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The Nature of Recollection and Familiarity: A Review of 30 Years of Research

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To account for dissociations observed in recognition memory tests, several dual-process models have been proposed that assume that recognition judgments can be based on the recollection of details about previous events or on the assessment of stimulus familiarity. In the current article, these models are examined, along with the methods that have been developed to measure recollection and familiarity. The relevant empirical literature from behavioral, neuropsychological, and neuroimaging studies is then reviewed in order to assess model predictions. Results from a variety of measurement methods, including task-dissociation and process-estimation methods, are found to lead to remarkably consistent conclusions about the nature of recollection and familiarity, particularly when ceiling effects are avoided. For example, recollection is found to be more sensitive than familiarity to response speeding, division of attention, generation, semantic encoding, the effects of aging, and the amnestic effects of benzodiazepines, but it is less sensitive than familiarity to shifts in response criterion, fluency manipulations, forgetting over short retention intervals, and some perceptual manipulations. Moreover, neuropsychological and neuroimaging results indicate that the two processes rely on partially distinct neural substrates and provide support for models that assume that recollection relies on the hippocampus and prefrontal cortex, whereas familiarity relies on regions surrounding the hippocampus. Double dissociations produced by experimental manipulations at time of test indicate that the two processes are independent at retrieval, and single dissociations produced by study manipulations indicate that they are partially independent during encoding. Recollection is similar but not identical to free recall, whereas familiarity is similar to conceptual implicit memory, but is dissociable from perceptual implicit memory. Finally, the results indicate that recollection reflects a thresholdlike retrieval process that supports novel learning, whereas familiarity reflects a signal-detection process that can support novel learning only under certain conditions. The results verify a number of model predictions and prove useful in resolving several theoretical disagreements.

Results from cognitive, neuropsychological, and neuroimaging studies of human memory increasingly indicate that recognition memory performance reflects two distinct memory processes or types of memory, often referred to as *recollection* and *familiarity*. The distinction is illustrated by the common experience of recognizing a person as familiar but not being able to recollect who the person is or where they were previously encountered. Such introspections suggest that memory judgments can be based either on recollection of information about previous study events or on assessments of stimulus familiarity. Although the development of formal dual-process models by cognitive psychologists only began in the 1970s, the distinction between these two types of memory has been discussed since the time of Aristotle. Given the rapid growth of empirical findings that are being interpreted within a dual-process framework, there is an increasing need to carefully examine dual-process models, as well as the methods that have been developed to measure these processes, and to evaluate and integrate the related empirical literature. The aim of this article is to characterize the functional nature and neuroanatomical substrates of recollection and familiarity by examining the existing models in light of the empirical evidence.

Do we need more than a single type of memory or process to account for recognition memory performance? If it is possible to account for performance with a model that involves only a

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single type of memory then this simpler model should be preferred. Although a majority of memory researchers today would likely agree that at least two processes or types of memory are needed to account for the existing recognition memory literature, it is useful to briefly consider the type of results that have led to this conclusion. I start by briefly describing four empirical dissociations that have been used as support for the claim that recognition involves more than a single type of memory. These examples will also be useful in illustrating the general domains from which the empirical evidence has accumulated.

First, studies of processing speed have indicated that familiarity is faster than recollection. For example, under speeded test conditions subjects are found to be able to make accurate discriminations that can be based on familiarity, such as distinguishing between items that were recently studied and nonstudied items, more quickly than they can make discriminations that require them to recollect specific information about the study event, such as determining when or where an item was previously studied (e.g., Hintzman & Caulton, 1997; Gronlund, Edwards, & Ohrt, 1997; Hintzman, Caulton, & Levin, 1998). I refer to these two types of recognition tests as item and associative recognition tests, respectively. A number of related studies have shown that as the time allowed to make a response is increased, the probability of accepting a new item that is either similar to a studied item, or is from an inappropriate study list, first increases then decreases, producing biphasic accuracy/response-time functions (e.g., Dosher, 1984; Gronlund & Ratcliff, 1989; Hintzman & Curren, 1994; Jacoby, 1999; McElree, Dolan, & Jacoby, 1999; Rotello & Heit, 2000). These results indicate that a fast familiarity process leads the related new items to be incorrectly accepted, and only with additional retrieval time are subjects able to recollect the information that allows them to reject those items.

Second, the analysis of recognition confidence responses indicates that recollection and familiarity can produce distinct receiver operating characteristics (ROCs). For example, when hit rates are plotted against false alarm rates as a function of response confidence (i.e., an ROC), the observed empirical functions are curvilinear and their shapes change across conditions such that they require no less than two functionally independent memory parameters to describe them (e.g., Kelley & Wixted, 2001; Kim, Hilford, & Adams, 1999; Rotello, Macmillan, & Reder, 2001; Yonelinas, 1994, 1999; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996), indicating that at least two separate memory components are needed to account for recognition performance. Moreover, in item recognition tests, as long as performance is above chance, the ROCs are always curvilinear, whereas in associative recognition tests the ROCs are quite distinct in the sense that they are often much more linear in shape (e.g., Arndt & Reder, 2001; Kelly & Wixted, 2001; Slotnick, Klein, Dodson, & Shimamura, 2000; Rotello, Macmillan, & Van Tassel, 2000; Yonelinas, 1997, 1999; but see Qin, Raye, Johnson, & Mitchell, 2001). Thus, models that provide a good fit for item recognition ROCs tend to provide a poor fit of the associative ROCs, indicating that different processes are contributing to performance in the two types of tests.

Third, recollection and familiarity exhibit distinct electrophysiological correlates. For example, event related potentials (ERPs) recorded on the scalp during recognition tests indicate that items that are "remembered" or that are associated with accurate memory for some detail of the study event are related to ERPs that exhibit distinct temporal and spatial scalp distributions from those related to items that are recognized on the basis of familiarity in the absence of recollection (e.g., Curran, 2000; Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Smith, 1993; Klimesch, Doppelmayr, Yonelinas, Kroll, Lazzara, Rohm, & Gruber, 2001). Although these results do not indicate which brain regions support recognition performance, they do indicate that there are at least two separate brain processes involved.

Fourth, recollection is more severely disrupted than familiarity by certain brain injuries, indicating that these two processes are dependent on different brain regions. For example, amnesic patients exhibit significantly greater memory impairments on associative than item recognition tests, indicating that the regions damaged in amnesia are more important for the former than latter type of recognition judgment (e.g., Aggleton, McMackin, Carpenter, Hornak, Kapur, Halpin, Wiles, Kamel, Brennan, Carton, & Gaffan, 2000; Hurst & Volpe, 1982; Huppert & Piercy, 1976; 1978). Moreover, consistent with the examples described above, ROC studies in amnesics have indicated that only one process (i.e., familiarity) is needed to account for their recognition performance (Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1997), as expected if they exhibited a severe deficit in recollection. Moreover, ERP studies of amnesics have indicated that although the ERP correlate of recollection is absent in these patients, they often still exhibit the familiarity correlate (e.g., Tendolkar, Schoenfeld, Golz, Fernandez, Kuhl, Ferszt, & Heinze, 1999; Düzel, Vargha-Khadem, Heinze, & Mishkin, 2001).

The examples just described indicate that recognition tests that can be based on familiarity are functionally distinct and rely on partially separate neural substrates than those that require subjects to recollect information about the study event. Such dissociations are expected if recognition performance relies on two distinct memory processes. In contrast, if all recognition memory judgments were based on the assessment of a single form of memory, then these types of dissociations should not have been observed.

Given that there are two different processes or types of memory that contribute to recognition, the question is then how best to describe them. The terms “recollection” and “familiarity” have been used in different ways by different theorists. In some cases, recollection and familiarity are treated as retrieval processes or memory assessment mechanisms. In others, the terms refer to different types of mnemonic information or subjective states, whereas others use the terms to refer to different memory storage locations or systems. As this review will make clear, although there is good agreement about some aspects of recollection and familiarity, there are also numerous disagreements that have led to important debates. The goal of the current article is to characterize recollection and familiarity by ascertaining the points of agreement and disagreement among the current models and then using the empirical evidence to assess the claims made by the models.

The review is organized into four main sections. The first section (Dual-Process Models) describes the dominant dual-process theories and identifies areas of agreement and disagreement about the nature of recollection and familiarity. The second section (Measurement Methods) examines different methods that have been used to assess these two processes. The third section (Empirical Findings) examines the effects of experimental manipulations on recollection and familiarity as well as the related neurological and neuromonitoring studies. The fourth section (Characterizing Recollection and Familiarity) assesses the model predictions about recollection and familiarity and evaluates the various measurement methods in light of the results.

DUAL-PROCESS MODELS

A number of memory models have been proposed that assume that recognition memory judgments can be based on two distinct forms of memory. The core assumptions of many of these models are often quite similar; however, they differ in critical ways and in many cases make conflicting predictions about the functional nature and the neural substrates of the underlying processes or systems.

The Atkinson Model

Atkinson and colleagues (Atkinson & Juola, 1973, 1974; Atkinson, Hertmann, & Wescourt, 1974; Juola, Fischler, Wood, & Atkinson, 1971) proposed a conditional search model of recognition memory in which subjects either make a fast response based on the familiarity of the test item or, if the familiarity process produces an ambiguous response, engage in an extended memory search. Familiarity is assumed to reflect the activation of nodes in a lexical store in which each node represents an individual word or object. Whenever a node is accessed it is activated and this activation decreases gradually over time. Thus, in a recognition test, the nodes corresponding to studied items will be more active on average than those corresponding to nonstudied items, and assessments of activation can be used to discriminate between studied and nonstudied items. The familiarity process is assumed to be well described by signal detection theory in the sense that activation levels of old and new items form overlapping Gaussian distributions. As in earlier applications of signal detection theory to human memory (e.g., Banks, 1970; Kintsch, 1967; Murdock, 1965; Parks, 1966), the subject is assumed to set a criterion and accept items exceeding this criterion as having been studied; unlike these earlier theories, the subject is assumed to set an additional lower criterion and accept items falling below this criterion as being new. For items falling between these criteria, assessments of activation are equivocal; thus for these items the subject is assumed to engage a recollection process whereby they search a separate event-knowledge store that holds a list of the items that were encoded when the items were studied. Familiarity and recollection are assumed to differ in the sense that they support memory for perceptual and semantic (or meaning-based) information, respectively.

The Neuroanatomical Models

Several dual-process models have been developed with the primary purpose of accounting for the memory deficits observed in patients with focal brain lesions. A number of models assume that medial temporal lobe damage (e.g., hippocampus and the surrounding temporal lobe including the parahippocampal gyrus; see Fig. 1) results in a form of amnesia that disrupts recollection but leaves familiarity intact. For example, Huppert and Piercy (1976; 1978) argue that healthy subjects can base recognition memory judgments on assessments of item familiarity or on the basis of retrieving contextual or list membership information about study events, whereas amnesics are limited primarily to assessments of familiarity. Similarly, Mayes (1988; Mayes, Meudell, & Pickering 1985; Mayes, 1992) argues that amnesia results in a deficit in context memory that leaves item memory relatively preserved. Similar arguments have been made by several others (e.g., Hirsh et al., 1986; Verfaellie & Treadwell, 1993; Wickelgren, 1979).

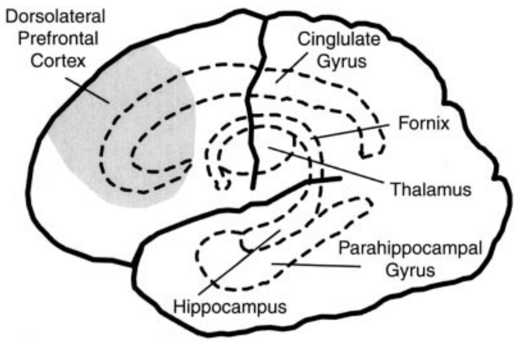

FIG. 1. Brain regions implicated as being involved in recollection and familiarity.

A number of more recent models challenge the notion that recollection is selectively disrupted in all patients with medial temporal lobe damage and suggest that the hippocampal region is critical for recollection, whereas surrounding structures in the medial and inferior temporal lobe (e.g., the parahippocampal gyrus) are important for familiarity (e.g., Aggleton & Brown, 1999; Eichenbaum, Otto, & Cohen, 1993). Thus, patients with selective hippocampal damage are expected to exhibit selective recollection deficits, whereas patients with more extensive damage that extends into the parahippocampal gyrus will exhibit deficits in both recollection and familiarity.

Although most of the neuroanatomically based dual-process models have focused on the contribution of the medial temporal lobes, a number of models indicate that the thalamus and frontal lobes also play critical roles in recollection and familiarity. For example, Aggleton and Brown (1999) argue that a circuit linking the hippocampus and anterior thalamus via the fornix supports recollection, whereas a circuit linking the perirhinal cortex (an anterior region of the parahippocampal gyrus) to the medial dorsal thalamus supports familiarity. They also argue that direct projections from the thalamus to the frontal lobes indicate that the frontal lobes likely play a critical role in both recollection and familiarity and that these regions may be important for both encoding and retrieval operations. Moreover, as discussed in more detail below, Tulving argues that the frontal lobes play an important role in recognition memory and that different frontal regions may be differentially related to recollection- and familiarity- based memory judgments.

The Mandler Model

Mandler and colleagues (Mandler, 1979, 1980, 1991; Graf & Mandler, 1984; Graf, Squire, & Mandler, 1985; Mandler & Boeck, 1974; Mandler, Pearlstone, & Koopmans, 1969; Rabinowitz, Mandler, & Patterson, 1977) argued that recognition memory judgments can be based on the assessment of item familiarity or on the basis of a memory search process. When an event is studied, it leads to an increase in activation or familiarity, which is the intraitem integration of the perceptual aspects of that item in memory. Familiarity is assumed to support not only recognition memory judgments but also performance on implicit memory tasks such as word stem completion (see Roediger & McDermott, 1993). In contrast, recollection is assumed to reflect a search process that supports both recognition and recall performance, whereby elaborative information or interitem information (i.e., information relating the event to its context or to other events) is retrieved. Mandler et al. (1969) initially argued for a conditional search model, such that recollection was only initiated if familiarity led to an ambiguous response, but in subsequent articles the model was modified such that the processes are independent and operate in parallel, but with familiarity typically being faster than recollection (e.g., Mandler, 1980). Recollection is expected to be selectively disrupted by damage to the medial temporal lobes, and familiarity is assumed to reflect the activation of existing memory representations in the neocortex.

The Jacoby Model

Jacoby and colleagues (Jacoby, 1983, 1984, 1991; Jacoby & Dallas, 1981; Jacoby & Kelley, 1992; Jacoby & Witherspoon, 1982; Jacoby, Kelley, & Dywan, 1989; Kelley & Jacoby, 1990; Whittlesea, Jacoby, & Girard, 1990) have argued that recognition memory judgments can be based on the assessment of processing fluency (i.e., familiarity) or on the recovery of the context and elaboration given to an item when it was initially studied (i.e., recollection). A fundamental distinction between the two processes is assumed to be that recollection reflects an analytic, consciously controlled process, whereas familiarity is a relatively automatic process.

Unlike previous models, familiarity is not treated as an inherent characteristic of an item or event; rather, it is thought to arise when fluent processing of an item is attributed to past experience with that item. For example, in a recognition memory test, if some items are processed more fluently than others (e.g., they are presented slightly more clearly than other test items), subjects might attribute this processing fluency to past experience with those items and judge them to be familiar. Processing fluency is also expected to lead items to be more easily identified in implicit memory tests like perceptual identification (Jacoby & Dallas, 1981), and thus, familiarity and perceptual implicit memory should be related. However, familiarity is not limited to perceptual fluency, but rather can also reflect conceptual fluency (i.e., enhanced processing of the meaning of the stimuli), and thus familiarity should not be identical to perceptual implicit memory, which tends to be insensitive to conceptual manipulations (Jacoby, 1984; 1991; Jacoby & Kelley, 1992).

Familiarity is assumed to be somewhat faster than recollection, but the two processes are assumed to be independent and to operate in parallel. Although the neuroanatomical substrates of these processes have not been specified, amnesics are expected to rely primarily on familiarity, suggesting that the medial temporal lobes are particularly important for recollection. Familiarity is not assumed to reflect the operation of a distinct memory system from recollection, nor to rely on activation of existing representations. Rather, both recollection and familiarity are thought to rely on detailed memory for prior episodes. Thus, familiarity and recollection should be capable of supporting new learning, such as with nonwords and new associations.

The Tulving Model

Tulving and colleagues have argued that there are several functionally distinct memory systems (Tulving, 1985, 1982; Tulving & Schacter, 1990; Tulving & Markowitsch, 1998; Nyberg, Cabeza, & Tulving, 1996; Wheeler, Stuss, & Tulving, 1997), including *episodic memory*, which gives rise to the conscious experience of "remembering" (i.e., recollection), and *semantic memory*, which gives rise to the conscious experience of "knowing" (i.e., the feeling of familiarity in the absence of remembering). Although Tulving's model is not often described as a dual-process model of recognition, it is similar to the Atkinson model in assuming that recognition memory performance reflects the operation of two separate memory systems. The episodic system stores personally experienced events and their temporal relations to each other, whereas the semantic system stores general knowledge about the world. Recall performance is thought to rely primarily on the episodic system, whereas recognition relies heavily on both systems. Both systems are expected to be flexible and to support the learning of new information, although the semantic system may be slower to learn new information than the episodic system. Perceptual implicit memory was initially thought to rely on semantic memory (Tulving, 1982), but later was assumed to reflect a *visual word form* system that was separate from the semantic system (Tulving & Schacter, 1990), thus leading to the expectation that familiarity and perceptual implicit memory should be distinct. Information is assumed to pass through the semantic system before it is encoded into the episodic system such that the formation of episodic memories depends upon the semantic system. However, at time of retrieval, the two systems are assumed to operate independently and in parallel in the sense that information can be retrieved from either of the two systems separately (Tulving, 1985, 1995; Tulving & Markowitsch, 1998).

The episodic system is assumed to rely on the medial temporal and frontal lobes, and thus damage to either region can lead to deficits in recollection (Wheeler, Stuss, & Tulving, 1997; Schacter & Tulving, 1994). However, a further division within the temporal lobes is assumed to hold, in which the hippocampus is critical for episodic memory, whereas the surrounding temporal lobe regions are critical for semantic memory (Tulving & Markowitsch, 1998). Moreover, the right prefrontal regions are assumed to be critical for retrieval from episodic memory, whereas left prefrontal regions are important for retrieval from semantic memory and for the encoding into episodic memory (e.g., Nyberg, Cabeza, & Tulving, 1996).

The Yonelinas Model

Yonelinas and colleagues (Dobbins, Kroll, Yonelinas, & Liu, 1998; Yonelinas, 1994, 1997, 1999, 2001a, 2001b; Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998; Yonelinas, Kroll, Dobbins, & Soltani, 1999; Yonelinas, Dobbins, Szymanski, Dhaliwal, & King, 1996) have argued that recollection and familiarity differ in terms of the type of information that they provide and in the extent to which each process influences recognition confidence. Familiarity is assumed to reflect the assessment of "quantitative" memory strength information in a manner similar to that described by signal detection theory. In contrast, recollection reflects a threshold retrieval process whereby "qualitative" information about a previous event is retrieved. That is, subjects may retrieve many different aspects of a study event (e.g., temporal and spatial context, as well as associations between different components of an event), but, for some items, subjects are unable to retrieve any accurate qualitative information about the study event (i.e., some items fall below the recollective threshold). For these items subjects are expected to rely on assessments of familiarity. Recollection is expected to support relatively high confidence recognition decisions compared to familiarity, which supports a wide range of recognition confidence responses. The model assumes that at time of retrieval recollection and familiarity are initiated in parallel and are independent. Familiarity is expected to be faster than recollection (Yonelinas & Jacoby, 1994, 1996), and recollection is expected to be reduced with hippocampal damage, whereas familiarity should be reduced if additional temporal lobe structures are damaged (Yonelinas et al., 1998). Recollection is particularly well suited to support learning of novel associations, and familiarity is only expected to support novel learning under very limited conditions (Yonelinas 1997, 1999; Yonelinas, Kroll, Dobbins, & Soltani, 1999). Most importantly, familiarity is not expected to support associative memory for two distinct items, unless the two items can be unitized or treated as a single larger item (e.g., in the way that a nose, mouth, and eyes can form a face).

Points of Agreement and Disagreement among the Models

Dual-process models are often treated as a unified set of theories or as slight variations on the same basic theory. There is some support for these assertions in the sense that most of the models are in good agreement about a number of central characteristics of recollection and familiarity, but the models do differ in some important ways. Nine critical areas are identified below, ranging from points in which almost all the models are in agreement, to points in which a wide variety of opposing positions have been taken. Each of these areas are discussed further after the empirical results are presented.

