1990). Constructing and reconstructing the past and the future in the present. In E. T. Higgins and R. M. Sorrentino (Eds.), *Handbook of motivation and cognition: Foundations of social behavior* (pp. 482–526). New York: Guilford Press.

Kausler, D. H., and Puckett, J. M. (1980). Adult age differences in recognition memory for a nonsemantic attribute. *Experimental Aging Research, 6*, 349–355.

Kemper, T. (1984). Neuroanatomical and neuropathological changes during aging and dementia. In M. L. Albert and Janice E. Knoefel (Eds.), *Clini-*

cal neurology of aging (2nd ed.) (pp. 3–67). New York: Oxford University Press.

Kopelman, M. D. (1987). Two types of confabulation. *Journal of Neurology, Neurosurgery, and Psychiatry, 50*(11), 1482–87.

Kopelman, M. D., Guinan, E. M., and Lewis, P. D. R. (1995). Delusional memory, confabulation, and frontal lobe dysfunction: A case study in De Clerambault's syndrome. *Neurocase, 1,* 71–77.

Kroll, N. E. A., Knight, R. T., Metcalfe, J., Wolf, E. S., and Tulving, E. (1996). Cohesion failure as a source of memory illusions. *Journal of Memory and Language, 35*(2), 176–196.

Light, L. L., and Zelinski, E. M. (1983). Memory for spatial information in young and old adults. *Developmental Psychology, 19*(6), 901–906.

Lindsay, D. S., and Johnson, M. K. (1989). The eyewitness suggestibility effect and memory for source. *Memory and Cognition, 17*(3), 349–358.

Lindsay, D. S., Johnson, M. K., and Kwon, P. (1991). Developmental changes in memory source monitoring. *Journal of Experimental Child Psychology, 52*(3), 297–318.

Lindsay, D. S., and Read, J. D. (1994). Psychotherapy and memories of childhood sexual abuse: A cognitive perspective. *Applied Cognitive Psychology, 8*(4), 281–338.

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

Luria, A. R. (1976). *The neuropsychology of memory.* Washington, D.C.: V. H. Winston.

Maher, B. (1974). Delusional thinking and perceptual disorder. *Journal of Individual Psychology, 30*(1), 98–113.

Malloy, P., and Duffy, J. (1994). The frontal lobes in neuropsychiatric disorders. In F. Boller and J. Grafman, *Handbook of neuropsychology,* Vol. 9 (pp. 203–232). New York: Elsevier.

Markham, R., and Hynes, L. (1993). The effect of vividness of imagery on reality monitoring. *Journal of Mental Imagery, 17*(3–4), 159–170.

Martin, A., Haxby, J. V., Lalonde, F. M., Wiggs, C. L., and Ungerleider, L. G. (1995). Discrete cortical regions associated with knowledge of color and knowledge of action. *Science, 270,* 102–105.

Mather, M. (1998). Emotional review and memory distortion. Manuscript.

Mather, M., Henkel, L. A., and Johnson, M. K. (1997). Evaluating characteristics of false memories: Remember/know judgments and memory characteristics questionnaire compared. *Memory and Cognition, 25,* 826–837.

Mather, M., Johnson, M. K., and De Leonardis, D. (In press). Stereotype reliance in source monitoring: Age differences and neuropsychological test correlates. *Cognitive Neuropsychology.*

McCarthy, G. (1995). Functional neuroimaging of memory. *Neuroscientist, 1,* 155–163.

McKay, A. P., McKenna, P. J., and Baddeley, A. D. (1995). Memory pathology in schizophrenia. In R. Campbell and M. A. Conway, (Eds.), *Broken memories: Case studies in memory impairment* (pp. 124–136). Oxford: Blackwell.

Metcalfe, J., Funnell, M., and Gazzaniga, M. S. (1995). Right-hemisphere memory superiority: Studies of a split-brain patient. *Psychological Science, 6*(3), 157–164.