1. There is general agreement that familiarity is faster than recollection (Atkinson, Mandler, Jacoby, and Yonelinas). Most of these models assume that both processes are initiated in parallel (Mandler, Jacoby, and Yonelinas), whereas one model assumes that familiarity is completed before recollection (Atkinson). Although the neuroanatomical models make no explicit claims about response speed, several models assume that familiarity is subserved by brain regions that are earlier in the processing stream (e.g., parahippocampal gyrus, than regions supporting recollection (e.g., the hippocampus), thus they are consistent with the expectation that familiarity is the faster of the two processes.

2. Most of the models assume that recollection and familiarity function independently at the time of retrieval (Mandler, Jacoby, Tulving, and Yonelinas). Atkinson assumes that recollection and familiarity rely on two independent memory storage systems, but he assumes that familiarity is initiated first and that only if familiarity fails is the recollection process initiated. Very few of the neuroanatomical models explicitly address how the two processes are related. However, because they assume that it is possible to selectively disrupt recollection, this process must be partially independent of familiarity. How the two processes are related at the time of encoding is less clear. For example, Atkinson does not elaborate on encoding mechanisms, but because the two processes are assumed to rely on distinct storage systems, they could involve independent encoding mechanisms. In contrast, Tulving argues that information must pass through the semantic system before entering the episodic system, thus the processes act sequentially during encoding even though they can operate independently during retrieval.

3. Familiarity is often described as reflecting a continuous index of memory strength, whereas recollection is thought to reflect the retrieval of specific information about a study event (Atkinson, Jacoby, Yonelinas, and several neuroanatomical models). Some models have formalized familiarity using signal detection theory (Atkinson and Yonelinas), such that old items are more familiar than new items but they form overlapping Gaussian distributions. In contrast, the retrieval process has been formalized by at least one model as a threshold process (Yonelinas) such that subjects sometimes fail to retrieve any qualitative information about a studied item.

4. An assumption adopted by some models is that recollection and familiarity reflect conceptual and perceptual processes, respectively (Atkinson and Mandler). However, Jacoby argues that familiarity reflects conceptual as well as perceptual fluency, and Tulving treats familiarity as arising from semantic memory that contains abstract knowledge. Thus, familiarity might not be limited solely to perceptual information.

5. Recollection and familiarity are sometimes described as reflecting controlled and automatic processes, respectively (Jacoby). Although most models do not explicitly address the automatic/controlled distinction, many of them are broadly consistent with this claim. For example, to the extent that familiarity is a particularly fast process (Atkinson, Mandler, and

Yonelinas) it might be described as being relatively automatic. Moreover, the activation process that is sometimes assumed to underlie familiarity is often described as relatively automatic, whereas the search process underlying recollection is more controlled and effortful (Atkinson and Mandler).

6. One difference between recollection and familiarity that is proposed by at least some models is that familiarity decreases more rapidly than recollection. That is, models that treat familiarity as resulting from temporary activation of neural networks or lexical representations (Atkinson, Mandler, Eichenbaum, et al., 1993) predict that familiarity should decrease fairly rapidly. Mandler argues that differences in forgetting rates should be observed across retention intervals varying up to several weeks. In contrast, Eichembaum et al. (1993) suggest that differences in forgetting should be most pronounced when examining performance very shortly after encoding.

7. A point of considerable disagreement among the models centers on the extent to which these processes can support learning of novel information. Some models treat recollection as being necessary for the learning of new associations and representations, whereas familiarity reflects the activation of preexisting representations. For example, Atkinson treats familiarity as the activation of existing lexical nodes, and Mandler treats familiarity as item activation. Thus, familiarity should not support novel learning. However, Jacoby suggests that both recollection and familiarity rely on detailed memory for prior events, thus one might expect both processes to support novel learning. Similarly, Tulving argues that semantic memory can support novel learning even without the episodic system. In contrast to these two positions, Yonelinas argues that familiarity does not support associative memory for different aspects of an event, unless these different aspects are treated as a unified whole. Thus, familiarity should support learning of new items, such as nonwords, but should not support learning of associations between arbitrarily paired items (e.g., word pairs) unless they are encoded as a single unified item.

8. There is also disagreement about how familiarity should be related to implicit memory. For example, Tulving argues that implicit memory relies on memory systems that are separate from those supporting recognition memory. In contrast, Mandler and Jacoby argue that the same process that supports recognition can also support perceptual priming in tasks like stem completion. However, Jacoby argues that familiarity is influenced by conceptual fluency, thus it might be more closely related to conceptual implicit memory, such as that seen on exemplar generation tasks (see Roediger & McDermott, 1993), than to perceptual implicit memory.

9. There are also disagreements about the neural substrates of recollection and familiarity. Most of the models are consistent in assuming that recollection is dependent on the medial temporal lobes and thus predict that amnesics should exhibit deficits in recollection (Mandler, Jacoby, Yonelinas, and neuroanatomical models). However, there is less agreement about whether familiarity is completely preserved in these patients. Mandler and some of the neuroanatomical models make the assumption that familiarity is preserved in amnesia. However, other models assume that the fate of familiarity depends on the precise location of the medial temporal lobe damage. For example, several models propose that the hippocampus is important for recollection, whereas regions in the surrounding medial temporal lobe, such as the parahippocampal gyrus, are important for familiarity (Tulving, Yonelinas, and some neuroanatomical models).

Regions outside the medial temporal lobes, such as the frontal lobes, are also thought to be involved in recollection and familiarity, but there is little agreement about the specific regions or about the precise roles of these regions. For example, Aggleton and Brown (1999) argue that a circuit linking the hippocampus and frontal lobes via the fornix and anterior thalamus supports recollection, whereas a circuit linking the parahippocampal gyrus to the frontal lobes via the medial dorsal thalamus supports familiarity. Tulving argues, more specifically, that the right frontal lobe is involved in attempts to retrieve from episodic memory (i.e., recollection), whereas the left frontal lobe is involved in retrieval from semantic memory (i.e., familiarity) and that the act of retrieving from semantic memory results in encoding into episodic memory and thus the left frontal lobe should be related to recollection encoding.

MEASUREMENT METHODS

In order to evaluate the theoretical claims about recollection and familiarity, it is necessary to develop methods that can be used to measure these processes. All measurement methods rely on critical assumptions. If these assumptions are not met then the methods cannot be expected to lead to valid conclusions. For this reason it is necessary to carefully consider the assumptions of each measurement method. The methods that have been used to examine recollection and familiarity fall into two general classes. *Task-dissociation methods* (e.g., response-speed methods, recall/recognition comparisons, and item/associative recognition comparisons) aim to identify a task or test condition that isolates one of the two process. If performance on that task is found to dissociate from performance in a standard recognition test condition in which both recollection and familiarity are expected to operate, then this can be used to make inferences about the effects of different variables on recollection and familiarity. Certain patterns of results produced by the task-dissociation methods are inherently ambiguous, however, and this has led to the development of several *process-estimation methods* (e.g., process-dissociation, remember/know, and ROC procedures). This class of measurement methods involve developing a set of model equations that can be used along with observed measures of performance to derive parameter estimates representing the contribution of recollection and familiarity to overall performance. Each of these measurement methods is described and assessed below.

Task-Dissociation Methods

Response-speed methods. Because familiarity is expected to be faster than recollection (e.g., Atkinson, Mandler, Jacoby, and Yonelinas), response speed should be useful in separating the contribution of these two processes. Three different response-speed methods have been used. In the *response-time method*, recognition performance is examined separately for fast and slow recognition responses under standard nonspeeded recognition conditions. Fast responses are expected to reflect familiarity, whereas slow responses should include a greater contribution of recollection. In the *response-deadline method*, subjects are forced to make a speeded recognition response at a specified time after the test stimulus is presented (e.g., within 700 ms), and performance is compared to that from a nonspeeded recognition test condition. Speeded responses should be based primarily on familiarity, whereas nonspeeded responses should reflect a mixture of recollection- and familiarity-based responses. A variation of the deadline method is the *speed–accuracy trade-off (SAT) method* in which subjects are signaled to respond at variable intervals following the onset of each test item, thereby generating a time course function that measures the growth of retrieval accuracy as a function of processing time. The point at which performance exceeds chance can be used to make inferences about the retrieval speed in different test conditions.

One potential limitation of the response-deadline method relates to the fact that the test instructions are different in the two test conditions. That is, in one condition subjects are required to make speeded responses, whereas responses are unspeeded in the other. Differences in test instructions may influence how the processes behave, thus complicating the comparison of the two test conditions. The response-time and speed–accuracy trade-off methods, however, do not suffer from this problem because the instructions are held constant across the different conditions.

Recall/recognition methods. If the recollection process that operates in recognition is similar to the search process that is used in tests of recall (e.g., Mandler, and Tulving) then performance on recall tests can be used as an index of recollection. By comparing recall performance to recognition, which reflects recollection and familiarity, it should be possible to make inferences about the effects of different variables on recollection and familiarity. For example, if a variable has a larger effect on recall than recognition, then it can be said to have a larger effect on recollection than familiarity.

A potential limitation associated with the recall/recognition method is that the two test conditions differ in terms of retrieval cues and the type of responses that they require. These differences may inadvertently influence recollection and familiarity and thus may provide biased measures of these processes. That is, in the recognition test, the target items are presented and subjects are instructed to make yes/no or forced-choice recognition responses, whereas in the recall test, no target items are presented as retrieval cues, and subjects are required to produce the studied items. Even if the same recollection process is utilized in the recall and recognition tests, recollection may behave differently in the two tests because of the different test cues or response requirements. This point is discussed further after the presentation of the empirical findings.

Another potential limitation associated with the recall/recognition method, and one that has haunted behavioral scientists for generations, is the problem of scaling differences. For example, comparisons of recognition and recall are complicated by the fact that the scales used to measure them may not be linear across the range of observed scores (Loftus, 1978). That is, a 10% decrease in recall may not be equivalent to a 10% decrease in recognition accuracy. This is most problematic when floor or ceiling effects are observed in one of the two tasks, but even when floor and ceiling effects are avoided nonlinearities may still persist. Several methods have been developed to deal with this scaling issue. One approach is a parametric method in which performance on each task is examined under a variety of different levels. If the tasks dissociate regardless of the overall level of performance, then this indicates that the results are not just an artifact of the specific level of performance observed in one set of test conditions. Similarly, one may look across studies to verify that the same pattern holds across the studies. If performance levels vary across those studies and the dissociation is consistently observed, then it suggests that the dissociation is real.

Item/associative recognition methods. If recollection reflects the retrieval of qualitative information about the study event (e.g., Atkinson, Jacoby, Yonelinas, and Mandler), then it should be useful in associative recognition memory tests in which subjects are required to make recognition judgments about the co-occurrence of different items or different aspects of the study event, such as item–item associations (e.g., were these two words paired together at study?), item–context associations (e.g., was the item presented on the left or right side of the screen?), or item–feature associations (e.g., was this word spoken by a male or female voice?). In contrast, if familiarity reflects the memory strength of single items, then it should be useful in discriminating between studied and nonstudied items, as in a test of item recognition, but it should be less useful in most tests of associative recognition. Thus, tests of associative recognition can be used as an index of recollection, whereas tests of item recognition are expected to reflect both recollection- and familiarity-based responses. An advantage of the item/associative method over the recall/recognition method is that the test cues and required responses can be held constant in the associative and item test conditions. Some associative tests, however, may be influenced to some degree by familiarity, such as recency or temporal order judgments (e.g., which item was presented more recently?), because more recent items may be perceived as more familiar. Moreover, as discussed above, some models predict that familiarity can support the learning of some types of associations (e.g., when the two items form a unified whole item), thus in some conditions familiarity might contribute to associative memory judgments. Nonetheless, compared to item recognition tests, the associative tests should rely less on familiarity because all the items in that test were recently studied, whereas in item recognition only the old items were studied.

Other, less common task-dissociation methods have also been used to isolate familiarity. For example, because amnesics are expected to rely primarily on familiarity, these patients can be used to provide an index of familiarity-based recognition. Similarly, if familiarity reflects a signal detection process, then it might be expected to lead to more false alarms that the recollection process, thus false alarms can be used as an index of familiarity. Finally, because manipulations like dividing attention are expected to reduce recollection to a greater extent than familiarity, divided attention conditions can be used to assess familiarity.

Each of the task-dissociation methods makes assumptions about recollection and familiarity, and each is associated with different advantages and disadvantages. One general limitation associated with the task-dissociation methods is that they provide imprecise estimates of recollection or familiarity, and thus some patterns of results will be inherently ambiguous. As an illustration, consider the response-deadline method. If an experimental manipulation has an effect on slow responses and a similar, but smaller, effect on fast responses, this can arise if the manipulation has a larger effect on recollection than familiarity or if recollection is selectively influenced by the manipulation, but the fast responses include some recollection- as well as familiarity-based responses. That is, if performance in the speeded condition does not clearly dissociate from performance in the nonspeeded condition, the precise reason for that particular result will be ambiguous. In many cases it is sufficient to show that a variable has a disproportionately large effect on one of the two processes, and thus the task-dissociation methods are quite useful. However, there are cases in which it is theoretically important to determine if a process is, or is not, influenced by a given variable. In order to overcome these limitations, several modeling methods have been developed which aim to provide quantitative estimates of the contribution of recollection and familiarity to overall recognition performance. These methods are described next.

Process-Estimation Methods

The process-dissociation procedure. This method utilizes a modification of the item and associative recognition tasks discussed above, in which recollection is measured as the ability to remember where or when an item was earlier studied. The idea is that if a subject can recollect a given item, then they should be able to determine when or where it was initially studied, whereas familiarity should not support such a discrimination. As the method was first developed by Jacoby (1991), subjects first study a visually presented list of items under incidental encoding conditions, then study a separate list of heard items under intentional encoding conditions. Then, in one test condition (i.e., the inclusion test) subjects are instructed to respond "yes" if the test item was studied previously (i.e., include items from both study lists). In another test condition (i.e., the exclusion test) subjects are instructed to respond "yes" only to items from the heard list (i.e., exclude the items from the seen list). Because both recollection and familiarity can be used in the inclusion condition, the probability of correctly accepting an item from the seen list is equal to the probability that item is recollected plus the probability that it is not recollected but is accepted on the basis of familiarity [$P(\text{Inclusion}) = R + (1 - R)F$]. In contrast, the probability that a seen item is incorrectly accepted in the exclusion condition is equal to the probability that it is familiar in the absence of recollection [($P(\text{Exclusion}) = (1 - R)F$]. The R and F parameters can be estimated by contrasting inclusion and exclusion performance [e.g., $R = P(\text{Inclusion}) - P(\text{Exclusion})$; $F = P(\text{Exclusion})/(1 - R)$].

The process-dissociation procedure is consistent with most dual-process models in assuming that recollection and familiarity are independent. The primary method of assessing the independence of recollection and familiarity is to look for dissociations between these processes. If the two processes are fully independent then it should be possible to find manipulations that influence recollection without influencing familiarity and others that have the opposite effect. In contrast, if the two processes are dependent then such dissociations should not be possible. Several earlier reports have examined whether controlled and automatic memory processes behave independently in studies of word-stem completion in which the process-dissociation procedure has been used, and it appears that there are conditions in which they behave independently and others in which there is a dependence between the two processes (e.g., Jacoby, 1998; Jacoby, Begg, & Toth, 1996; Jacoby & Shrout, 1997; Jacoby, Yonelinas, & Jennings, 1997; Curran & Hintzman, 1995, 1997a, 1997b; Russo, Cullis, & Parkin, 1998). More relevant for the current purposes, however, are studies that have examined the independence assumption in recognition memory tests, which generally indicate that recollection and familiarity behave independently (Caldwell & Masson, 2001; Kelley & Jacoby, 2000; Yonelinas, 2001a, 2001b; Yonelinas & Levy, 2001; Yonelinas & Jacoby, 1995a, 1995b; but see Dehn & Engelkamp, 1997). However, these previous reports considered only a small number of manipulations and have been limited primarily to consideration of results from the process-estimation methods. Rather than reiterating the evidence presented in those reports, a full assessment of the independence assumption will be held until after the current review of the empirical literature. Because the current review is more exhaustive than those previous reports and examines the operation of recollection and familiarity using tasks that do not rely on the independence assumption, it will provide a more thorough evaluation of how these two processes are related. To anticipate the results, recollection and familiarity are found to operate independently under most experimental conditions, but there are boundary conditions, outside of which the independence assumption may not hold.

A potential limitation of the process-dissociation procedure is that it uses a rather strict measure of recollection—the ability to determine in which study list the item was presented. The study list is defined by the type of encoding manipulation (incidental vs intentional), list membership (list 1 vs list 2), and study modality (heard vs read). Thus, if the subject recollects any of these aspects of the study event they can use this as a basis for excluding items, and this will be measured as recollection. However, if they recollect some other aspect of the study event (e.g., "I remember coughing as the item was studied") that does not support the required discrimination—sometimes referred to as partial recollection—this will not be measured as recollection. Several studies have shown that partial recollection can influence the parameter estimates, particularly when the two study lists are made very similar and subjects are able to remember many different aspects of the study events that do not support list discrimination (e.g., Gruppuso, Lindsay, & Kelly, 1997; Mulligan & Hirshman, 1997; Wagner, Gabrieli, & Verfaelli, 1997; Yonelinas & Jacoby, 1996). However, under the conditions initially developed by Jacoby, and described above, partial recollection appears to be relatively infrequent (Yonelinas & Jacoby, 1996; Yonelinas, 2001a, 2001b).

Another potential problem with the procedure is that it uses different test instructions in the inclusion and exclusion conditions, and this may influence the parameter estimates. For example, the method assumes that recollection is equally likely in the inclusion and exclusion conditions. To the extent that recollection is required in the exclusion test (i.e., subjects must discriminate between items from the two lists), whereas it is not explicitly required in the inclusion test (i.e., subjects only have to discriminate between old and new items), subjects may use recollection more often in the exclusion than inclusion condition. One method of ensuring the use of recollection in both test conditions is to mix the inclusion and exclusion test trials (e.g., see Jacoby, Toth, & Yonelinas, 1993). Alternatively, modifications of the procedure have been developed in which list discriminations are required in both inclusion and exclusion conditions (e.g., Yonelinas & Jacoby, 1994). Note, however, that an initial comparison of standard inclusion instructions and modified instructions in which list discriminations were required indicated that performance was comparable in the two conditions, suggesting that the modification may be unnecessary (Yonelinas, 1994).

The process-dissociation method also assumes that the contribution of familiarity is constant in the inclusion and exclusion conditions. The modified process-dissociation method just described, in which the test instructions are comparable in the inclusion and exclusion conditions, can be used to ensure similar use of familiarity in both conditions. Alternatively, a test of this assumption is to examine the false alarm rates for nonstudied items. If they are equal in the inclusion and exclusion conditions it suggests that the subjects' reliance on familiarity is comparable in the two conditions. If differences do arise, methods have been developed to compensate for differences in response bias (e.g., Yonelinas & Jacoby 1996; Yonelinas, Regehr & Jacoby, 1996; Roediger & McDermott, 1994; Buchner, Erdfeld, & Vaterrodt-Plunnecke, 1995).

The remember/know procedure. In order to measure the contribution of different types of memory to overall memory performance, Tulving (1985) developed the *remember/know procedure,* in which subjects are required to introspect about the basis of their memory judgments and report whether they recognize items on the basis of remembering (i.e., recollection of episodic information about the study event) or knowing (i.e., the item is familiar in the absence of recollection).[1] Tulving, however, did not specify exactly how these responses were related to the underlying memory systems, and this has led to some variability in how remember/know results are reported and interpreted. Given that subjects are instructed to respond "remember" whenever an item is recollected, the proportion of remember responses should provide a measure of recollection. Estimating familiarity, however, is not as simple. In several early studies, the proportion of know responses was used as an estimate of familiarity (e.g., Gardiner, 1988). Because remember and know responses are mutually exclusive (i.e., for a given item subjects are only allowed to make one response), this method assumes that the underlying processes are also mutually exclusive, which is inconsistent with all of the dual-process models. It is now clear, however, that know responses do not provide an unbiased measure of familiarity (e.g., see Gardiner & Richardson-Klavehn, 2000; Yonelinas & Jacoby, 1995; Wagner et al., 1997). That is, subjects are not instructed to respond "know" whenever an item is familiar; rather, they are instructed to respond "know" whenever an item is "familiar and not recollected." Thus the proportion of know responses will tend to underestimate the probability that an item is familiar.

To compensate for this underestimation, an *independence remember/know* method (Yonelinas & Jacoby, 1995) is often used (e.g., Jacoby, Yonelinas, & Jennings, 1997; Mangels, Picton, & Craik, 2001; Ochsner, 2000; Wagner et al., 1997; Yonelinas, 2001a). Because subjects are instructed to respond "remember" whenever they recollect a test item, the probability of a remember response is used as an index of recollection ("remember" $= R$). In contrast, because subjects are instructed to respond "know" whenever an item is familiar and not recollected ["know" $= F(1 - R)$], the probability that an item is familiar will be equal to the probability that it received a know response given it was not recollected [$F =$ "know"$/(1 - R)$]. It is important to realize that this method assumes that recollection and familiarity are independent, as does the process-dissociation procedure, and thus it is consistent with most dual-process models in this respect.

The unique aspect of the remember/know procedure is that it measures recollection and familiarity on the basis of subjective reports. One advantage of this is that it provides a very inclusive measure of recollection in the sense that recollection is not limited to what a subject can produce in a recall test or what they can recollect on an associative recognition test. Rather, it can include any associative information about

[1] Subjects are sometimes given another response option (i.e., guessing) to be used in cases that subjects guess that the item was studied. It appears that these subjective experiences are similar to know responses in that they are often justified as familiarity-based, but also include various inferences that are not directly related to memory (Gardiner, Ramponi, & Richardson-Klavehn, 1998). Hirshman (1998) argued that guess responses simply reflect low confidence recognition response and thus are not fundamentally different from know responses. In the following review, the studies using the guess responses were not found to lead to different conclusions from those using the standard remember/know response method, so guess responses were not reported. However, subjects did appear to adopt a more strict criterion for know than for guess responses; thus the results support Hirshman's argument about these guessing responses.

the study episode. However, relying on subjective reports may be problematic if subjects have no direct access to the processes that support recognition or if their reports are inaccurate. The consistency of the results from remember/know studies that is reported below, however, indicates that subjects generally do interpret the distinction in similar ways. Moreover, studies showing that estimates of recollection derived from remember/know responses converge with those from other measures of recollection and familiarity that do not rely on subjective reports, suggesting that subjects generally do have access to these memory processes (Yonelinas, 2001b). This latter point is addressed further in the current article.

A related criticism is that reports of remembering and knowing do not reflect the contribution of recollection and familiarity at all, but rather reflect subjective states of awareness that are completely orthogonal to the processes of recollection and familiarity (e.g., “Remember and know responses are not intended as introspective measures of any underlying hypothetical constructs, such as memory systems or processes” p. 230, Gardiner & Richardson-Klavehn, 2000; also see Gardiner, Ramponi, & Richardson-Klavehn, 1999). In support of this position, it is argued that remember and know responses do not always produce results that are in agreement with results from other methods for estimating recollection and familiarity. However, as will become apparent in the following review, there is very little support for this claim.

Another criticism of the procedure is that remembering and knowing may not reflect two distinct forms of memory; rather, they may simply reflect differences in familiarity or confidence (Donaldson, 1996; Hirshman & Master, 1997; Inoue & Bellezza, 1998). For example, it is sometimes the case that memory discrimination as indexed by the d' or A' statistics is the same for remember responses and for overall recognition, as would be expected if remember responses simply reflected high confidence familiarity-based responses (see Donaldson, 1996). However, other studies indicate that these measures of accuracy are not equivalent for remember responses and overall recognition (e.g., Gardiner & Gregg, 1997; Hirshman, Fisher, Henthorn, Arndt, & Passannante, 2002; Hockley & Consoli, 1999; see also Dobbins, 2001), indicating that a simple confidence interpretation cannot account for remember/know responses. Moreover, direct comparisons of confidence responses with remember/know responses indicate that they are functionally dissociable (Gardiner & Java, 1991; Parkin & Walter, 1992; Rajaram, 1993), providing further evidence that remembering and knowing do not simply reflect high and low confidence recognition responses. Furthermore, an examination of individual differences in remember/know studies shows that hit rates reflect two unique and systematic sources of variance, indicating that recognition cannot be viewed as a single underlying strength process (Dobbins, Khoe, Yonelinas, & Kroll, 2000). Finally, for items that are remembered, subjects can often make accurate associative memory judgments such as determining in what study list or study location an item was earlier encountered, whereas for items that are accepted on the basis of knowing, subjects are not able to retrieve accurate associative information (Perfect, Mayes, Downes, & Van Eijk, 1996), indicating that remembering and knowing differ in the type of mnemonic information they support rather than simply in terms of memory strength.

The receiver operating characteristic procedure. By examining the effect of varying response criterion on hits and false alarms (i.e., examining the Receiver Operating Characteristic or ROC), it is possible to estimate the contribution of recollection and familiarity to recognition performance (Yonelinas, 1994; Yonelinas et al., 1997). The idea is to derive an equation that describes how hits and false alarms should be related (i.e., an ROC) if performance reflects a combination of recollection and familiarity. The equation is then fit to the observed empirical ROC in a manner similar to that used when conducting a linear regression. But in this case, the function is not linear, and the two parameters that are estimated reflect recollection and familiarity rather than slope and intercept. Empirical ROCs are typically derived by requiring subjects to rate the confidence of their yes/no recognition responses and then plotting hits against false alarms as a function of response confidence. The model equation is derived as follows. Subjects are assumed to respond “yes” to an old item if it is recollected (R) or if it is not recollected ($1 - R$) and the familiarity of the old item exceeds the subject’s response criterion (F_o). Thus, Hits $= R + (1 - R)F_o$. In contrast, subjects will respond “yes” to a new item if the familiarity of the new item exceeds the response criterion (F_n). Thus, false alarms $= F_n$. Familiarity is assumed to be well described by signal detection theory (e.g., Swets, 1986; MacMillan & Creelman, 1991). Thus $F_o = \Phi(d'/2 - c_i)$ and $F_n = \Phi(-d'/2 - c_i)$, which simply means that the proportion of the old and new items that will be recognized is equal to the proportion of the old and new item distributions that exceed the response criterion (c_i) given the distance between the old and new familiarity distributions is d'. These equations can be combined into a single equation [i.e., $P(\text{“yes”}|\text{old})_i = R + (1 - R)\,\Phi(d'/2 - c_i) + P(\text{“yes”}|\text{new})_i - \Phi(-d'/2 - c_i)$] that describes the relationship between hits and false alarms as a function of response confidence, and this equation can be fit to the observed ROC to provide estimates for recollection (R) and familiarity (d').

As with the previous estimation methods, the ROC method is consistent with most dual-process models in assuming that recollection and familiarity are independent. One advantage of this particular method is that only one recognition test condition is required, and thus recollection and familiarity can be examined within a single task rather than relying on comparisons across two tasks that involve different retrieval cues or types of responses.

The ROC method, however, makes several additional assumptions. First, familiarity is assumed to reflect a signal detection process, whereby old items are more familiar than new items, and all items exceeding a response criterion are accepted as having been studied. The familiarity distributions are assumed to be Gaussian, and the old and new distributions have equal variance. Moreover, if recollection occurs it is assumed to lead to a relatively confident recognition response, whereas familiarity responses will support a wider range of confidence responses. Tests of these assumptions—discussed in the empirical section below—have generally provided support for the assumptions, and direct comparisons of the parameter estimates from this method have been found to converge with those derived using the process-dissociation and remember/know procedures (Yonelinas, 2001a, 2001b).

A critical limitation of the ROC method, however, is that in order to derive stable ROCs, and to determine whether floor and ceiling effects are avoided for each subject, it is necessary to collect a large number of responses from each subject—usually more than 60 items per subject condition. This may not be practical in some experimental contexts and this may limit the use of the measurement procedure.

One other estimation method has been proposed by Mandler (1980) in which cued recall performance is used as an index of recollection, whereas recognition is used as an index of recollection and familiarity. The method is consistent with other estimation methods in assuming that recollection and familiarity are independent. However, it has not been used very extensively and thus is discussed no further (for a critical evaluation of the method see Clark, 1999).

In sum, numerous task-dissociation and process-estimation methods have been developed to assess recollection and familiarity, and thus the experimenter has a variety of different tools to choose from. Most of these methods are based on assumptions that are theoretically motivated and that have been supported by the empirical literature. Nonetheless, it is likely that these assumptions are sometimes violated. Thus, a conservative approach—and the approach taken in the empirical review below—is to avoid relying on any one measurement method, but instead look for convergence across a variety of methods. If the same conclusions are supported by measurement methods that make different assumptions, then one can be confident that the results are not an artifact of any one violated assumption of a particular test procedure.

The current article is useful in assessing the assumptions of the different measurement methods in the sense that it will make it possible to compare the results of these different methods across a large body of studies. If a method produces an inconsistent pattern of conclusions across similar experiments, or if a particular method produces a pattern of results that is inconsistent with the other measurement methods, then this indicates that the assumptions underlying the method may have been violated.

EMPIRICAL FINDINGS

The goal of this section is to provide a relatively comprehensive review of the studies that are informative about the functional nature and neural substrates of recollection and familiarity. Experiments were included in the review if there were a sufficient number of similar studies to assess the generalizability of those results. For example, experimental manipulations, such as word concreteness, and special populations, such as Asberger's syndrome patients, have been examined in only one or two different studies that directly speak to the recollection/familiarity distinction, thus they are not included in the review below.

The empirical studies are reviewed in the following order: *encoding manipulations* (i.e., levels of processing, generation, dividing attention, study duration, and benzodiazepines), *retrieval manipulations* (i.e., retrieval time, divided attention during test, perceptual matching, forgetting rates, fluency manipulations, false recognition, and shifting response criterion), *stimulus variables* (i.e., word frequency and novel vs familiar materials), *special populations* (i.e., amnesics, aged, and frontal patients), and *neuromonitoring* (i.e., event related potentials and neuroimaging).

Empirical evidence from studies using task-dissociation and process-estimation methods are discussed, and when available, performance scores obtained from each process-estimation study are used to derive estimates of recollection and familiarity in each experimental condition in order to determine the overall effect of each variable on the two processes. It was necessary to derive process estimates because those estimates were often not reported in the original studies, particularly in early remember/know studies. A full listing of the scores and process estimates for each process-estimation experiment is provided in the Appendix. Measures of recognition performance were taken from tables or estimated from figures in the original articles. Estimates of recollection and familiarity were then derived on the basis of those scores. In some cases, the estimates based on those scores were different from the average estimates reported in the original articles; however, in all cases these differences were minor and they did not affect the overall pattern of results.

To facilitate the comparison of recollection and familiarity estimates, the process estimates were calculated as probabilities, and differences in false alarms were accounted for by subtracting false alarms from hits. Although there is evidence that d' may provide a more accurate measure of familiarity (see Yonelinas et al., 1996), using this measure did not change the overall pattern of results. For the process-dissociation procedure, the false alarms were subtracted from the hits in the inclusion and exclusion conditions then recollection was estimated as the corrected inclusion score minus the corrected exclusion score. Familiarity was estimated as the exclusion score for old items divided by one minus the estimate of recollection, then the average false alarm rate across inclusion and exclusion conditions was subtracted from the familiarity estimate. For the remember/know procedure, recollection was estimated as the proportion of remember responses to old items minus the proportion of remember responses to new items. Familiarity was estimated for old and new items separately and then the familiarity estimate for the new items was subtracted from that for the old items (Yonelinas & Jacoby, 1995). For the old and new items, familiarity was estimated as the probability of a know response divided by one minus the probability that that type of item received a remember response. For the ROC procedure, a search algorithm was used to derive a probability estimate of recollection and a d' estimate of familiarity (see Yonelinas et al., 1998). The estimate of familiarity was converted from a d' score into a probability by calculating the hit rate that would arise given the d' value and a false alarm rate of 10%, which was close to the observed false alarm rate for familiarity in many remember/know studies. Note, however, that using different false alarm rates did not change that pattern of results.

When an experiment included multiple variables, the effect of each variable was examined by averaged across the other variables. However, when an experiment examined the effects of an experimental variable as well as a special population or pharmacological agent, only the performance of the control group or placebo group was used when examining the effects of the experimental manipulation. In this way, the results of the analysis indicate the effects of the experimental variables on healthy normal subjects. When an experiment examined multiple levels of a variable (e.g., in comparing short vs long study duration, an experiment might included durations of 1, 2 and 3 s) the two extreme scores were used to calculate the overall size of the effect.

Encoding Manipulations

Levels of processing (LOP). Processing the meaning of a stimulus (e.g., is the word concrete or abstract?) compared to processing perceptual aspects of a stimulus (e.g., is the word in upper or lower case?) at time of study leads to an increase in recollection and a smaller but consistent increase in familiarity. Task-dissociation methods suggest that meaning-based (i.e., deep processing) compared to perceptual-based processing (i.e., shallow processing) at encoding increases both recollection and familiarity, but that recollection may be more sensitive to the effect than familiarity. For example, deep processing compared to shallow processing leads to pronounced enhancements in both recognition and recall performance (e.g., Craik & Lockhart, 1972; Asthana & Nagrani, 1984). This suggests that both recollection and familiarity are sensitive to LOP, but, because direct comparisons between recall and recognition have not been made, it is not clear whether one process is more sensitive to this manipulation than the other. Within recognition tests, however, LOP effects are observed in both nonspeeded and speeded recognition conditions, and they are generally smaller in magnitude under the speeded conditions (e.g., Mulligan & Hirshman, 1995; Toth, 1996; but see Gillund & Shiffrin, 1984), suggesting that recollection is more sensitive to the manipulation than familiarity.

A large number of studies have examined LOP using estimation methods and the results indicate that deep processing leads to a large increase in recollection and a smaller but very consistent increase in familiarity (Gardiner, 1988; Gardiner, Java, & Richardson-Klavehn, 1996; Gardiner, Ramponi, & Richardson-Klavehn, 1999; Gregg & Gardiner, 1994; Java, Gregg, & Gardiner, 1997; Khoe, Kroll, Yonelinas, Dobbins, & Knight, 2000; Komatsu et al., 1994; Perfect, Williams, & Anderton-Brown, 1995; Rajaram, 1993; Toth, 1996; Wagner, Gabrieli, & Verfaellie, 1997; Wagner, Stebbins, Masciari, Fleischman, & Gabrieli, 1998; Yonelinas, 2001; Yonelinas, Kroll et al., 1998). In order to illustrate the differential effects of LOP on recollection and familiarity, the average effects of the manipulation seen across the different process estimation experiments were plotted (Fig. 2). The figure shows that deep encoding compared to shallow encoding led to an average increase of approximately .30 in the probability that items would be recollected, whereas familiarity estimates increased by less than .20. This pattern is extremely robust and is consistently observed in studies using the remember/know, process-dissociation, and ROC procedures. In all of the 17 process-estimation experiments conducted, semantic processing led to an increase in recollection. Moreover, in only 1 of the 17 experiments did the familiarity estimate not increase with meaningful encoding (Experiment 2 in Java et al., 1997). Importantly, the estimate of recollection in the deep condition in that experiment was one of the highest reported (.67 compared to the average recollection estimate of .53). As discussed below, ceiling effects related to excessively high levels of recollection can have pronounced effects on the familiarity estimates provided by the estimation methods.

Note that in three of the LOP experiments (i.e., Experiment 1 in Gardiner, 1988; Experiment 3 in Toth, 1996; Wagner et al., 1995), the effect of LOP on familiarity was very similar in magnitude to that seen on recollection. Although

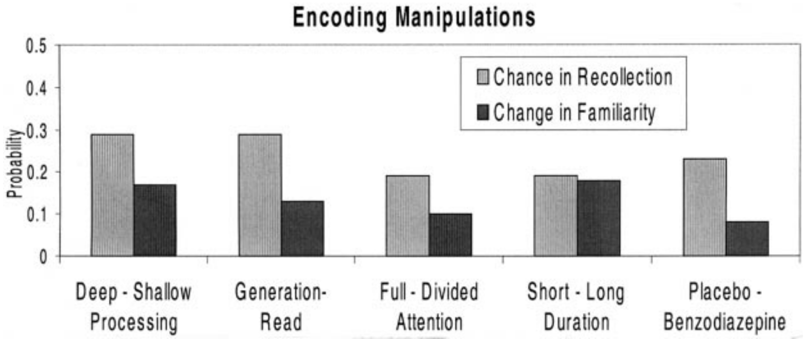

FIG. 2. The average effects of encoding manipulations on estimates of recollection and familiarity.

performance in some of these experiments was quite high, the results suggest that there may be conditions under which LOP has comparable effects on recollection and familiarity.

Generation. Generating a word at the time of study (e.g., solving the anagram "alssc" for the word "class"), compared to reading the word, leads to an increase in recollection and a smaller but consistent increase in familiarity. The results from the task-dissociation methods are somewhat ambiguous, but are consistent with the results of the process-dissociation methods in showing that generating compared to reading leads to a large increase in recollection and a smaller increase in familiarity. For example, generation leads to large increases in recall and recognition memory (e.g., Slamecka & Graf, 1978; Clark, 1995), suggesting that both recollection and familiarity are sensitive to the manipulation. Direct comparisons between recall and recognition have not been made, so it is not clear whether recollection is more sensitive to the manipulation than familiarity. However, the results from process-dissociation (Dodson & Johnson, 1996; Jacoby, 1991; Verfaellie & Treadwell, 1993; Jennings & Jacoby, 1993; Wagner et al., 1989) and remember/know studies (Curran & Hildebrandt, 1999; Donaldson, MacKenzie & Underhill, 1996; Gardiner, 1988; Gardiner, Java & Richarson-Klavehn, 1996; Gardiner, Ramponi, & Richardson-Klavehn, 1999; Wippich, 1992) show that both recollection and familiarity increase for generated compared to read items, but that recollection benefits to a greater extent than does familiarity (Fig. 2). All 11 process-estimation experiments that examined the effects of generation showed the same pattern of results with the exception of one experiment (i.e., Experiment 1 in Wagner et al., 1998) which indicated that generation led to a slight *decrease* in familiarity. The estimate of recollection in the generation condition, however, was one of the highest of all the experiments (i.e., .67 compared to the average of .46), suggesting that high levels of recollection may have influenced the estimates of familiarity in that experiment.

Divided attention during study. Dividing attention during encoding (e.g., requiring subjects to conduct a concurrent task while encoding the study items) reduces recollection. Although dividing attention typically has smaller effects on familiarity, the extent to which familiarity is influenced by this manipulation appears to be related to the manner in which attention is manipulated and the type of materials. The results from a majority of the measurement methods indicate dividing attention has larger effects on recollection than familiarity. For example, dividing attention has large disruptive effects on recall and smaller disruptive effects on recognition (see Craik, Govoni, Naveh-Benjamin, & Anderson, 1996), suggesting that recollection is more attention-demanding than familiarity. Similarly, dividing attention has larger disruptive effects on word-voice and word-location associative recognition than on item recognition (Troyer, Winocur, Craik, & Moscovitch, 1999), providing further evidence that recollection is the more attention-demanding of the two processes. In general, the results from the process-dissociation (Gruppuso, Lindsay, & Kelley, 1997; Jacoby & Kelley, 1992), remember/know (Gardiner & Parkin, 1990; Yonelinas, 2001; Parkin, Gardiner, & Rosser, 1995; Mangels, Picton, & Craik, 2001), and ROC procedures (Yonelinas, 2001) indicate that divided attention reduces recollection and familiarity, but that the effects on recollection are greater than those seen on familiarity (Fig. 2).

Familiarity, however, may not be reduced by dividing attention under some conditions. For example, one study using the process-dissociation procedure showed that divided attention had large disruptive effects on recollection and no measurable effect on familiarity (Jacoby & Kelley, 1992). This was the only experiment examining the effect of dividing attention using the process-dissociation procedure, thus the difference in conclusions may be related to the use of that test procedure. However, the consistency with which that procedure leads to conclusions that converge with those from other estimation methods argues against this. Another important difference between that study and all other studies of divided attention was that it was the only one in which the level of meaningful processing was held constant across the full and divided attention conditions by requiring subjects to process the meaning of the words in both attention conditions. In all the other experiments, subjects may have processed the items more meaningfully in the full attention conditions than in the divided attention conditions, thus increasing familiarity in the full compared to divided attention conditions. In fact, subjects report using more meaningful encoding strategies during full compared to divided attention conditions (e.g., Mangels, Picton, & Craik, 2001). Further studies examining this possibility will be useful in understanding the effects of attention on familiarity.

Further examination of the process-estimation studies suggests that attention may be equally important for recollection and familiarity for some materials. For example, the one experiment in which dividing attention was found to have comparable effects on recollection and familiarity was in a recognition test for unfamiliar faces (Parkin, Gardiner, & Rosser, 1995). Unfamiliar faces differ from words in several ways (e.g., faces are relatively novel, more complex, and less likely to be verbalized than words). Any one of these differences may lead to increases in attentional demands on familiarity.