Milner, B. (1971). Interhemispheric difference in the localization of psychological processes in man. *British Medical Bulletin, 27,* 272–277.

Milner, B., Petrides, M., and Smith, M. L. (1985). Frontal lobes and the temporal organization of memory. *Human Neurobiology, 4,* 137–142.

Mitchell, K. J., and Johnson, M. K. (Forthcoming). Source monitoring: Attributing memories to sources. In E. Tulving and F. I. M. Craik (Eds.), *The Oxford Handbook of Memory.* New York: Oxford University Press.

Mitchell, K. J., and Zaragoza, M. S. (1996). Repeated exposure to suggestion and false memory: The role of contextual variability. *Journal of Memory and Language, 35*(2), 246–260.

Moscovitch, M. (1989). Confabulation and the frontal systems: Strategic versus associative retrieval in neuropsychological theories of memory. In H. L. Roediger and F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 133–160). Hillsdale, NJ: Lawrence Erlbaum.

Moscovitch, M. (1995). Confabulation. In D. L. Schacter (Ed.), *Memory distortions: How minds, brains, and societies reconstruct the past* (pp. 226–251). Cambridge, MA: Harvard University Press.

Nelson, T. O., and Narens, L. (1990). Metamemory: A theoretical framework and some new findings. In G. H. Bower (Ed.), *The psychology of learning and motivation,* Vol. 26 (pp. 125–173). New York: Academic Press.

Nolde, S. F. (1997). Event-related potentials: Studies of memory access during source monitoring and old/new recognition. Doctoral dissertation, Princeton University.

Nolde, S. F., Johnson, M. K., and D'Esposito, M. (1998). Left prefrontal activation during episodic remembering: An event-related fMRI study. *NeuroReport, 9,* 3509–14.

Nolde, S. F., Johnson, M. K., and Raye, C. L. (1998). The role of prefrontal cortex in episodic memory. *Trends in Cognitive Sciences, 2,* 399–406.

Norman, D. A., and Bobrow, D. G. (1979). Descriptions: An intermediate stage in memory retrieval. *Cognitive Psychology, 11*(1), 107–123.

Norman, D. A., and Schacter, D. L. (1996). Implicit memory, explicit memory, and false recollection: A cognitive neuroscience perspective. In L. M.

Reder (Ed.), *Implicit memory and metacognition.* Hillsdale, NJ: Lawrence Erlbaum.

Norman, K. A., and Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory and Cognition, 25,* 838–848.

Nyberg, L., Cabeza, R., and Tulving, E. (1996). PET studies of encoding and retrieval: The HERA model. *Psychonomic Bulletin and Review, 3,* 135–148.

O'Connor, M., Walbridge, M., Sandson, T., and Alexander, M. (1996). A neuropsychological analysis of Capgras syndrome. *Neuropsychiatry, Neuropsychology and Behavioral Neurology, 9,* 265–271.

Park, D. C., and Puglisi, J. T. (1985). Older adults' memory for the color of pictures and words. *Journal of Gerontology, 40*(2), 198–204.

Parkin, A. J., Leng, N. R., Stanhope, N., and Smith, A. P. (1988). Memory impairment following ruptured aneurysm of the interior communicating artery. *Brain and Cognition, 7,* 231–243.

Pezdek, K. (1983). Memory for items and their spatial locations by young and elderly adults. *Developmental Psychology, 19,* 895–900.

Phelps, E. A., and Gazzaniga, M. S. (1992). Hemispheric differences in mnemonic processing: The effects of left hemisphere interpretation. *Neuropsychologia, 30*(3), 293–297.

Phelps, E. A., Hirst, W., and Gazzaniga, M. S. (1991). Deficits in recall following partial and complete commissurotomy. *Cerebral Cortex, 1*(6), 492–498.

Posner, M. I., and Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 55–85). Hillsdale, NJ: Lawrence Erlbaum.