A related study that was not included in the above analysis compared a full attention condition to a condition in which subjects were told to ignore the study items (Kinoshita, 1995). Under these latter conditions recognition performance was reduced essentially to zero for both remember and know responses, indicating that some minimal stimulus processing is required before recollection or familiarity are able to support performance.

Study duration. *Increasing study duration leads to comparable increases in recollection and familiarity*. Results from a large majority of measurement methods indicate that both recollection and familiarity increase with study duration. For example, increasing study duration leads to large increases in recall and recognition (e.g., Murdock, 1974; Paivio & Csapo, 1969), suggesting that both recollection and familiarity benefit from additional study time. Moreover, results using deadline procedures in conjunction with exclusion conditions indicate that repetition increases both recollection and familiarity. For example, under speeded recognition conditions, the false alarm rate to items from the excluded list was greater for items that had been repeated several times in the study list than those presented only once, suggesting that repetition increased the familiarity of the items (Jacoby, Jones, & Dolan, 1999). In contrast, under nonspeeded test conditions, false alarm rates for items from an excluded list were *lower* for items presented multiple times compared to those presented only once, suggesting that repetition increased recollection (i.e., the ability to exclude items). Similar results were reported using an SAT method (McElree, Dolan, & Jacoby, 1999) and using a remember/know procedure (Jacoby, Jones, & Dolan, 1998).

The estimation methods indicate that increasing study duration leads to comparable increases in recollection and familiarity (Fig. 2). For example, estimates from remember/know

(Dewhurst & Anderson, 1999; Gardiner, Kalinski, Dixon, & Java, 1996; Hirshman, Fisher, Henthorn, Arndt, & Passannante, 2002; Hirshman & Henzler, 1998; Gardiner & Radomski, 1999; Jacoby, Jones & Dolan, 1999; Kinoshita, 1997; Parkin & Russo, 1993; Yonelinas et al., 1996), process-dissociation (Jacoby, 1999; Yonelinas, 1994), and ROC studies (Yonelinas et al., 1996) converge in showing similar increases in recollection and familiarity with increased study duration. Note that one of the experiments suggested that familiarity increased to a greater extent than recollection (Experiment 1 in Gardiner et al., 1996), but this pattern did not replicate in a subsequent experiment in that study (Experiment 3 in Gardiner et al., 1996).

Increasing study duration by repeating items (distributed presentations) leads to larger increases in recollection and familiarity than simply increasing the study duration of each item (massed presentation), and this distributed presentation advantage appears to be slightly larger for recollection than familiarity. This pattern of results is observed in remember/know (Parkin & Russo, 1993; Parkin, Gardiner, & Rosser, 1995; but see Dewhurst & Anderson, 1999) and process-dissociation studies (Benjamin & Craik, 2001). The recollection and familiarity advantages seen for distributed presentation are consistent with the finding that there is a distributed presentation advantage in free recall (Hintzman, 1974) and the fact that amnesics show a distributed presentation advantage in recognition that is comparable to that observed in control subjects (Cermak, Verfaelli, Lanzoni, Mather, & Chase, 1996).

Benzodiazepines. *Benzodiazepines administered at time of encoding lead to a greater reduction in recollection than familiarity*. Benzopiazapines (e.g., lorazepam, triazolam, and midazolam) are used to treat anxiety and sleep disorders and can produce temporary memory impairments on recall and recognition that leave other cognitive functions like short-term memory and comprehension intact. These drugs are found to influence memory encoding, but do not disrupt retrieval of information encoded prior to treatment (e.g., Polster, McCarthy, O'Sullivan, Gray, & Park, 1993; Curran et al., 1993; Polster, 1993), and their memory effects are thought to be due to the fact that they facilitate γ-aminobutyric acid (GABA) receptors (Greenblatt, Shader, & Abernathy, 1983; Hobbs, Rall, & Verdoorn, 1996), which are particularly abundant in the hippocampus and limbic system. Direct comparisons of the effects of these drugs on recall and recognition have not been made. However, results from process-estimation methods indicate that benzodiazepines administered during encoding lead to a form of amnesia that has larger disruptive effects on recollection than familiarity (Fig. 2). For example, lorazepam has been examined in remember/know experiments (Curran, Gardiner, Java, & Allen, 1993; Bishop & Curran, 1995) and is found to reduce recollection but not familiarity. In similar studies, triazolam and midazolam are found to lead to reductions in both recollection and familiarity, but the effects on recollection are much greater than those on familiarity (Mintzer & Griffiths, 2000; Hirshman et al., 2002).

Retrieval Manipulations

Retrieval time. *Studies of speeded recognition indicate that familiarity is available earlier than recollection, and nonspeeded tests indicate that familiarity typically contributes to performance earlier than recollection*. Speeded response-time (RT) methods (i.e., deadline and SAT) indicate that the products of familiarity are available earlier than those of recollection. For example, item recognition memory accuracy increases above chance earlier than recognition memory for associative information such as study modality (Hintzman & Caulton, 1997), location (Gronlund, Edwards, & Ohrt, 1997), list membership (Hintzman, Caulton, & Levin, 1998), word pairing (e.g., Gronlund, & Ratcliff, 1989), whether the item was perceived or imagined (Johnson, Kounios, & Reeder, 1994), and whether words were studied in their singular or plural forms (Hintzman & Curran, 1994). Moreover, in recognition tests in which subjects must exclude items that are semantically related, visually related, from inappropriate study lists, or paired with items that they were not studied with, subjects tend to first accept then reject the related lures as the response time is increased, producing biphasic accuracy/response-time functions (e.g., Dosher, 1984; Gronlund & Ratcliff, 1989; Hintzman & Curren, 1994; Jacoby, 1999; McElree, Dolan, & Jacoby, 1999; Rotello & Heit, 2000). These results suggest that a fast familiarity process leads subjects to accept the related lures, but with additional retrieval time subjects are able to use recollection to avoid incorrectly accepting those lures.

Studies using the process-dissociation procedure (Fig. 3) indicate that for word recognition, recollection increases in nonspeeded test conditions compared to speeded conditions, whereas estimates of familiarity remain relatively constant (Benjamin & Craik, 2001; Yonelinas & Jacoby, 1994; Toth 1996; Yonelinas & Jacoby, 1996), suggesting that familiarity is faster than recollection. It appears that familiarity assessment, at least for the words used in these studies, can be completed in about 1 s, while recollection requires additional retrieval time. That is, in studies in which the speeded conditions required subjects to respond within approximately 1 s after the test word was presented [1000 ms in Toth (1996); 900 ms in Yonelinas & Jacoby (1994); 1200 ms in Yonelinas & Jacoby (1996)], familiarity was not greatly affected by response deadline, whereas in the experiment that used a 750-ms response deadline there was a tendency for familiarity to decrease slightly compared to the nonspeeded condition (Benjamin & Craik, 2001), suggesting that familiarity assessment requires at least this amount of time. Note that one study that was not included in the above analysis was a recognition memory test for action phrases that were either read aloud or enacted (Dehn & Engelkamp, 1997). In that study, speeding responses and dividing attention at test were found to lead to *increases* in familiarity. However, estimates of recollection approached .80 in that experiment, and thus ceiling effects, likely biased those process estimates.

Neither the remember/know nor ROC confidence procedures have been used to examine recollection and familiarity under speeded conditions. However, in one study, subjects were required to make remember/know responses after they made speeded or nonspeeded recognition decisions (Ramponi & Richardson-Klavehn, 1999), and in another they were required to make confidence judgments after making speeded or nonspeeded recognition responses (Rotello, Macmillan, & Van Tassel, 2000). Unfortunately, in neither of these studies were the remember/know or confidence judgments made under speeded test conditions, so the results cannot be used to derive estimates of recollection and familiarity under speeded conditions. It may be useful to examine remember/know and confidence judgments under speeded conditions. However, because these procedures require between three and six distinct responses, the decision and response selection demands are probably greater than in simple yes/no recognition tests. Thus, it may be difficult when using these methods to determine if the response-speeding

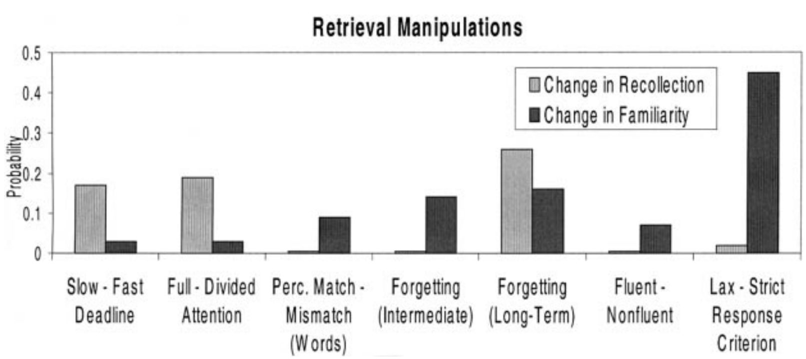

FIG. 3. The average effects of retrieval manipulations on estimates of recollection and familiarity.

manipulation has direct effects on the memory processes or whether it affects decision or response execution processes.

The analysis of response times in nonspeeded recognition test conditions indicates that familiarity contributes to performance earlier than recollection. For example, list organization (e.g., number of categories in which the study list was sorted) correlates with recall performance and slow recognition responses, but not with fast recognition responses, suggesting that recollection contributes more to slow than fast recognition responses (Mandler & Boeck, 1974). Similarly, an examination of response times in nonspeeded process-dissociation recognition tests indicates that the contribution of familiarity peaks earlier than that for recollection (Yonelinas & Jacoby, 1994).

One apparent exception to the finding that familiarity is faster than recollection comes from remember/know studies where know responses are generally found to be slower than remember responses (e.g., Dewhurst & Conway, 1994; Trott, Friedman, et al., 1999). However, these effects likely reflect the fact that the instructions in remember/know tests require subjects to respond know only if the item is "familiar and not recollected." Because subjects are essentially instructed to wait until both processes are complete before making a know response, the pattern of results is not surprising.

Divided attention during test. Dividing attention at the time of test disrupts recollection but does not appear to influence familiarity. The measurement methods provide clear evidence that recollection is more sensitive to effects of dividing attention at time of retrieval than familiarity, and the limited number of process-estimation studies that have been conducted indicate that familiarity is not affected at all by the manipulation (Fig. 3). For example, dividing attention at the time of retrieval has large disruptive effects on recall and much smaller effects on recognition (Anderson, Craik, & Naveh-Benjamin, 1998; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996), suggesting that recollection is more influenced than familiarity by attention. Similarly, dividing attention has a larger disruptive effect on associative than item recognition (Troyer, Winocur, Craik, & Moscovitch, 1999), providing additional evidence that recollection is more sensitive than familiarity to effects of dividing attention. Two experiments have examined the effects of dividing attention at test using the process-dissociation procedure and both indicate that dividing attention reduces recollection but has no influence on familiarity-based judgments (Gruppuso, Lindsay, & Kelley, 1997; Dodson & Johnson, 1996). The effect of dividing attention during test has not been examined using either the remember/know or the ROC methods. Such studies may be useful, but as with the response-speed manipulations, because these methods require multiple different response types, they may not be well suited to simultaneously examine effects of divided attention at time of test.

Perceptual Matching. Changing the perceptual characteristics of a word between study and test (e.g., changing the presentation modality between visual and auditory modalities) leads to a decrease in familiarity, but not recollection. In contrast, for nonverbal items, changing the perceptual characteristics of an item can reduce both processes, although the effects may vary with the type of materials. For words, changing the modality between study and test generally reduces familiarity, but does not influence recollection. For example, changing modality can have larger effects on speeded compared to nonspeeded test conditions (Toth, 1996; but see Mulligan & Hirshman, 1995), suggesting that the manipulation has larger effects on familiarity than recollection. Similarly, estimates using the remember/know procedure (Fig. 3) indicate that changing presentation modality of words does not influence recollection but does reduce familiarity (e.g., Gregg & Gardiner, 1994; although see Rajaram, 1993), particularly when the encoding conditions focus on the perceptual aspects of the study words (Gregg & Gardiner, 1994).

For nonverbal materials, changing the perceptual characteristics of an item between study and test can decrease recollection and familiarity, but the effects appear to depend on the materials and the perceptual manipulation. For example, changing the angle in which common objects are presented leads to reductions in recognition accuracy that are comparable for amnesic and control subjects (Srinivas & Verfaellie, 2000), suggesting that familiarity-based recognition benefits from perceptual matching. In contrast, remember/know studies indicate that changing the size or reflection of drawings of familiar items can lead to decreases that influence recollection primarily (Rajaram, 1996). Moreover, estimates derived from the remember/know and process-dissociation procedures (Yonelinas & Jacoby, 1995) suggest that changing the size of random geometric shapes between study and test leads to a decrease in both recollection and familiarity.

A related, but somewhat different, effect is the picture-superiority effect, which reflects the fact that recognition memory for words is better if the item was studied as a picture than if it was studied as a word (e.g., Rowe & Pavio, 1971). Remember/know (e.g., Rajaram, 1993, 1996; Dewhurst & Conway, 1994; Wagner et al., 1997) and process-dissociation studies (Wagner et al., 1997) indicate that the picture-superiority effect is observed in both recollection and familiarity. Although this may appear to be inconsistent with the perceptual matching effects just discussed, the picture-superiority effect is related to increased elaboration or the involvement of additional semantic codes utilized when encoding pictures compared to words. For example, the effect can be eliminated or even reversed if visual elaboration is required during both picture and word encoding conditions (Experiments 2–4 in Dewhurst & Conway, 1994). Note that estimates of recollection are very high (greater than .6) in all of these picture-superiority experiments, thus care should be taken when interpreting these results.

Forgetting rates. Across intermediate-term delays (i.e., 10 s of seconds or 8 to 32 intervening items) familiarity decreases rapidly while recollection is relatively unaffected. In contrast, across long-term delays (i.e., minutes to months) both recollection and familiarity exhibit pronounced forgetting effects. Although the effects of forgetting across intermediate delays have not been studied extensively, the existing results from task-dissociation and process-dissociation studies indicate that familiarity decreases more rapidly than recollection. For example, across 32 intervening items in a continuous recognition test, recognition memory for single items decreases significantly, whereas recognition memory for word–word associations remains unchanged (Hockley, 1991, 1992), suggesting that familiarity, but not recollection, decreases across these delays. A similar pattern of disproportional forgetting for item recognition compared to associative recognition is also seen in study-test procedures in which a study list is followed by a separate test list (Hockley, 1991, 1992). Process-dissociation methods have only been used to examine intermediate term forgetting in two process-dissociation experiments (Yonelinas & Levy, 2002), but both experiments are consistent in showing that familiarity decreases more rapidly than recollection across these retention intervals (Fig. 3).

In contrast, over long-term retention intervals both recollection and familiarity exhibit significant forgetting effects. For example, measured across delays extending up to 7 days, word–word (Hockley & Cinsoli, 1999) and word–list association memory (Bornstein & LeCompte, 1995) are found to decrease at rates that are similar to those found for item recognition, suggesting that both recollection and familiarity decrease at comparable rates across these delays. Results from remember/know studies (Fig. 3) are consistent in showing that both processes decrease over long retention intervals that extend up to 6 months (Gardiner, 1988; Gardiner & Java, 1991; Hockley & Consoli, 1999; Knowlton & Squire, 1995). In many cases the decrease in recollection is greater than the decrease in familiarity. However, there are two reasons to be careful when interpreting this latter difference. First, because estimates of familiarity were generally much lower than those of recollection, and the experiments produced no experimental crossovers, it is possible that floor effects may have contributed to these differences in long-term forgetting functions. Second, one study suggested that over long-term delays, familiarity may decrease *faster* than recollection (Mandler, Pearlstone, & Koopmans, 1969). In that study, recognition memory performance at an intermediate delay was not correlated with list organization (the number of categories that a list was divided into), but as the delay increased up to 5 weeks the correlation between recognition and list organization increased. These results were interpreted as indicating that familiarity must have decreased more rapidly than recollection across these delays.

Fluency manipulations. Manipulations designed to increase the processing fluency of test items lead to an increase in familiarity-based recognition responses for both studied and nonstudied items, while leaving recollection-based responses unaffected. A variety of manipulations designed to increase the processing fluency of test items have been found to influence recognition memory. For example, briefly flashing a word just prior to presenting it in a recognition test increases the likelihood that the word will be judged to have been in the prior study list (Jacoby & Whitehouse, 1989). Similarly, visually presenting a word more clearly than other words in a test (Whittlesea, Jacoby, & Girard, 1990), revealing a word letter by letter compared to presenting the entire word (e.g., the "revelation effect" Watkins & Peynircioglu, 1990), or presenting a word in a conceptually predictive compared to unrelated context (e.g., "The stormy sea tossed the BOAT"; Whittlesea, 1993; Whittlesea & Williams, 2000) will increase the probability that an item will be recognized. These manipulations often influence studied and nonstudied items, thus they lead to increases in both hits and false alarms.

The task dissociation and process estimation methods are in agreement in showing that processing fluency influences familiarity, but not recollection. For example, the fact that fluency manipulations influence false alarms suggests that the manipulation affects familiarity. Consistent with this claim, fluency effects are more readily observed in item than associative recognition tests (Cameron & Hockley, 2000; Westerman, 2001), and amnesic patients exhibit normal revelation effects (Verfaellie & Cermak, 1999). The process estimation methods show that processing fluency increases familiarity, but not recollection (Fig. 3; note that because the fluency manipulations have similar effects on hits and false alarms the effect of processing fluency presented in Fig. 3 reflects the average across old and new items). For example, the remember/know procedure shows that familiarity rather than recollection is increased when the test item is briefly flashed just prior to its presentation in the test list (Kinoshita, 1997; Rajaram, 1993). Similarly, presenting test items in a semantically related context increases familiarity but not recollection in the remember/know procedure (Rajaram & Geraci, 2000). Finally, revealing items (i.e., the revelation effect) increases estimates of familiarity but not recollection as measured using both the process-dissociation and remember/know procedures (LeCompte, 1995).

An important aspect of these fluency effects is that they are often sensitive to changes in test conditions and instructions. For example, if the prepresented words are flashed for long enough that the subject becomes aware of the flashed item, or if the subject is informed that the experimenter is manipulating the visual clarity of the test items, then the effects of these fluency manipulations are reduced (Jacoby & Whitehouse, 1998; Whittlesea, Jacoby, & Girard, 1990). These results have been interpreted as indicating that these manipulations increase the processing fluency of items and that subjects misattribute this processing fluency to the earlier study event, but if the source of that processing fluency becomes obvious (i.e., the word was just prepresented) they will not make the mistake of attributing it to the earlier study list. More recently, Whittlesea and Williams (1998, 2000) have shown that items that are perceived as familiar when presented in isolation are instead experienced as being novel when presented in a rhyme or semantic context, and they argued that familiarity is not the result of fluency per se, but rather that fluent processing that occurs under unexpected circumstances produces the experience of familiarity.

False recognition. The probability that nonstudied items are falsely recollected is rare compared to the probability that they are falsely recognized on the basis of familiarity. However, when new items are high associates of the studied items then both processes can lead to high *levels of false recognition*. The probability that an item is falsely recalled is typically quite low compared to the probability that a nonstudied item is falsely recognized, suggesting that recollection is less susceptible to this type of an error than is familiarity. Moreover, false remember rates in standard remember/know studies are generally very low compared to false familiarity rates (e.g., the average estimates of recollection and familiarity for new items were .02 and .18, respectively, for the seven experiments described earlier examining generation effects using a standard remember/know recognition test procedure). However, under conditions in which study lists contain a number of highly associated items, subjects often falsely recall and falsely remember lure items that were associated with the studied items (e.g., Anastasi, Rhodes, & Burns, 2000; Gallo, McDermott, & Roediger, 2001; Israel & Schacter, 1997; Miller & Gazzaniga, 1998; Mintzer & Griffiths, 2000; Norman & Schacter, 1997; Roediger & McDermott, 1995; Schacter, Verfaellie, & Pradere, 1996; Schacter, Verfaellie, & Anas, 1997). The level of false recollection and false familiarity for related lures under these conditions was .23 and .18, respectively.

Several different accounts have been provided for the high false alarm rates seen with high associates (e.g., see Schacter, Norman, & Koutstaal, 1998). The increased level of false recollection could arise if subjects overtly or covertly generate a nonpresented lure item at time of study in response to an associate. Thus, at time of retrieval, subjects may recollect that the item was encountered but fail to recollect that it was self-generated rather than studied. Another possibility is that at time of retrieval, recollection may be based on the retrieval of semantic information that does not differentiate between a studied word and a highly associated lure item. Consistent with the latter account, as described above, recollection is particularly sensitive to semantic encoding.

Shifting response criterion. Relaxing the response criterion in a recognition test (e.g., increasing the subjects' tendency to accept items as having been studied) leads to a large increase in the probability that items will be accepted on the basis of familiarity, but has very little effect on recollection. Moreover, familiarity, but not recollection, increases in a manner consistent with signal detection theory. Relaxing the response criterion in recognition memory tests leads to increases in the probability that new items will be accepted (i.e., false alarms increase), suggesting that familiarity is sensitive to shifts in response criterion. Moreover, results from remember/know and process-dissociation experiments indicate that relaxing response criteria leads to large increases in the proportion of old items accepted on the basis of familiarity, whereas estimates of recollection remain relatively unchanged (Fig. 3). This pattern of results is seen when response criterion varies as a function of response confidence (Yonelinas et al., 1996; Yonelinas 2001; Yonelinas, Dobbins et al., 1997), changes in the reported proportion of target items in the test list (e.g., Strack & Foerster, 1995; Hirshman & Hanzel, 1998; Gardiner, Richardson-Klavehn, & Ramponi, 1997), changes in how lenient subjects are instructed to be (Postma, 1999), and changes in the proportion of test items that subjects are required to accept as old (Strack & Foerster, 1995). Consistent with these findings, an examination of performance across subjects indicates that increases in false alarms are associated with increases in overall hit rates, but not with increases in reports of remembering (Dobbins et al., 2000).

Figure 4 presents the estimates of recollection and familiarity from individual experiments to illustrate the manner is which changes in response criterion influence the two processes. An examination of Fig. 4 indicates that familiarity estimates increase in a manner consistent with signal detection theory, whereas recollection estimates do not (see Yonelinas, 2001a, for further discussion). That is, the familiarity functions increase gradually and form functions that are symmetrical along the 0,0 to 1,1 diagonal. This indicates that familiarity is well described as a signal detection process in which old and new items form Gaussian familiarity distributions such that the old items are on average more familiar than new items and the variance associated with the two distributions is approximately equal (see MacMillan & Creelman, 1991). Fur-

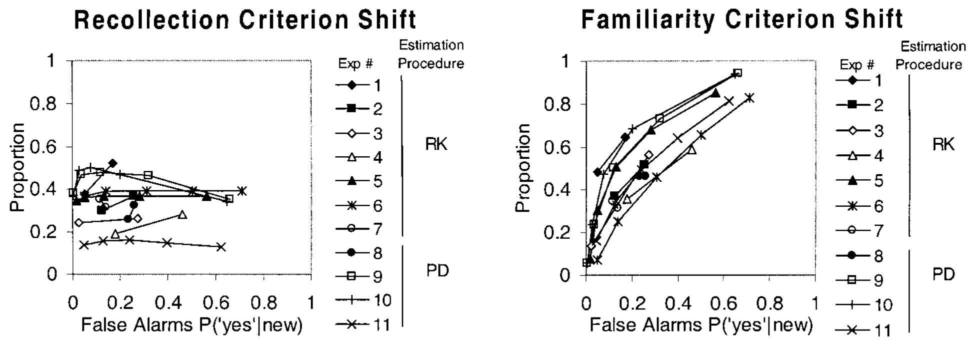

FIG. 4. Estimates of recollection (left) and familiarity (right) as a function of response criterion derived using the remember/know (RK) and process dissociation (PD) procedures from (1) Postma (1999), (2) Strack and Foerster (1995, Expt. 1), (3) Strack and Foerster (1995, Expt. 2), (4) Hirshman and Henzler (1998), (5) Yonelinas (2001a, Expt. 1), (6) Yonelinas, Dobbins, Szymanski, Dhaliwal, and King (1996, Expt. 2), (7) Gardiner, Richardson- Klavehn, and Ramponi (1997), (8) Dodson and Johnson (1996, Expt. 1), (9) Yonelinas (1994, Expt. 1), (10) Yonelinas (1994, Expt. 2), and (11) Yonelinas (1994, Expt. 3).

ther evidence that familiarity behaves in a manner consistent with signal detection theory is provided by studies of amnesics who exhibit symmetrical recognition memory functions similar to the familiarity functions seen in Fig. 4 (Yonelinas et al., 1998). In contrast to familiarity, the recollection estimates seen in Fig. 4 remain relatively constant as false alarm rates increase, suggesting that recollection is not well described as a standard signal detection process. Further evidence that recollection is not consistent with signal detection theory is provided by associative tests of recognition in which relatively linear receiver operating characteristics have been observed (e.g., Arndt & Reder, 2002; Rotello, Macmillan, & Van Tassel, 2000; Yonelinas, 1997, 1999; Yonelinas et al., 1999). Note, however, that associative ROCs are not always perfectly linear (e.g., Yonelinas et al., 1999, Yonelinas, 1999; Slotnick, Klein, Dodson, & Shimamura, 2000; Qin, Raye, Johnson, & Mitchell, 2001; Kelley & Wixted, 2001). Nonetheless, the observed ROCs in almost all of these cases indicate that a simple signal detection process is not sufficient to account for recollection.

Stimulus Variables

Word frequency. Most studies indicate that both recollection and familiarity are greater for low than for high frequency words and that the frequency effects on recollection are much larger than those seen on familiarity. Some methods of measuring recollection, however, indicate that there is a high frequency recollection advantage. Low frequency, or less common, words are associated with greater hit rates and lower false alarm rates than high frequency words (e.g., Gregg, 1976; Glanzer & Adams, 1985). The increased false alarm rate for high frequency words indicates that common words are judged to be more familiar during recognition than low frequency words. A separate question, however, is whether the low frequency advantage that is seen in the hit rate is due to recollection or familiarity.

In general, the task-dissociation methods indicate that recollection and, to a lesser extent, familiarity are greater for low than high frequency words. For example, in support of the claim that familiarity exhibits a low frequency memory advantage are results from studies of amnesics (e.g., Huppert & Piercy, 1976; Verfaellie, Cermak, Letourneau, & Zuffante, 1991) who exhibit better recognition memory for low than high frequency words. In support of the claim that recollection exhibits a low frequency advantage are studies examining manipulations expected to reduce recollection such as dividing attention (Kinoshita, 1995), midazolam-induced amnesia (Hirshman et al., 2002), and speeding responses (Balota, Burgess, Cortese, & Adams, 2002; Joordens & Hockley, 2000), which show that these manipulations reduce, and can even reverse, the low frequency hit rate advantage seen in recognition memory performance. Moreover, there is a low frequency advantage in most tests of associative recognition, such as tests of modality (Guttentag & Carroll, 1994), study voice (Guttentag & Carroll, 1994), study list (Guttentag & Carroll , 1997; Rugg, Cox, Doyle, & Wells, 1995), and memory for mental operations (Guttentag & Carroll, 1997).

Results from the process-estimation methods indicate that both recollection and familiarity increase for low compared to high frequency words, but that the effect on recollection is almost always larger than that seen on familiarity. For example, estimates from remember/know (Bowler, Gardiner, & Grice, 2000; Gardiner & Java, 1990; Hirshman et al., 2002; Huron et al., 1995; Joordens & Hockley, 2000; Strack & Foerster, 1995; Gardiner, Richardson-Klavhen, & Ramponi, 1997; Kinoshita, 1995; Guttentag & Carroll, 1997; Reder, Nhouyvanisvong, Schunn, Ayers, Angstadt, & Hiraki, 2000), process-dissociation (Guttentag & Carroll, 1997; Komatsu, Graf, & Uttl, 1994), and ROC studies (Arndt & Reder, 2002) converge in showing that there is a low frequency advantage for recollection and a smaller but consistent advantage for familiarity. On average, low compared to high frequency words lead to .16 and .09 increases in recollection and familiarity, respectively. Only 1 estimation experiment of 17 did not conform to this pattern (i.e., Experiment 1 in Reder et al., 1999) in the sense that it suggested that word frequency actually had a slightly larger effect on familiarity than recollection. However, the average recollection level in that study was .79 for the low frequency words, and thus the familiarity estimates were likely influenced by ceiling effects. The second experiment in that study also had high levels of recollection and suggested that familiarity was not greatly affected by word frequency. However, in the third experiment, in that study performance was much lower and the aberrant pattern was not observed.

Some measurement methods, however, indicate that recollection is *greater* for high than low frequency words. For example, there is a high frequency advantage in tests of recall (e.g., Gregg, 1976; Gregg, Montgomery, & Castano, 1980; but see Watkins, LeCompte, & Kim, 2000) and in word–word associative recognition (e.g., Clark, 1992; Clark & Burchett, 1994; although see Hockley, 1991), suggesting that recollection, at least as measured by these two tasks, exhibits a high frequency rather than a low frequency advantage.

Why there is a discrepancy about the effects of word frequency on recollection across different measurement methods is not clear; however, one potential explanation is that the different tasks measure different types of recollection or different types of recollected information. For example, to account for discrepancies between recall and list recognition, Guttentag and Carrol (1997) argued that list recognition tests rely on item-specific processing (e.g., distinctive processing of the properties of a single item), whereas recall relies on item-specific as well as relation-specific processing (e.g., processing the relationships between items). They suggested that item-specific processing is very effective with low frequency words, whereas relation-specific processing is most effective with high frequency items (i.e., it is easier to form a relationship between two high frequency words and to subsequently retrieve that relationship than to do so with two low frequency words). Thus, recognition and most forms of associative recognition exhibit a low frequency advantage because they rely on recollection of item-specific information, whereas recall and associative word-pair recognition exhibit a high frequency advantage because they rely additionally on recollection for the relations between items.

Memory for new items and new associations. Recollection can support memory for novel items and novel associations. In contrast, familiarity can support memory for novel items, but it can only support memory for new associations under some conditions. With respect to memory for novel items, the process estimation methods indicate that recollection and familiarity can support new learning. For example, the process-dissociation and remember/know procedures indicate that both recollection and familiarity support memory for randomly generated geometric shapes (Yonelinas & Jacoby, 1995). Similarly, the remember/know procedure indicates that both recollection and familiarity support memory for unfamiliar faces (Parkin, Gardiner, & Rosser, 1995), nonwords (Gardiner & Java, 1990; Whittlesea & Williams, 2000), and obscure melodies (Gardiner, Kaminsko, Dixon, & Java, 1996; Java, Kaminska, & Gardiner, 1995). The ROC procedure also indicates that recollection and familiarity support memory for unfamiliar faces (Yonelinas, Kroll, Dobbins, & Soltani 1999). Moreover, estimates of familiarity for nonwords are sometimes found to be greater than those for words (e.g., Gardiner & Java, 1990; Whittlesea & Williams, 2000; but see Perfect & Dasgupta, 1997), suggesting that, at least for some materials, familiarity may be more useful in discriminating between studied and nonstudied novel items than between studied and nonstudied items that are well known.

Memory for new associations between different items or between distinct aspects of an event can be supported by recollection, whereas familiarity often does not do so. In tests of word–word, word–modality, and word–list associative recognition, the observed ROCs are relatively linear compared to item recognition (e.g., Rotello et al., 2000; Yonelinas, 1997, 1999). Using the ROC estimation method to estimate recollection and familiarity leads to the conclusion that associative recognition is based on recollection and that familiarity does not benefit performance on these tasks. Moreover, for items that receive a remember response, but not those receiving a know response, subjects are able to make accurate associative recognition judgments (Perfect et al., 1996), indicating that recollection, but not familiarity, supports memory for new associations. Similarly, amnesic patients generally perform particularly poorly on associative recognition tests (see the discussion of amnesia below), suggesting that familiarity does not support memory for new associations.

There is, however, evidence that familiarity can support memory for novel associations under some conditions. For example, in an associative recognition test that required subjects to discriminate between previously studied drawings of faces and faces in which some of the features had been switched with those from other studied faces, the resulting ROCs were curvilinear and the estimates of familiarity were greater than zero, indicating that familiarity supported the associative recognition judgments (Yonelinas et al., 1999). However, this was observed only when faces were studied and tested in an upright orientation; when faces were studied and tested upside down, the ROCs became linear and the estimates of familiarity dropped to zero. These results were interpreted as indicating that when different aspects of an event are treated as a whole item (upright faces) familiarity supported learning of the associations between those features, whereas when separate features were treated as distinct parts (upside down faces) then familiarity was not able to support associative learning. Similar results have been reported in studies of word–word associative recognition in that linear ROCs were observed when word pairs were encoded as two separate words, whereas curved ROCs were observed when the word pairs were treated as new compound words (Quamme & Yonelinas, 2001). Moreover, in a recognition experiment using the process-dissociation procedure in which subjects were required to remember the spatial locations of objects, estimates of familiarity were greater than baseline performance, indicating that familiarity supported memory for object-location associations (Caldwell & Masson, 2001). Moreover, as discussed in more detail in the amnesia section below, patients with selective hippocampal lesions exhibit pronounced deficits on associative recognition tests that require associations across different types of information (e.g., face–voice pairs), but perform normally on tasks that require associations between similar types of information (e.g., face–face pairs) (Vargha-Kadehm et al., 1997; Mayes et al., 2001).

Special Populations

Amnesia. Damage that includes the hippocampus and surrounding temporal lobe dis-

rupts both recollection and familiarity, but generally has a larger disruptive effect on recollection. In contrast, relatively selective hippocampal damage appears to disrupt recollection, but not familiarity. Studies of recall and recognition in amnesia have suggested the hippocampus is particularly important for recollection, whereas the surrounding temporal cortex may be critical for familiarity. In studies that have included amnesic patients with damage that extends beyond the hippocampus, such as the surrounding temporal lobe, recall is sometimes found to be more disrupted than recognition (e.g., Huppert & Piercy, 1976; Hirst, Johnson, Kim, Phelps, Risse, & Volpe, 1986; Hirst, Johnson, Phelps, & Volpe, 1988; Isaac & Mayes, 1999; Johnson & Kim, 1985; Volpe, Holtzan, & Hirst, 1986), but other studies with similar groups of patients have reported comparable recall and recognition deficits (e.g., MacAndrew, Jones, & Mayes, 1994; Shimamura & Squire, 1987; Haist, Shimamura, & Squire, 1992; Kopelman & Stanhope, 1998). In fact, extensive temporal lobe damage can reduce both recall and recognition memory to chance levels (e.g., Hamann & Squire 1997; Stark & Squire, 2000). There is some evidence that the discrepancies observed in these groups can be caused in part by the different methods that have been used to match performance in amnesic and control subjects (Giovanello & Verfaellie, 2001).

In contrast, in studies of patients with relatively selective hippocampal or fornix damage, recall is typically found to be disrupted to a greater extent than recognition regardless of the matching procedures (e.g., Aggleton et al., 2000; Baddeley, Vargha-Khadehm, & Mishkin 2001; Hanley, Davies, Downes, & Mayes, 1994; Holdstock, Mayes, Cezayiri, Isaac Aggleton, & Roberts 2000; Mayes, Isaac, Holdstock, Hunkin, Montaldi, Downes, MacDonald, Cezayirli, & Roberts, 2001; Parkin & Hunkin, 1993; Vargha-Khadem et al., 1997). In fact, recognition memory in these latter patients is sometimes in the normal range (e.g., Aggleton & Shaw, 1996), although this is not always the case (e.g., Manns & Squire, 1999; Reed & Squire, 1997). The observation that disproportionate recall deficits are seen in hippocampal patients suggests that the hippocampus is particularly important for recollection. In contrast, the finding that the proportional recall deficits are sometimes found in patients with more extensive temporal lobe lesions suggests that the regions surrounding the hippocampus may be important for familiarity.

Amnesic patients generally exhibit disproportionate deficits on associative- compared to item-recognition tests, indicating that recollection is disproportionally disrupted by medial temporal lobe damage. For example, in comparison to tests of item recognition, amnesics perform more poorly in tests that require them to remember when an item was presented (e.g., Aggleton et al., 2000; Hurst & Volpe, 1982; Huppert & Piercy, 1976, 1978; Kopelman, 1989; Meudell, Mayes, Ostergaard, & Pickering, 1985; Parkin, Rees, Hunkin, & Rose, 1994; Parkin & Hunkin, 1993; Squire, 1982; Nunn, Graydon, Polkey, & Morris, 1999; but see Milner, Corsi, & Leonard, 1991; Sagar, Gabrieli, Sullivan, & Corkin, 1990; for cases of preserved recency judgments), where an item was presented (e.g., Hirst & Volpe, 1984; Chalfonte, Verfaellie, Johnson, & Reiss, 1996; but see Cave & Squire, 1991), which modality it was presented in (e.g., Pickering, Mayes, & Fairbairn, 1989), which list the item was in (Mayes et al., 2001), or how frequently it was presented (e.g., Huppert & Piercy, 1978; Meudell, Mayes, Ostergaard, & Pickering, 1985). Moreover, in contrast to controls, amnesics tend to judge incorrectly that pictures shown frequently have been presented recently and that those shown recently have been shown frequently (Huppert & Piercy, 1978; Muendell et al., 1985; Mayes, Baddeley, Cockburn, Meundell, Pickering, & Wilson, 1989), suggesting that their recognition performance is based on assessments of item familiarity. The disproportional associative recognition memory deficits just described have included studies of patients with selective hippocampal lesions as well as patients with more extensive temporal lobe lesions. Direct comparisons of the magnitude of the associative recognition deficits in these different patients groups, however, has not been made, thus it is not clear if the different groups have comparable associative recognition deficits.

There is, however, evidence that some forms of associative recognition may be more disrupted by hippocampal damage than others. For example, Mayes et al. (2001; Mayes et al., 1999) reported a patient with hippocampal damage who exhibited disproportionate deficits on temporal order, object–place, and voice–face associative recognition tests compared to word–word associative recognition tests. Similar findings were reported by Vargha-Khadem et al. (1997) with three hippocampal patients who exhibited deficits in recognition for face–voice and object–location associative recognition, but who performed normally on word–word and face–face associative recognition. These results suggest that the hippocampus is necessary to form associations between items or aspects of an event that involve different types of information or that are processed by different cortical regions (e.g., face processing versus word processing regions), but that it is not necessary when the different aspects of an event involve the same type of information.

Although the disproportionate recall and associative recognition deficits relative to item recognition can be related to frontal lobe damage (e.g., Janowsky, Shimamura, Kritchevsky, & Squire, 1989), these patterns of results have been observed in amnesic patients with no frontal symptoms or pathology (e.g., Hirst & Volpe, 1982; Kopelman, 1989; Kopelman, Stanhope, & Kingsley, 1997; Mayes et al., 2001, 1989; Parkin, Rees, Hunkin, & Rose, 1994; Parkin & Hunkin, 1993), indicating that the disproportional associative recognition and recall deficits seen in amnesics are not due to frontal lobe damage.

Results from the remember/know (Blaxton & Theodore, 1997; Knowlton & Squire, 1995; Schacter, Verfaellie, & Pradere, 1996; Schacter, Verfaellie, & Anes, 1997), process-dissociation (Verfaellie & Treadwell, 1993), and ROC (Yonelinas et al., 1997) estimation methods indicate that in studies that include patients with extensive temporal lobe damage, recollection is severely disrupted, whereas familiarity is disrupted to a lesser extent (see Fig. 5). There was one experiment in which the recollection deficit was not larger than the familiarity deficit (Experiment 1, Blaxton & Thodore, 1997). However, the recollection levels for the control subjects in that experiment were extremely low which made it difficult to observe a recollection deficit in the patients. Moreover, in a subsequent experiment with a similar group of patients (Experiment 2, Blaxton & Theodore, 1997) recollection was found to be severely disrupted, whereas familiarity was not greatly influenced. In that same remember/know study, left hemisphere temporal lobectomy patients exhibited a larger decrease in recollection, whereas right hemisphere patients appeared to exhibit a larger deficit in familiarity, suggesting that the two hemispheres may be differentially involved in recollection and familiarity. This result is interesting because it suggests that the two processes may be lateralized and contrasts with previous findings, suggesting that left and right temporal lobe regions may be critical for verbal and nonverbal materials, respectively (Milner, 1968). It

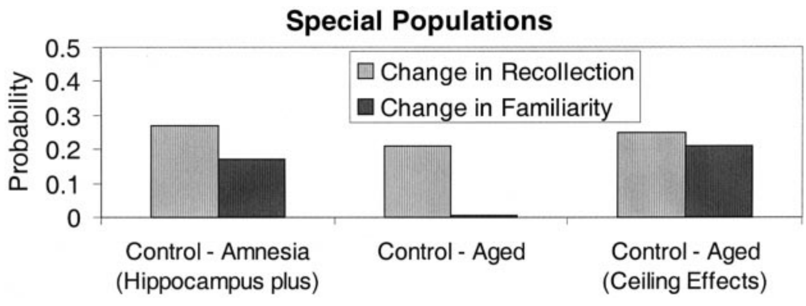

FIG. 5. The average change in recollection and familiarity estimates for special populations compared to control subjects.

will be important to verify that these remember/know results do not simply reflect different response biases to use remember and know responses in the left and right hemisphere lesioned patients.