Rajaram, S., and Roediger, H. L. III. (1997). Remembering and knowing as states of consciousness during retrieval. In J. D. Cohen and J. W. Schooler (Eds.), *Scientific approaches to consciousness* (pp. 213–240). Mahwah, NJ: Lawrence Erlbaum.

Ramachandran, V. S. (1995). Anosognosia in parietal lobe syndrome. *Consciousness and Cognition, 4*(1), 22–51.

Raye, C. L. (1976). Recognition: Frequency or organization? *American Journal of Psychology, 89,* 645–658.

Raye, C. L., Johnson, M. K., and Taylor, T. H. (1980). Is there something special about memory for internally generated information? *Memory and Cognition, 8*(2), 141–148.

Reinitz, M., Lammers, W., and Cochran, B. (1992). Memory-conjunction errors: Miscombination of stored stimulus features can produce illusions of memory. *Memory and Cognition, 20*(1), 1–11.

Reiser, B. J. (1986). The encoding and retrieval of memories of real-world experiences. In J. A. Galambo, R. P. Abelson, and J. B. Black (Eds.), *Knowledge structures* (pp. 71–99). Hillsdale, NJ: Lawrence Erlbaum.

Roediger, H. (1996). Memory illusions. *Journal of Memory and Language, 35*(2), 76–100.

Roediger, H. L., and McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(4), 803–814.

Ross, M. (1989). Relation of implicit theories to the construction of personal histories. *Psychological Review, 96*(2), 341–357.

Ross, M. (1997). Validating memories. In N. L. Stein, P. A. Ornstein, B. Tversky, and C. Brainerd (Eds.), *Memory for everyday and emotional events* (pp. 49–81). Hillsdale, NJ: Lawrence Erlbaum.

Rugg, M. D. (1995). Event-related potential studies of human memory. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 789–801). Cambridge, MA: MIT Press.

Schacter, D. L. (1995). Memory distortion: History and current status. In D. L. Schacter (Ed.), *Memory distortion* (pp. 1–43). Cambridge, MA: Harvard University Press.

Schacter, D. L., Alpert, N. M., Savage, C. R., et al. (1996). Conscious recollection and the human hippocampal formation: Evidence from positron emission tomography, *Proceedings of the National Academy of Sciences of the United States of America, 93,* 321–325.

Schacter, D. L., Curran, T., Galluccio, L., Milberg, W. P., and Bates, J. F. (1996). False recognition and the right frontal lobe: A case study. *Neuropsychologia, 34*(8), 793–808.

Schacter, D. L., Harbluk, J. L., and McLachlan, D. R. (1984). Retrieval without recollection: An experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behavior, 23*(5), 593–611.

Schacter, D. L., Koutstaal, W., Johnson, M. K., Gross, M. S., and Angell, K. E. (1997). False recollection induced via photographs: A comparison of older and younger adults. *Psychology and Aging, 12,* 203–215.

Schacter, D. L., Norman, K. A., Koutstaal, W. (1998). The cognitive neuroscience of constructive memory. *Annual Review of Psychology, 49,* 289–318.

Schacter, D. L., Reiman, E., Curran, T., Yun, L. S., Bandy, D., McDermott, K. B., and Roediger, H. L. III. (1996). Neuroanatomical correlates of veridical and illusory recognition memory: Evidence from positron emission tomography. *Neuron, 17,* 267–274.

Senkfor, A. J., and Van Petten, C. (1998). Who said what: An event-related potential investigation of source and item memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24,* 1005–25.

Shallice, T. (1988). *From neuropsychology to mental structure.* New York: Cambridge University Press.

Shallice, T., Fletcher, P., Frith, C. D., Grasby, P., Frackowiak, R. S. J., and Dolan, R. J. (1994). Brain regions associated with acquisition and retrieval of verbal episodic memory. *Nature, 368,* 6472.

Shimamura, A. P. (1995). Memory and frontal lobe function. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 803–813). Cambridge, MA: MIT Press.