One recent study contrasted remember/know judgments in patients with extensive temporal lobe lesions with patients who were expected to have more selective hippocampal lesions. The study found that patients with extensive temporal lobe lesions had deficits in recollection and familiarity, whereas the patients with more selective hippocampal lesions had selective deficits in recollection (Lazzara, Yonelinas, Kroll, Kishiyama, Sauve, Zusman, & Knight, 2001). These results are consistent with earlier findings in suggesting that the hippocampus is critical for recollection, whereas the surrounding temporal lobe regions are critical for familiarity.

Aging. Normal aging disrupts recollection but leaves familiarity largely unaffected. These deficits are associated with poor encoding and are related in part to frontal lobe dysfunction. Studies examining the effects of normal aging on recognition, associative recognition, and recall tests suggest that aging disrupts recollection to a greater extent than does familiarity. For example, normal aging leads to greater recall than recognition deficits (e.g., Craik & Jennings, 1992; Craik & McDowd, 1987; Naveh-Benjamin, 2000; Schonfield & Robertson, 1966). Similarly, recognition for single items is less disrupted by aging than associative recognition for word–word (Naveh-Benjamin, 2000), word–font (Naveh-Benjamin, 2000), word–color (Chalfont & Johnson, 1996), word–voice (Mark & Rugg, 1998), object–location (Chalfonte & Johnson, 1996), word–list (Trott, Freidman et al., 1999), recency judgments (Fabiani & Friedman, 1997), and memory for source (McIntyre & Craik, 1987; Schacter, Harbluk, & McLachlan, 1984; Stanhope, 1988).

The estimation methods indicate that aging leads to a selective reduction in recollection (see Fig. 5), but when performance levels are exceptionally high, estimates of both processes appear to be influenced (for an earlier review see Light, Prull, La Voie, & Healy, 2000). For studies in which performance is not excessively high (i.e., recollection estimates were less than .60), the process-dissociation (Benjamin & Craik, 2001; Caldwell & Masson, 2001; Jennings & Jacoby, 1993; Jacoby, 1999; Jennings & Jacoby, 1997; Rybash & Hoyer, 1996) and the remember/know procedures (e.g., Parkin & Walter, 1992; Perfect, Williams, & Anderton-Brown, 1995; Java, 1996, Norman & Schacter, 1997; Friedman & Trott, 2000) indicate that aging leads to a decrease in recollection, but does not influence familiarity. This is consistent with the results from the task dissociation methods. In contrast, for studies in which estimates of recollection are greater than .60 (Fig. 5), the process-dissociation (Jennings & Jacoby, 1997) and the remember/know procedures (Perfect et al., 1995; Schacter, Kourstaal, Johnson, Gross, & Angell, 1997; Perfect & Dasgupta, 1997; Mark & Rugg, 1998) suggest that recollection and familiarity estimates are similarly reduced by aging. The apparent effect of aging on estimates of familiarity in the latter studies are likely related to ceiling effects.

The recollection deficits associated with aging are due in part to poor encoding, but there is some evidence that retrieval problems may also be involved. For example, postexperimental questionnaires indicate that older subjects tend to use elaborative and associative encoding strategies less often than younger controls (Naveh-Benjamin, 2000; Perfect & Dasgupta, 1997). Moreover, the associative memory deficits related to aging are reduced with incidental compared to intentional encoding instructions (Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000), and when subjects are given special instructions to attend to the aspect of the study event that they will be tested for (Hashtroudi, Parker, Luis, & Reisen, 1989; Naveh-Benjamin & Craik, 1995), suggesting that older subjects may fail to engage in elaborative encoding strategies under intentional conditions. Similarly, recollection deficits in the remember/know procedure are reduced when encoding strategies are controlled (Perfect & Dasgupta, 1997; Perfect et al., 1995). Furthermore, as discussed in more detail below, electrophysiological responses and patterns of neural activation that are correlated with successful encoding are abnormal in aged subjects (e.g., Cabeza et al., 1997; Friedman, Ritter, & Snodgrass, 1996; Friedman & Trott, 2000; Grady, McIntosh, Horwitz, & Maisog, 1995), suggesting that the aging deficits are related to abnormal encoding. However, reductions in brain activation during retrieval have also been observed (e.g., Cabeza et al., 1997; Cabeza, Anderson, Houle, Mangels, & Nyberg, 2000; Schacter, Savage, Alpert, Rauch, & Albert, 1996), even when overall performance is controlled, suggesting that aging may influence retrieval as well as encoding. Similarly, electrophysiological responses during retrieval are sometimes reduced in aged compared to young subjects (Trott et al., 1997; but see Mark & Rugg, 1998), suggesting that aging may disrupt retrieval.

The recollection deficits observed in aging have been linked to a decrease in frontal lobe functioning. For example, age-related neuronal loss is particularly pronounced in the frontal lobes (e.g., Haug & Eggers, 1991), and the associative memory impairment exhibited in aging is correlated with various psychometric measures of frontal dysfunction such as performance on card sorting tasks and verbal fluency tasks (Craik, Morris, Morris, & Loewen, 1990; Fabiani & Friedman, 1997; Spensor & Raz, 1994). Similarly, Glisky, Polster, and Routhieaux (1995) found that aged individuals with poor frontal function (e.g., card sorting and verbal fluency) perform poorly on word–voice association recognition, but normally on word recognition; whereas aged individuals with poor medial temporal lobe function (e.g., verbal and visual recall tests) do poorly on word recognition but normally on associative recognition. Similarly, age-related decreases in remember responses correlate with deficits in card sorting performance in older individuals (Parkin & Walter, 1992; but see Perfect & Dasgupta, 1997). Finally, frontal lobe activations that are associated with successful retrieval of temporal order information are abnormal in aged subjects (e.g., Cabeza et al., 2000; Schacter, Savage, Alpert, Rauch, Albert, et al., 1996), and memory-related electrophysiological signals over frontal scalp sites are sometimes reduced in aged subjects (e.g., Trott et al., 1999; but see Mark & Rugg, 1998), providing further support for the claim that the recollection deficit seen in aging is related to frontal lobe dysfunction. However, age-related reductions in hippocampal volume have been related to reductions in memory (Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998), and hippocampal reductions in activation during encoding have been observed in aged subjects (e.g., Grady et al., 1995), suggesting that deficits in aging may also be related to hippocampal dysfunction.

Frontal lobe lesions. Lesions to the dorsolateral prefrontal cortex lead to reductions in recollection but have either smaller or no effects on familiarity. These impairments are often related to encoding problems, but may also partially reflect retrieval problems. Studies of recognition, recall, and associative recognition suggest that damage to regions in the frontal lobes disrupts recollection but leaves familiarity relatively unaffected. For example, frontal lobe patients have been found to exhibit greater recall than recognition deficits (e.g., Janowsky, Shimamura, Kritchevsky, & Squire, 1989; Jetter, Poser, Freeman, & Markowitscch, 1986; Wheeler, Stuss, & Tulving, 1995; but see Kopelman & Stanhope, 1998), suggesting that recollection is disproportionately disrupted in these patients. Similarly, frontal patients have been found to exhibit deficits in memory for the source of facts, even when fact memory was relatively intact (Janowsky, Shimamura, & Squire, 1989; Johnson, O'Connor, & Cantor, 1997; Schacter, Kaszniak, Kilstrom, & Valdiseri, 1991), and they show greater deficits in recency judgments (Milner, Corsi, & Leonard, 1991) and frequency judgments (Jurado, Junque, Pujol, Oliver, et al., 1997) than item recognition judgments. The fact that recognition memory can sometimes be relatively normal in frontal patients suggests that familiarity is well preserved in this group.

The dorsolateral region of the frontal lobes appears to be particularly important for recollection, and there is some evidence that the left and right hemispheres may be differentially involved in recollection of verbal and nonverbal materials, respectively. For example, associative recognition memory deficits are observed in patients with dorsolateral prefrontal lobe lesions, but not in frontal lobe patients in which dorsolateral regions are spared (Kopelman, Stanhope, & Kingskey, 1997). Patients with dorsolateral damage in the left or right hemispheres show recall (Jetter et al., 1986; Gershberg & Shimamura, 1995) and associative recognition memory deficits (Kopelman, Stanhope, & Kingsley, 1997), suggesting that both hemispheres are important for recollection. However, right hemisphere frontal lesions disrupt recency judgments for nonverbalizable materials, whereas left frontal lobe lesions disrupt recency judgments of verbal material (Milner, Corsi, & Leonard, 1991), suggesting that there may be some lateralization of memory function with respect to materials. However, in a study examining frequency estimations of verbal stimuli, both left and right hemisphere frontal lobe patients exhibited deficits, and the right hemisphere patients were found to exhibit more pronounced deficits than left hemisphere patients (Jurado, Junque, Pujol, Oliver, et al., 1997).

Frontal lobe patients have not been extensively studied using the process-estimation methods, but a few case reports have provided intriguing results. For example, a few case studies have shown that patients with large frontal lesions to the left or right hemisphere can exhibit elevated levels of false remember responses and high confidence false alarms, suggesting that recollection is disrupted (see Schacter, Norman, & Koutstaal, 1998). Moreover, a patient with damage to the right ventral prefrontal region was found to perform normally on recall, recognition, and associative recognition tests, but correct recognition responses were associated with fewer remember and more know responses than seen in controls (Levine, Black, Cabeza, Sinden, Mcintosh, Toth, Tulving, & Stuss, 1998; Levine, Freedman, Dawson, Black, & Stuss, 1999). This result suggests that ventral prefrontal damage may disrupt the subjective experience of recollection, or the ability to report on recollection, even when the ability to recollect associative information about previous events is preserved. Future studies using the process-estimation methods in larger groups of frontal lobe patients will be critical in verifying these results.

The memory impairments typically observed in frontal patients are due in part to a reduced tendency to spontaneously categorize or use organizational strategies during encoding, but may also reflect deficits in strategic processes during retrieval (Hirst & Volpe, 1988; Gershberg & Shimamura, 1995; Parkin, Ward, Bindschaedler, Squires, & Powell, 1999; Shimamura, 1996). For example, semantic orienting instructions during encoding can lead to a reduction in the recognition deficits observed in frontal patients (Parkin, 1997; Mangels, 1997), suggesting that their deficits may be due in part to encoding problems. Similarly, measures of list organization are lower in frontal patients (Gershberg & Shimamura, 1989; Mangels, 1997) and they report using organizational strategies less often than controls (Gershberb & Shimamura, 1995). However, although incidental compared to intentional encoding instructions can eliminate deficits in memory for temporal order seen in frontal patients, deficits in free recall are still observed (Mangles, 1997), suggesting that frontal lobe damage may also lead to retrieval deficits. Similarly, frontal damage often leads to confabulation (e.g., Moscovitch, 1989) and even in nonconfabulating patients can lead to excessively high false alarms rates in recognition (Parkin, Bindschaedler, Harsent, & Metzler, 1996; Schacter et al., 1996; Curran, Schacter, Norman, & Galluccio, 1997), suggesting that the frontal lobes may play a role at time of retrieval. Moreover, strategic instruction during test has been shown to reduce the recall deficits observed in frontal lobe patients (Gershberb & Shimamura, 1995; Incisa della Rocchetta & Milner, 1993).

Neuromonitoring

Event-Related Potentials (ERPs). During encoding, items that are associated with a widespread positive-going ERP deflection are more likely to be later recognized, and this effect is more pronounced for items that are later recollected compared to those recognized on the basis of familiarity. During retrieval, familiarity-based responses are related to an early *frontal-central scalp positivity, whereas recollection is related to a later left-parietal positivity. A very long-lived right frontal positivity has been related to both recollection- and familiarity-based recognition responses*. During encoding, items that are later retrieved exhibit more positive-going potentials across both hemispheres than items that are subsequently forgotten (for reviews see Rugg, 1995; Wagner, Koutstaal, & Schacter, 1999). The effect is generally found to be larger for recall than for recognition (Paller et al., 1988), and larger effects have been reported for remember than for know responses (Friedman & Trott, 2000), suggesting that the effects are more strongly related to recollection than familiarity. Moreover, larger effects were reported under conditions in which subjects used associative encoding strategies that linked two words together than when they used nonassociative encoding strategies (Weyerts, Tendolkar, Smid, & Heinz, 1997). The effect, however, has been observed for both remember and know responses (Freidman & Trott, 2000; Smith, 1993; Friedman & Trott, 2000) and has been related to items that were later recognized but not successfully recollected in an associative recognition test (Freedman & Trott, 2000), suggesting that the encoding effect can also lead to familiarity-based recognition. Note that there is some evidence that the encoding ERP effects may reflect several subcomponents (Mangels, Picton, & Craik, 2001); however, the functional significance of these effects is not yet clear. Moreover, although the encoding effects have not often been extensively examined using nonverbalizable materials, there is some evidence that the effects are smaller or absent for pictorial materials (see Wagner et al., 1999).

These encoding-related ERPs suggest that the encoding mechanisms that lead to subsequent recollection-based recognition responses are also engaged, but to a much lesser extent, in leading to subsequent familiarity-based recognition responses. The results do not rule out the possibility that the encoding mechanisms supporting recollection and familiarity are partially distinct because the method may simply be insensitive to such differences, but they provide no direct evidence that the two processes rely on qualitatively distinct encoding mechanisms. Further studies will be necessary to determine exactly which functions the encoding ERP effects reflect. One possibility is that they reflect the type of elaboration that has large effects on recollection and smaller effects on familiarity, such as that related to deeper levels of semantic processing, increased attention, or generation processes.

During retrieval, recollection is related to an ERP positivity that is maximal over left parietal sites, whereas familiarity is related to an earlier positivity that has a frontal-central distribution.[2] For example, the recollective ERP correlate has been related to reports of remembering (Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Rugg, Schloerscheidt, & Mark, 1998; Smith, 1993; Klimesch, Doppelmayr, Yonelinas, Kroll, Lazzara, Rohm, & Gruber, 2001) and with the retrieval of study event associations such as word–modality (Wilding et al., 1995; Wilding & Rugg, 1997), word–voice (Rugg, Schloerscheidt, & Mark, 1998; Wilding & Rugg, 1996, 1997), temporal source (Trott et al., 1997, 1999), and word–word (Donaldson & Rugg, 1998; Tendolkar, Doyle, & Rugg, 1997) and word plurality (Curran, 2000). The familiarity ERP correlate has been related to know responses (Duzel et al., 1997; Smith, 1993; Klimesch et al., 2001; but also see Trott, Freidman, et al., 1999) and to recognized items that are not associated with correct associative memory judgments (Curran, 2000). Moreover, ERP studies of amnesic patients indicate that the recollection-based ERP correlate is reduced or eliminated by hippocampal damage (e.g., Smith & Halgren, 1989; Mecklinger, von Cramon, & Matthes-von Cramon, 1998; Rugg, Roberts, Potter, Pickles, & Nagy, 1991; Tendolkar, Schoenfeld, Golz, Fernandez, Kuhl, Ferszt, & Heinze, 1999), while the familiarity correlate, in some cases, is unaf-

[2] The fact that some of the ERP effects are larger over one hemisphere than the other should be interpreted cautiously, because it is difficult to determine the neural generators of scalp ERPs, and because most of the relevant studies have used verbalizable materials; thus the observed hemispheric asymmetries may arise because of the type of stimuli that have been examined.

fected (e.g., Tendolkar, Schoenfeld, Golz, Fernandez, Kuhl, Ferszt, & Heinze, 1999; Duzel, Vargha-Khadem, Heinze, & Mishkin, 2001), suggesting that the hippocampus is necessary for recollection, but not familiarity.

The two different retrieval-related ERP effects indicate that recollection and familiarity involve partially distinct neural generators and that the neural activation related to familiarity is observable earlier than that related to recollection. Because it is difficult to determine the location of the neural generators on the basis of scalp ERPs, it is not clear which brain regions are involved in generating those ERPs. The lesion results, however, suggest that the hippocampal region plays an important role in recollection.

Recognition memory retrieval has also been associated with a late (400–1200 ms) frontal positive ERP component that is often larger over right than left scalp sites. The effect is typically larger under conditions in which associative compared to item recognition is required (Mark & Rugg, 1998; Wilding, 1999; Ranganath & Paller 1999, 2001; Senkfor & Van Patten, 1998), but is related to both correct and incorrect associative memory judgments (e.g., Ranganath & Paller 1999, 2001; Senkfor & Van Patten, 1998; Wilding & Rugg, 1996; Trott, Friedman, et al., 1999) and with both remember and know responses (Duzel et al., 1997; Trott et al.,1999), suggesting that it is involved in both recollection and familiarity. Because of the long duration and frontal distribution of this effect, it has been interpreted as reflecting a process whereby the products of memory retrieval are monitored (e.g., Ranganath & Paller 1999; 2001; Wilding & Rugg, 1996).

Neuroimaging. During encoding, activation in the prefrontal cortex, hippocampus, parahippocampal gyrus, and bordering fusiform gyrus is often associated with subsequent recollection. During memory retrieval, activation in the prefrontal cortex, hippocampus, parahippocampal gyrus, and parietal lobe is associated with recollection, whereas somewhat distinct prefrontal activations are related to familiarity. The frontal activations appear to reflect elaborative processing during encoding and with memory attempt or monitoring during retrieval, whereas the medial temporal activations appear to involve the formation and retrieval of recollected information. During encoding, activation in prefrontal regions and the medial and inferior temporal lobes (i.e., the hippocampus, parahippocampal, and fusiform gyri) is often associated with subsequent recognition memory, and these effects appear to be more closely related to recollection than familiarity. For example, activations in the prefrontal, parahippocampal, and fusiform regions have been found to be greater for items that were subsequently associated with "remember" or high confidence recognition responses compared to "know" or low confidence responses (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Wagner et al., 1999; Henson, Rugg, Shallice, Josephs, & Dolan, 1999), suggesting that these regions are involved in recollection. Similarly, hippocampal regions are found to be more active when subjects are encoding pairs of items than when they are encoding single items (e.g., Henke, Weber, Kneifel, Wieser, & Buck, 1999), and activations throughout the medial temporal lobe regions, including the hippocampus and parahippocampal gyrus, are found to predict subsequent free recall (Strange, Otten, Josheps, Rugg, & Dolan, 2002). Frontal and medial temporal lobe activations related to encoding are often larger in the left than right hemisphere, particularly for materials that can be verbally encoded, whereas right hemisphere or bilateral regions tend to be more involved during the encoding of materials that are less easily verbalized such as visual patterns (e.g., Brewer et al., 1998; Martin, Wiggs, & Weisberg, 1997; Wagner, Poldrack, Eldridge, Desmond, Glover, & Gabrieli, 1998). Memory-related activations have been observed throughout the prefrontal cortex during encoding, and there is evidence that different subregions within the prefrontal cortex may be functionally distinct (e.g., see Buckner, Logan, Donaldson, & Wheeler, 2000; Cabeza & Nyberg, 2000); however, it is not yet understood how these subregions relate to recollection and familiarity.

The encoding-related frontal lobe activations appear to reflect elaborative or organizational processes that facilitate subsequent recollection-based responses, whereas the medial temporal lobe activations are more directly related to the storage of that elaborative information. For example, frontal lobe activation increases with the organizational demands of the task and is reduced by dividing attention (Fletcher et al., 1998; also see Iidaka et al., 2000). Moreover, aging, which is known to reduce spontaneous elaborative encoding, leads to changes in encoding-related prefrontal activation (Cabeza et al., 1997; Grady, McIntosh, et al., 1995). Finally, left frontal activation associated with semantic elaboration has been observed in a patient with hippocampal damage who was impaired in a subsequent memory test (Buckner & Koutstaal, 1998), suggesting that without the hippocampus, the elaborative encoding processes supported by the frontal lobes are not sufficient to support subsequent recollection.

During recognition memory retrieval, hippocampal and parahippocampal regions are related to recollection, but not familiarity. For example, in recognition memory tests of drawings, bilateral hippocampal and parahippocampal regions were related to associative recognition, but not to item recognition (Yonelinas, Hopfinger, Buonocore, Kroll, & Baynes, 2001). Moreover, in recognition tests for words, remember responses, but not know responses, were associated with left hippocampal and parahippocampal activation (Henson et al., 1999; Eldridge, Knowlton, Furmanski, Bookheimer, & Engel, 2000).

Prefrontal regions are involved in both recollection and familiarity during retrieval, but the two processes appear to rely on partially distinct subregions. For example, left anterior prefrontal regions are more active for items that are remembered than for those that are known (Henson et al., 1999; but see Eldridge et al. 2000) and in associative recognition compared to item recognition tests (Ranganath et al., 2001; Nolde, Johnson, & D'Esposito, 1998; Rugg, Fletcher, Frith, Frackowiak, & Dolan, 1996; Raye, Johnson, Michell, Nolde, & D'Esposito, 2000), suggesting that these regions play a greater role in recollection- than familiarity-based discriminations. In contrast, bilateral dorsolateral prefrontal activations have been associated with both types of recognition judgments (e.g., Ranganath et al., 2000). In fact, right dorsolateral prefrontal regions have been found to be more active during know and low confidence recognition responses than during remember or high confidence responses (Henson, Rugg, Shallice, & Dolan, 2000; Henson et al., 2001; Eldridge et al., 2000), which has been interpreted as reflecting additional monitoring requirements that are necessary when test items are close to a familiarity response criterion. The anterior cingulate has also been found to be more active for know than for remember responses (Henson et al., 1999; Eldridge et al., 2000). Although the precise roles of these prefrontal regions are not yet clear, they are generally thought to be involved in retrieval success or retrieval monitoring (see Rugg & Henson, 2001). Whether the left versus right prefrontal activations related to recollection and familiarity are dependent on the verbal nature of the retrieved information is not yet known.

Parietal lobe activation has been related to recognition retrieval (Cabeza & Nyberg, 2000; Rugg & Henson, 2001; Lepage, Ghaffar, Nyberg, & Tulving, 2000) and appears to be related primarily to recollection. For example, remember responses have been found to lead to greater parietal activation than know responses (e.g., Henson et al., 1999; Eldridge et al., 2000), suggesting that this region may be more involved in recollection than familiarity. The functional significance of these activations are not yet clear, but they have been associated with attention shifting, orienting, and visual imagery, any of which may play a critical role when recognized items are recollected.

In sum, the neuroimaging results suggest that the frontal lobes along with the medial and inferior temporal lobes are involved during encoding that supports later recollection. The frontal regions appear to be involved in elaborative encoding, whereas the temporal lobe appears to reflect memory storage. The imaging methods have not yet provided insights into the regions involved in encoding related to familiarity-based responses. However, this may be because there have not been many studies designed specifically to examine familiarity-related activations. During time of retrieval, recollection involves the frontal and medial temporal lobe regions, whereas familiarity appears to involve partially distinct frontal regions. The medial temporal lobes would appear to reflect retrieval of recollected information, whereas the frontal regions reflect retrieval success or monitoring.

CHARACTERISING RECOLLECTION AND FAMILIARITY

Processing Speed

One of the core assumptions of a number of dual-process models is that familiarity is faster than recollection (Atkinson, Jacoby, Mandler, and Yonelinas). A variety of empirical results support this assumption. First, response-speed studies indicate that familiarity is available earlier than recollection. Second, under non-speeded test conditions familiarity-based responses tend to be faster than recollection-based responses. Third, ERP studies indicate that the electrophysiological correlates of familiarity are observed earlier than those associated with recollection.

The finding that familiarity is faster than recollection is consistent with neuroanatomical models that propose that familiarity is supported by regions earlier in the processing stream than those supporting recollection (Aggleton, Tulving, and Yonelinas). The current results, however, do not directly address the question of whether familiarity is completed before recollection is initiated (Atkinson) or whether the two processes are initiated in parallel (Mandler, Jacoby, and Yonelinas). The fact that the products of familiarity are available earlier than those of recollection could be accounted for by either class of model. Note that if recollection is only initiated when familiarity fails then one might expect to see bimodal response-time distributions; an early distribution of familiarity responses and a later distribution of recollection responses. An examination of recognition memory response-time distributions, however, provides no support for the prediction that the RT distributions are bimodal (e.g., Ratcliff & Murdock, 1976). However, it is not clear that the Atkinson model necessarily predicts bimodal RT distributions. That is, as long as the variability in response times related to familiarity is great enough, then the response time distributions for recollection and familiarity may overlap sufficiently to produce a unimodal RT distribution.

The Relationship between Recollection and Familiarity

Most dual-process models assume that recollection and familiarity operate independently during retrieval (Mandler, Jacoby, Yonelinas, and Tulving). The empirical evidence is generally consistent in showing that the two processes are independent under most standard test conditions, but there are test conditions under which this assumption does not appear to hold. One line of evidence that is consistent with the independence assumption comes from studies of special populations and neuromonitoring studies that show that recollection and familiarity rely on partially distinct neural substrates. If the two processes rely on distinct brain regions, then it is possible that these regions could operate independently. However, it is important to note that finding that recollection and familiarity rely on separate brain regions does not rule out the possibility that one region may be functionally dependent on the other.

In order to determine whether recollection and familiarity are operating independently, it is necessary to assess whether they can be functionally dissociated. That is, if one process operates independently of the other, it should be possible to find variables that influence one process without influencing the other. If the two processes are fully independent, it should be possible to produce double dissociations (e.g., find variables that have selective effects on one process and other variables that have selective effects on the other process). In contrast, if the two processes are dependent, rather than independent, then recollection and familiarity should behave in similar ways and such dissociations should not be observed.

The empirical literature indicates that recollection and familiarity can be doubly dissociated by retrieval manipulations, verifying that the two processes operate independently at retrieval. For example, response speeding and dividing attention during time of test reduce recollection but leave familiarity unaffected. Conversely, relaxing response criterion and increasing processing fluency lead to changes in familiarity, but do not influence recollection. Similarly, forgetting over intermediate retention intervals selectively influences familiarity, and changing the modality of words between study and test also appears to selectively affect familiarity.

Another line of evidence indicating that the two processes operate independently at retrieval comes from the observation that the results of the process-estimation methods are verified by the results from the task-dissociation methods. The estimation methods all assume that recollection and familiarity are independent, whereas the task-dissociation methods make no explicit assumptions about how the two processes are related. To the extent that the task-dissociation methods verify the results of the estimation methods, the results indicate that the assumptions underlying the estimation methods were not violated because such violations would have biased the parameter estimates. In a large majority of cases the task-dissociation methods verified the conclusions derived from the process-estimation methods. For example, associative/ item recognition procedures lead to the same conclusions as the estimation methods with respect to the effects of divided attention at study, response speed, divided attention at test, forgetting over intermediate and long-term intervals, amnesia, and aging. Similarly, speeded/nonspeeded recognition procedures converge with the estimation methods with respect to conclusions regarding the levels of processing, study duration, and word frequency effects. Moreover, recall/recognition comparisons lead to the same conclusions as the estimation methods with respect to levels of processing, generation, dividing attention at study, study duration, divided attention at test, false recognition, amnesia, and aging. The only variable for which there is disagreement is word frequency, which, as discussed further below, may reflect the fact that recall and word–word associative recognition involve a form of recollection that is somewhat distinct from that measured by other measurement methods.

Although recollection and familiarity operate independently under most test conditions there may be special cases in which they are not independent. For example, in studies in which performance levels were extremely high, the estimation methods produced patterns of results that were inconsistent with the results from studies in which such ceiling effects were avoided (e.g., the effects of aging). Although the ceiling effects may simply reflect a methodological limitation associated with the estimation methods (this point is discussed further in the measurement methods section below), it is possible that when performance levels are extremely high, the two processes no longer operate independently. For example, if subjects remember a large proportion of the test items, and thus find only a few items to be familiar in the absence of recollection, this may affect how subjects map their subjective experiences onto remember and know responses or how likely they are to endorse items in exclusion conditions, and thus the two processes may no longer independently contribute to performance. Moreover, Jacoby, Begg, and Toth (1997) have shown that in tasks like stem completion, the processes that support performance in that task operate independently under some test instructions (i.e., direct retrieval) but can operate in a dependent manner under other instructions (i.e., generate–recognize). Although these effects have not yet been observed in recognition memory, it may be possible to develop recognition test conditions in which a dependence is observed between recollection and familiarity.

Most dual-process models make no explicit assumptions about how recollection and familiarity are related during time of encoding. However, because some models assume that the two processes rely on separate storage systems (Atkinson and Tulving) it is possible that they might be sensitive to different encoding manipulations. In fact, Tulving argues that only certain types of encoding dissociations should be observed. That is, he argues that information must pass through the semantic system that supports familiarity before entering the episodic system that supports recollection. Thus, it should be possible to find encoding manipulations that influence recollection to a greater extent than familiarity, but any encoding manipulation that influences familiarity should also have similar effects on recollection.

The existing evidence is consistent with Tulving's proposal. For example, encoding manipulations such as levels of processing, dividing attention, generation, and the administration of benzodiazepines influence recollection to a greater extent than familiarity, whereas no encoding manipulations have been identified that have larger effects on familiarity than recollection. Although it is possible that future studies will produce such dissociations, the observed pattern is consistent with the claim that during encoding, information must pass through the regions supporting familiarity before engaging the regions that support recollection.

The Signal Detection/Threshold Distinction

Most dual-process models assume that familiarity reflects the assessment of a continuous memory strength index, whereas recollection reflects the retrieval of qualitative or associative information about a study event (Atkinson, Mandler, Jacoby, and Yonelinas). Moreover, familiarity is sometimes formalized using signal detection theory, whereas recollection has been formalized as a threshold process (Atkinson and Yonelinas). The evidence generally supports these claims. For example, remember responses often are accompanied by above-chance associative recognition, whereas familiarity-based responses are not. Moreover, as response criterion is relaxed familiarity increases gradually, as expected if old items are more familiar than new items and they form overlapping equal-variance Gaussian distributions, whereas recollection estimates remain relatively constant, as expected if recollected information leads to high confidence recognition responses. Moreover, ROCs in amnesics are well described by signal detection theory, whereas associative recognition memory ROCs in healthy subjects indicate that recollection is often better described as a threshold process. Several studies, however, have shown that associative ROCs are not always perfectly consistent with a single threshold process, suggesting that either associative recognition tasks can sometimes be supported by familiarity or recollection can sometimes operate in more of a continuous manner (see Yonelinas, 1997, 1999; Qui, Raye, Johnson, & Michell, 2001). Nonetheless, the existing results are clear in showing that the simple signal detection process that accurately describes familiarity does not provide a satisfactory account of recollection.

The Conceptual/Perceptual Distinction

One of the central assumptions of the early dual-process models (Mandler and Atkinson) is that recollection reflects a conceptual or elaborative process, whereas familiarity reflects a more sensory or perceptual process. The results provide some support for this claim in showing that recollection and familiarity are preferentially sensitive to conceptual and perceptual manipulations, respectively. For example, recollection increases more with semantic compared to perceptual encoding conditions than does familiarity. Moreover, other elaborative encoding manipulations like generation compared to read conditions and full compared to divided attention conditions are also found to increase recollection to a greater extent than familiarity. In contrast, perceptual fluency manipulations influence familiarity but not recollection, supporting the claim that familiarity is more sensitive to perceptual manipulations than recollection. Similarly, changing the presentation modality of words between study and test leads to decreases in familiarity, but does not influence recollection.

Both processes, however, are sensitive to conceptual manipulations to some extent, and thus the results are more consistent with models that propose that familiarity can support conceptual as well as perceptual information (Jacoby). For example, although deep compared to shallow processing, full compared to divided attention, and generate compared to read conditions tend to increase recollection more than familiarity, in all of these cases familiarity is found to increase to some extent. Moreover, conceptual fluency manipulations lead to increases in familiarity, suggesting that familiarity is sensitive to conceptual manipulations.

In sum, although there is support for the claim that recollection and familiarity are differentially sensitive to conceptual and perceptual manipulations, the conceptual/perceptual distinction does not provide a completely satisfactory characterization of these processes. These results indicate that familiarity cannot be described as reflecting the activation of entirely presemantic or lexical representations, as the Mandler and Atkinson models propose, but must reflect in part conceptual fluency (Jacoby) or the products of a semantic memory system (Tulving).

The Controlled/Automatic Distinction

Jacoby (1991) argues that one of the fundamental differences between recollection and familiarity is that they reflect controlled and automatic processes, respectively, and a number of other models are consistent with this claim (Atkinson, Mandler, and Yonelinas). Thus, the two processes are expected to be differentially sensitive to variables that have different effects on controlled and automatic processes (see Hasher & Zacks, 1979; Shiffrin & Schneider, 1977). For example, relative to recollection, familiarity should be less attention demanding, more perceptual than conceptual, require less processing time, and be less likely to involve conscious awareness.

In general, at time of retrieval, familiarity is more automatic than recollection. For example, during time of test, familiarity is less demanding of attention, faster, and more perceptual than recollection. It should be pointed out, however, that familiarity is not automatic in an absolute sense. For example, familiarity does appear to decrease with extremely short response deadlines and when subjects are told to ignore the study items. Moreover, familiarity is not automatic in the sense that the subject is unable to control whether that process leads to a behavioral response—in the way an air puff to the eye may automatically lead to an eye-blink. There are numerous examples indicating that subjects have control over whether familiarity is used as a basis of responding. For example, recollection can be used to oppose the effects of familiarity (e.g., in the exclusion conditions), familiarity-based responses can be withheld until recollection is completed (e.g., in remember/know conditions), subjects can vary their response criterion on familiarity-based responses, and fluency effects on familiarity can be reduced if subjects become aware that fluency is being manipulated. Thus, it appears that although the products of familiarity are available relatively automatically compared to recollection, the use of familiarity information is not obligatory.

Whether recollection is more accessible to conscious experience than familiarity is not clear. The results from remember/know studies suggest that subjects can become consciously aware of both recollection and familiarity and they can report on them when asked to do so. Thus, it would appear that both processes are accessible to conscious awareness. Nonetheless, it is possible that under conditions in which subjects are not explicitly asked to introspect about their subjective experiences, they may be less conscious of familiarity than recollection. As far as I am aware, however, none of the existing studies have directly addressed this issue.

During encoding, the evidence that familiarity is an automatic process is considerably weaker. Dividing attention during encoding has larger detrimental effects on recollection than familiarity, indicating that the encoding mechanisms that are required for recollection are more attention-demanding than those supporting familiarity. However, dividing attention at encoding often does have some detrimental effect on familiarity, indicating that additional attention at encoding does benefit subsequent familiarity-based recognition. Moreover, increasing study duration leads to comparable increases in both recollection and familiarity, indicating that the encoding time required for recollection and familiarity does not differ substantially.

Intermediate-Term versus Long-Term Memory

Several dual-process models assume that familiarity should decrease more rapidly than recollection. For example, models that assume that familiarity reflects temporary item activation (Atkinson and Mandler) lead to the expectation that familiarity should decrease rather rapidly.

Moreover, Eichenbaum et al. (1993) proposes that the parahippocampal region, which supports familiarity-based responses, reflects an intermediate-term storage system that, at least initially, should exhibit a faster forgetting rate than recollection. In agreement with the latter claim, the results suggest that over short retention intervals (i.e., 8 to 32 intervening items) familiarity does decrease rapidly, whereas recollection is relatively unaffected. Across longer term delays (i.e., across minutes to months) both recollection and familiarity are found to exhibit considerable forgetting.

The finding that familiarity decreases more rapidly over short-term retention intervals than does recollection provides support for the notion that familiarity reflects temporary activation (Atkinson and Mandler). However, familiarity and recollection often remain well above chance after 6 months, indicating that this “activation” can be quite long-lived. Thus, even though familiarity does initially decrease rapidly, it appears to be more than simply an “intermediate-term” storage.

Can Familiarity Support Novel Learning?

The models that assume that familiarity reflects activation of preexisting representations (Atkinson, Mandler) predict that familiarity should not support novel learning. In contrast, Jacoby and Tulving argue that familiarity can be quite flexible and should be able to support novel learning. A somewhat intermediate position is adopted by Yonelinas, who argues that familiarity should support learning of new items, but it should not support learning of associations between arbitrarily paired items unless the two items are unified and treated as a single item.

The results are in closest agreement with the latter proposal. That is, familiarity supports memory for new items such as random geometric shapes, nonwords, and unfamiliar faces. In contrast, familiarity does not generally support learning of new associations as seen in tests of associative recognition. For example, items that elicit a know response are not related to above-chance associative recognition judgments; estimates from the ROC method indicate that familiarity estimates often approach zero for associative recognition tests; and amnesic patients exhibit pronounced deficits on most associative recognition tests. However, there is some evidence that familiarity can support memory for associations under a limited set of conditions. For example, familiarity does appear to support associative recognition between different parts of faces when the faces are presented in an upright orientation and of word–word associations when the word pairs are treated as new compound words. The finding that familiarity can support learning of novel items and novel associations when the separate items are treated as a single item suggests that familiarity supports memory only for aspects of study events that are unitized (Yonelinas). The unitization hypothesis is also broadly consistent with several other findings. For example, there is evidence that familiarity can support memory for object–location associations (Caldwell & Masson, 2001). In this study, subjects participated in a computer game in which they were required to place drawings of common objects into different locations within complex realistic contexts. Although further studies will be necessary to determine exactly what aspects of this study were critical in leading familiarity to support associative recognition judgments, one possible explanation is that the level of complexity and interaction that was promoted in that experiment led to the integration of the object and location information. There is evidence from a few other studies that patients with selective hippocampal lesions can learn new word–word and face–face associations, but not new face–voice associations (e.g., Vargha-Khadem et al., 1997). The more pronounced impairment in face–voice associations seen in hippocampal patients may arise because it is more difficult to unitize faces with auditory information than it is to unitize two words or two faces. The latter results suggest that familiarity may be capable of supporting memory for novel associations when the two items are processed in the same cortical regions, whereas recollection may be needed to associate items that are processed in different cortical regions (Mayes et al., 2001).

The finding that familiarity can support new learning is inconsistent with models that treat familiarity as the activation of existing representations (Atkinson and Mandler). Although it may be possible to develop models in which familiarity reflects some form of activation, it must be more complex than in these early models and must be able to support learning of novel items and novel associations under some conditions. Nonetheless, it does not appear that familiarity can support all forms of novel learning equally well (Tulving and Jacoby); rather, it only supports new learning under a limited set of conditions. The unitization hypothesis (Yonelinas) can account for some of these findings, but further work is needed to determine what the necessary and sufficient conditions are for unitization to occur. Such studies will be essential in determining the limits of learning that the brain can support without the hippocampus and in so doing will further our understanding of the function of the medial temporal lobes.

The Relationship between Familiarity and Implicit Memory

Some dual-process models assume that familiarity contributes to both recognition and perceptual implicit memory (Mandler), while other models assume that they reflect distinct forms of memory (Tulving). There is an extensive body of research showing that familiarity is functionally dissociable from performance on perceptual implicit memory tasks, indicating that familiarity is not identical to perceptual implicit memory (for similar arguments see Jacoby & Kelley, 1992; Stark & Squire, 2000; Wagner & Gabrieli, 1998). First, encoding manipulations such as levels of processing, study duration, and divided attention generally increase estimates of familiarity, but, they do not generally influence perceptual implicit memory (see Roediger & McDermott, 1993; Light & Prull, 1995; Mulligan, 1999). Second, familiarity is greater for generated than read items, whereas the opposite is true for perceptual implicit memory (e.g., Jacoby, 1983; Roediger & McDermott, 1993; Winnick & Daniel, 1970; Slameka & Graf, 1978). Third, familiarity exhibits a picture-superiority effect, whereas perceptual implicit memory shows the opposite effect (i.e., verbal implicit memory is better if the items were studied as a word rather than as a picture—Wagner, Gabrieli, & Verfaelie, 1997). Fourth, benzodiazapines generally reduce familiarity to some extent, whereas these drugs typically do not influence perceptual implicit memory (e.g., Weingartner, Eckardt, Molchan, & Sunderland, 1992). In fact, the one drug that has the smallest effect on familiarity (i.e., lorazapam) has effects on the perceptual system (e.g., Wagemans, Notebaert, & Boucart, 1989) and has been shown to disrupt performance on perceptual implicit memory tests (e.g., Bishop & Curran, 1995; Danion et al., 1992; Vidailhet, Danion, Chenin, & Kazes, 1999). Fifth, familiarity is reduced in amnesic groups with extensive temporal lobe damage, and these groups typically do not exhibit deficits on perceptual implicit tests (e.g., see Gabrieli, 1998). In fact, an encephalitis patient with extensive temporal lobe atrophy was found to perform at chance on recognition memory tests, but performed normally on perceptual priming tests (Hamann & Squire 1997; Stark & Squire, 2000), indicating that recollection and familiarity could be eliminated without disrupting perceptual implicit memory. Sixth, the ERP correlates of familiarity are distinct from those typically associated with perceptual implicit memory (e.g., Paller, Kutas, & McIsaac, 1998; Rugg, Mark, Schloerscheidt, Birch, & Allan, 1998), suggesting that these two forms of memory reflect partially distinct neural substrates. Finally, the neuroimaging results from perceptual priming studies often implicate extrastriate regions in the occipital lobe (see Cabeza & Nyberg, 2000), and there is little evidence linking this region to familiarity.