Shimamura, A. P., Janowsky, J. S., and Squire, L. R. (1990). Memory for the temporal order of events in patients with frontal lobe lesions and amnesic patients. *Neuropsychologia, 28*(8), 803–813.

Skurnik, I. W. (1998). Metacognition and the illusion of truth. Doctoral dissertation, Princeton University.

Squire, L. R., and Knowlton, B. J. (1995). Memory, hippocampus, and brain systems. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 825–837). Cambridge, MA: MIT Press.

Stuss, D. T., Alexander, M. P., Lieberman, A., and Levine, H. (1978). An extraordinary form of confabulation. *Neurology, 28*(1), 1166–72.

Stuss, D. T., and Benson, D. F. (1986). *The frontal lobes.* New York: Raven Press.

Stuss, D. T., Eskes, G. A., and Foster, J. K. (1994). Experimental neuropsychological studies of frontal lobe functions. In F. Boller and J. Grafman (Eds.), *Handbook of neuropsychology,* Vol. 9 (pp. 149–185). New York: Elsevier.

Suengas, A. G., and Johnson, M. K. (1988). Qualitative effects of rehearsal on memories for perceived and imagined complex events. *Journal of Experimental Psychology: General, 117*(4), 377–389.

Tulving, E. (1983). *Elements of episodic memory.* New York: Clarendon Press.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26*(1), 1–12.

Tulving, E., Kapur, S., Markowitsch, H. J., Craik, F. I. M., Habib, R., and Houle, S. (1994). Neuroanatomical correlates of retrieval in episodic memory: Auditory sentence recognition. *Proceedings of the National Academy of Sciences of the United States of America, 91,* 2012–15.

Ungerleider, L. G. (1995). Functional brain imaging studies of cortical mechanisms for memory. *Science, 270,* (5237).

Weinberger, D. R. (1988). Schizophrenia and the frontal lobe. *Trends in Neuroscience, 11*(8), 367–370.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120*(2), 272–292.

Williams, M. W., and Hollan, J. D. (1981). The process of retrieval from very long-term memory. *Cognitive Science, 5,* 87–119.

Zaragoza, M. S., and Koshmider, J. W. III. (1989). Misled subjects may know more than their performance implies. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(2), 246–255.

Zaragoza, M. S., and Lane, S. M. (1994). Source misattributions and the suggestibility of eyewitness memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(4), 934–945.

Zaragoza, M. S., Lane, S. M., Ackil, J. K., and Chambers, K. L. (1997). Confusing real and suggested memories: Source monitoring and eyewitness suggestibility. In N. L. Stein, P. A. Ornstein, B. Tversky, and C. Brainerd (Eds.), *Memory for everyday and emotional events* (pp. 401–425). Hillsdale, NJ: Lawrence Erlbaum.

Notes

1. We assume features of memories are distributed in those brain areas that originally processed the information (see for example Damasio, 1989). When we say that features must be "bound" together to form memories, we are not implying that a new single representation replaces these features. Rather, we mean that a process ("binding") relates the feature representations in such a way that they are more likely to be activated together later (Cohen and Eichenbaum, 1993).
2. We sometimes use the words "criterion" and "criteria" in an everyday sense to include what features are considered and how different features are weighted, as well as the threshold amount (or match of such information to a standard) that is required for a given source attribution. This usage may confuse some readers because the same terms are sometimes employed in the literature to refer to the decision threshold in a signal detection analysis of old-new recognition in which information is assumed to vary only along a single dimension (such as strength). In the SMF, both the qualitative and quantitative characteristics of mental experiences affect source attributions. Here we refer to "weights" when emphasizing flexibility in which qualities of mental experience are given the most focus or highest importance, and to "criteria" when we are emphasizing flexibility in the nature (amount or pattern) of information that is required for a particular source attribution. The two factors together are components of overall evaluative processes that make attributions about the nature of mental experiences.

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