Further evidence that the processes that support performance on implicit tests are functionally distinct from those seen in recognition tests comes from studies using the process dissociation procedure in these different types of memory tests. For example, the automatic influences of memory in stem completion tests are found to be greater for items that were read than those that were generated (e.g., Jacoby et al., 1993), whereas familiarity is greater for generated than for read items (e.g., Jacoby, 1991). Moreover, in recognition, familiarity is found to decrease more rapidly than recollection across intermediate delays (e.g., Yonelinas & Levy, 2002), whereas in stem completion the two processes that contribute to performance are found to decrease at similar rates (e.g., McBride & Dosher, 1999).

Although familiarity is dissociable from perceptual implicit memory, which indicates that the two forms of memory cannot be identical, it is probably premature to conclude that the same processes that support perceptual implicit memory do not contribute to familiarity-based recognition. First, perceptual priming effects are typically small (i.e., 5–20%) compared to familiarity effects (i.e., 20–60%). Thus, it is possible that familiarity-based recognition reflects the contribution of several subprocesses, only one of which also contributes to perceptual implicit memory. As discussed below, other processes, such as those supporting conceptual implicit memory, may contribute to familiarity and thus overshadow the perceptual priming effects. Second, there are often differences in the retrieval cues that are provided in the perceptual implicit and recognition tests, and thus the dissociations observed between these tests could be due in part to those cue differences. In support of this claim, some of the dissociations between familiarity and perceptual implicit memory disappear when examining implicit tasks like lexical decision in which the entire word is presented, as it is in recognition memory tests. For example, like familiarity, lexical decision performance generally benefits from full compared to divided attention (see Bentin Moscovitch & Nirhod, 1998) and deep compared to shallow levels of processing (Duchek & Heely, 1989; Bentin et al., 1998). Studies that directly contrast familiarity to perceptual implicit memory with tasks that use similar test cues will be useful in fully assessing the relationship between these forms of memory. Nonetheless, the current results do not support models that treat familiarity and perceptual implicit memory as reflecting exactly the same process (Mandler).

Jacoby (1991) argued that familiarity-based recognition judgments were not limited to assessments of perceptual fluency, but rather they relied heavily on assessments of conceptual processing fluency. If this is the case then familiarity may be similar to conceptual implicit memory. In support of this claim, an examination of the existing results indicates that familiarity-based recognition responses are functionally quite similar to performance on conceptual implicit memory tasks. For example, like familiarity, conceptual implicit memory, as measured on tasks like the exemplar generation, increases with deep compared to shallow encoding (Hamann, 1990), picture naming compared to word reading (Vaidya & Gabrieli, 1996), word generation compared to word reading (Srinivas & Roediger, 1990), long compared to short study durations (Challis & Sidhu, 1993), and full compared to divided attention (e.g., Mulligan & Stone, 1999; Light, Prull, & Kennison, 2000). Moreover, like familiarity, conceptual implicit memory is not disrupted by lorazapam (Bishop & Curran, 1998) or by frontal lobe lesions (Gershberg, 1997). Note that although familiarity often appears to be preserved in aging, conceptual implicit memory results are mixed, indicating deficits in some cases and preserved performance in others (see Light, Prull, La Voie, & Healy, 2000). As with familiarity, some groups of amnesics exhibit normal conceptual implicit memory (e.g., Gardner, Boller, Moreines, & Butters, 1973; Graf, Shimamura, & Squire, 1985; Shimamura & Squire, 1984; Carlesimo, 1994; Cermak, Verfaellie, & Chase, 1995; Vaidya, Gabrieli, Keane, & Monti, 1995), whereas others exhibit significant deficits (e.g., Blaxton, 1992). In addition, a recent study directly contrasting conceptual implicit memory and familiarity in different amnesic groups indicated that selective hippocampal lesions did not disrupt familiarity or conceptual implicit memory, whereas more extensive temporal lobe lesions extending into the parahippocampal gyrus disrupted both familiarity and conceptual implicit memory (Lazzara, et al., 2001). These results indicate that both familiarity and conceptual implicit memory rely on regions in the parahippocampal gyrus. The similarities between familiarity and conceptual implicit memory suggest that these types of memory are similar and may in fact rely on common mechanisms. Nonetheless, there are important differences in the tasks used to measure these forms of memory that may lead to dissociations. Future studies directly contrasting familiarity and conceptual implicit memory will be important in addressing this issue.

Neuroanatomical Substrates

A number of dual-process models assume that the medial temporal lobes are particularly important for recollection (Tulving, Mandler, Jacoby, Yonelinas), and this claim has been supported by results from a variety of studies. For example, patients with damage to the medial temporal lobes exhibit greater deficits in recollection than in familiarity and greater disruption of recollection- than familiarity-related ERPs. Similarly, benzodiazepines, which act on the hippocampus and limbic system, are found to lead to disproportional deficits in recollection. Finally, neuroimaging studies indicate that the hippocampal and parahippocampal regions within the medial temporal lobe are often activated during recollection- but not familiarity-based recognition responses.

Various models assume that the most important region for recollection within the medial temporal lobes is the hippocampus, whereas the parahippocampal gyrus is more directly related to familiarity (Eichenbaum, Aggleton, Tulving, and Yonelinas). Studies from lesion patients provide strong support for this claim, whereas neuroimaging results provide only mixed support. For example, patients with relatively selective hippocampal lesions tend to exhibit selective deficits in recollection, whereas patients with lesions that include the hippocampus and surrounding parahippocampal regions exhibit deficits in both recollection and familiarity, indicating that the hippocampus and surrounding parahippocampal regions are necessary for recollection and familiarity, respectively. The neuroimaging results, however, indicate that activation in the hippocampus and parahippocampal gyrus is often related to recollection during encoding and retrieval, but not to familiarity. Why the parahippocampal region is necessary for familiarity, but only appears to activate in association with recollection, is not yet clear, and further studies will be necessary to resolve this apparent paradox.

The frontal lobes are thought to play a critical role in both recollection and familiarity (Tulving and Aggleton). The results are clear in showing that the prefrontal cortex is critical for recollection, but are somewhat less clear about the role these regions play in familiarity. For example, patients with frontal lobe lesions, particularly to the dorsolateral prefrontal cortex, exhibit pronounced deficits in recollection and appear to exhibit preserved familiarity-based recognition. Moreover, in studies of normal aging, frontal lobe pathology is related to the selective recollection deficits observed in those subjects. Similarly, neuroimaging studies indicate that the frontal lobe activation during encoding is correlated with subsequent recollection-based responses rather than familiarity-based responses. However, during retrieval, both recollection- and familiarity-based responses are related to frontal lobe activation, suggesting frontal involvement in both types of recognition responses. The fact that frontal lobe lesions do not lead to deficits in familiarity suggests that these regions do not play a necessary role in this process. However, another possibility is that the frontal lobes are necessary for familiarity, but that the role they play is not rigidly localized to one specific frontal region, but rather can be supported by other frontal regions when one region is damaged. Consistent with this claim, there is evidence that the frontal lobes are fairly plastic and can functionally reorganize after injury (e.g., Buckner, Corbetta, Schatz, Raichle, & Petersen, 1993).

The precise roles that the frontal lobes play in recognition memory are only poorly understood. The prolonged nature of the frontal ERP effects observed in recognition, suggest that the frontal lobes play a role in monitoring the products of memory retrieval. The fact that they are observed for both recollection- and familiarity-based responses suggests that both processes require some sort of frontally mediated monitoring or decision process. The neuroimaging results have also indicated that the frontal regions may be involved in both recollection- and familiarity-based responses and have further suggested that they reflect partially distinct regions in the prefrontal cortex. Verifying that the frontal lobes do play a necessary role in familiarity-based responses and clarifying exactly what functional role these regions play in recognition are critical questions for future studies.

Tulving and colleagues have argued that recollection- and familiarity-based retrieval are lateralized to right and left frontal hemispheres, respectively, and that the left frontal lobe is involved during encoding into episodic memory (i.e., encoding that supports later recollection-based judgments). The two hemispheres appear to exhibit some degree of lateralization with respect to materials, but there is little consistent evidence to suggest that they are differentially involved in recollection and familiarity. For example, lesions to frontal or medial temporal lobe regions in the left hemisphere tend to have more pronounced effects on memory for verbal than nonverbal materials, whereas lesions to the right hemisphere tend to have more pronounced effects on nonverbal materials. Moreover, neuroimaging studies indicate that memory for verbal materials tends to involve the frontal and medial temporal regions in the left hemisphere to a greater extent than the right and that nonverbalizable materials tend to involve the right hemisphere more than the left. A number of early neuroimaging studies suggested that retrieval from episodic memory (i.e., recollection) involved the right hemisphere to a greater extent than the left, whereas retrieval from semantic memory (i.e., familiarity) involved the left more than the right (see Nyberg et al., 1996). Lesion studies, however, have provided no support for this distinction, and several recent neuroimaging studies have suggested the opposite; that left frontal regions are involved in recollection retrieval, whereas right frontal regions may be more important for familiarity.

In sum, the lesion and neuroimaging results provide strong evidence that recollection relies on the prefrontal cortex and the hippocampus. In contrast, the neural substrates of familiarity are less well understood, but there is some indication that the temporal lobe regions outside the hippocampus and possibly frontal regions may be important. Although the results from lesion and neuroimaging studies are only beginning to uncover the neural substrates of recollection and familiarity, they already have played a critical role in differentiating between alternative theories and are important in setting further constraints on the development of future models. Nonetheless, numerous neuroanatomical questions about these two processes remain to be answered. For example, although the frontal lobes are critical for recollection, and may be important for familiarity, it is not yet clear exactly what functional roles these regions play. Moreover, some models indicate the different thalamic regions may be involved in recollection and familiarity (Aggleton). Unfortunately, there is currently little evidence from human studies that is useful in determining the role these regions play in recollection and familiarity. Moreover, neuroimaging studies have indicated that other regions such as the parietal lobe and cingulate are involved in recognition, but it is not yet clear what functional role they play or exactly how they are involved in recollection and familiarity.

Assessing the Measurement Methods

The current review provides a unique opportunity to assess the different measurement methods across a wide variety of studies. The results from these studies provide direct support for many, but not all, of the assumptions underlying the different task-dissociation methods. For example, the finding that familiarity is faster than recollection indicates that response-speeding methods provide a useful way of separating recollection and familiarity. Similarly, in general, comparisons of item recognition performance with recall and associative recognition performance are in agreement with other measurement methods, indicating that recall and associative recognition tasks provide a reasonable method of assessing recollection. Although comparisons across these different tasks may be complicated by differences in retrieval cues and response requirements, the results were generally consistent with other methods in which retrieval cues and response requirements were kept constant, suggesting that these differences did not play a critical role in most studies. However, one important caveat regarding recall and associative recognition methods is with respect to word-frequency effects in the sense that word–word associative recognition and recall were affected differently by word frequency than all other measures of recollection. These results indicate that care must be taken when interpreting the results from these two measures of recollection because they may not always generalize to other measures of recollection.

The results also provide support for the assumptions underlying the three process-estimation methods, at least within certain limits, and indicate that these methods are in close agreement about the nature of recollection and familiarity. For example, as discussed above, the results indicate that recollection and familiarity operate independently at time of retrieval and thus provide support for the independence assumption underlying the process-dissociation, remember/know, and ROC methods. The convergence of the remember/know results with those of the other estimation and task-dissociation methods indicates that subjects are aware of recollection and familiarity and can reliably report on these processes. However, one possible exception was a patient with damage to right ventral prefrontal regions who exhibited normal associative recognition but made very few remember responses. Although further work is needed to verify and replicate this result, it is important in suggesting that the use of recollection may not always be associated with the conscious experience of remembering. The convergence of the results from the ROC methods with those from other estimation and task-dissociation methods indicates that the method's underlying assumptions are reasonable; namely that familiarity is well described as a signal-detection processes and that recollection supports relatively high confidence responses.

Thus, the current results are in agreement with several previous studies that have directly contrasted the different estimation methods within single experiments and have concluded that these three methods lead to comparable conclusions (e.g., Perfect, Mayes, Downes, & Van Eijk, 1996; Guttentag & Carroll, 1997; Yonelinas & Jacoby, 1995; Yonelinas, Dobbins, et al., 1996; Yonelinas, 2001a, 2001b; Rugg, Schloerscheidt, & Mark, 1998), and they are in disagreement with the claim that the remember/know procedure measures subjective experiences that are unrelated to recollection and familiarity (e.g., Gardiner, Ramponi, & Richardson-Klavehn, 1999; Gardiner & Richardson-Klavehn, 2000).

One important methodological issue that became obvious in reviewing the existing studies was that the estimation methods appeared to be critically affected by excessively high levels of performance (i.e., ceiling effects). Although most experiments avoided ceiling effects, when they were observed the estimation methods appeared to lead to aberrant conclusions. For example, in the 10 experiments using estimation methods to examine the effects of generate compared to read conditions, 9 of those experiments indicated that generating compared to reading words at study led to an increase in familiarity estimates. In contrast, one experiment using the process-dissociation procedure indicated that generation led to a *decrease* in familiarity estimates (Wagner et al., 1989). Importantly, that was the experiment with the highest level of recollection in the generation condition (.67 compared to the average of .42 in the other experiments). Another process-dissociation experiment in which estimates of recollection were extremely high (e.g., approaching .80) also led to aberrant results (Dehn & Engelkamp, 1997). That is, unlike numerous other process-estimation studies and task-dissociation studies, that experiment suggested that dividing attention and response speeding led to *increases* in familiarity.

The ceiling effect problem was also observed in studies using the remember/know procedure. For example, in studies of word frequency, 16 of 17 different experiments indicated that familiarity and recollection increased more for low than high frequency words and that the effect was larger for recollection than familiarity. The one experiment that did not show this pattern used the remember/know procedure (i.e., Experiment 2 in Reder et al., 1999) and had an average recollection estimate of .80 for low frequency words. In another experiment in that same study, performance was lower and the aberrant pattern was not observed (Experiment 3 in Reder et al., 1999). Note that Experiment 2 in that study also suffered from ceiling effects but it exhibited a pattern that was consistent with the majority of other studies. Thus, it appears that although ceiling effects can influence the pattern of process estimates, they do not do so in every case.

Ceiling effects were also seen in studies of aging. In studies in which ceiling effects were avoided (i.e., recollection was less than .60) aging was found to lead to a decrease in recollection but did not influence familiarity. In contrast, in studies in which estimates of recollection were greater than .60, the parameter estimates suggested that familiarity was disrupted by aging. In fact, in one case (Perfect et al., 1995) the familiarity deficits seen in the aged were greater than the recollection deficits observed in that group.

Other authors have discussed the problem of ceiling effects on the process-dissociation procedure (e.g., Curran & Hintzman, 1995; Jacoby, Toth, & Yonelinas, 1993; Yonelinas, Regehr, & Jacoby, 1995; Yonelinas, 2001); however, the current results indicate that the problem is more general than was earlier thought. For example, it has been noted previously that as recollection increases, exclusion scores must decrease, and they can often approach 0. Estimates of familiarity are undefined when exclusion scores are equal to 0 and this can lead to distorted parameter estimates. A similar problem appears to hold in remember/know experiments. For example, as recollection increases, the number of items available for familiarity-based responses decreases. To the extent that the measure of familiarity is based on fewer and fewer responses, these measures should become unreliable. Moreover, as discussed above as performance approaches ceiling, the two processes may no longer independently contribute to performance, thus leading to biased estimates.

If ceiling effects can distort the estimates from the process-estimation methods then what are the boundary conditions in which the estimation methods can be expected to lead to valid process estimates? Based on the findings in this review, it appears that when estimates of recollection increase beyond .60 that the estimation methods can lead to distorted estimates of familiarity. Thus, a conservative approach would be to design experiments such that recollection estimates do not exceed .50 and overall levels of accuracy do not approach 0 or 100%.

Although the different experiments and measurement methods generally led to consistent conclusions, there were isolated cases in which an experiment was not in agreement with the majority of other studies. Some of those discrepancies may have been spurious, but it is important to carefully examine each one because they could provide important insights into the nature of recollection and familiarity and the different measurement methods. First, there were several within-method discrepancies (i.e., two experiments used the same method to examine a manipulation, but led to different conclusions), but in most cases these differences most likely reflected a Type II error (i.e., incorrectly accepting the null hypothesis). For example, with the levels of processing manipulation, the three estimation methods, the recall/recognition methods, and the results from two response-deadline experiments indicated that familiarity was less sensitive to the levels of processing manipulation than recollection. In contrast, one experiment using the deadline method reported similar levels of processing effects at fast and slow response deadlines, suggesting that familiarity was not less sensitive to the manipulation than recollection (Gillund & Shiffrin, 1984). A similar pattern was seen in studies examining the effects of changing presentation modality between study and test. In general, there was a small but consistent decrease in familiarity when the modality was switched between study and test. Consistent with this, one response-deadline study (Toth, 1996) indicated that modality match effects were larger for the fast than slow response condition. In contrast, a similar response-deadline experiment failed to find a significant difference in the modality effects between fast and slow responses (Mulligan & Hirshman, 1995).

Two other examples of within-method inconsistencies were seen in studies of amnesia. First, most studies indicated that recency judgments were more disrupted than item recognition judgments in amnesia (Aggleton et al., 2000; Hurst & Volpe, 1982; Huppert & Piercy, 1976, 1978; Kopelman, 1989; Meudell et al., 1985; Parkin et al., 1994; Parkin & Hunkin, 1993; Squire, 1982), whereas a few studies indicated that the deficits were comparable on these two types of test (Milner, Corsi, & Leonard, 1991; Sagar, Gabrieli, Sullivan, & Corkin, 1990). The former results are consistent with a large number of studies indicating that associative recognition memory judgments are more disrupted by amnesia than are item recognition judgments. The failure to find a disproportionate deficit in recency judgments in some experiments may have reflected a Type II error, but it may also be the case that recency judgments are less disrupted in amnesia than other types of associative recognition judgments. That is, familiarity may be more useful in recency judgments than in other associative tests because the more recent items are more familiar. Another case of a within-method inconsistency was seen in recall and recognition comparisons in amnesics with damage extending beyond the hippocampus. Some studies showed that these patients exhibited a disproportionately large deficit in recall compared to recognition (e.g., Huppert & Piercy, 1976; Hirst et al., 1986, 1988; Isaac & Mayes, 1999; Johnson & Kim, 1985) but others did not (MacAndrew et al., 1994; Shimamura & Squire, 1987; Haist et al., 1992). The failure to find a larger recall than recognition deficit could be due to a lack of statistical power, but it may also reflect the fact that both recollection and familiarity process are disrupted in these patients (e.g., Yonelinas et al., 1998). Further studies of amnesia contrasting recency judgments with other associative memory judgments, as well as studies contrasting recall and recognition in different amnestic groups, will be useful in resolving these issues.

One important across-method difference (i.e., when different measurement methods lead to different conclusions about the effects of a manipulation) was with respect to the effects of word frequency on recollection. That is, recall and word–word associative recognition performance was better for high than low frequency words, suggesting that recollection exhibited a high frequency advantage, but other associative recognition tests, as well as the remember/know, process-dissociation, and ROC procedures, indicated that recollection was greater for low than high frequency words. This conflicting pattern of results was not limited to a few isolated experiments, suggesting that these differences were reliable. Why then did this discrepancy arise? Recall tests differ from recognition in the sense that they provide no retrieval cues and they require subjects to generate target items; thus it is possible that either of these two factors could lead to differences between recall and recognition tests. However, neither of these differences can account for the observed word frequency dissociations because a high frequency advantage was also observed in word–word associative recognition—a task in which retrieval cues are provided and subjects are not required to generate target items. As discussed above, one account of the discrepancy is that item recognition and most forms of associative recognition rely on recollection of item-specific information, whereas recall and word–word associative recognition rely additionally on recollection for the relations between items. Although further studies will be necessary to test this account, the results are important in suggesting that there are two different types of recollection processes or two different types of recollected information.

In sum, there are a wide variety of measurement tools available to assess recollection and familiarity. The assumptions underlying most methods are well supported by the empirical results; however, methods relying on recall, word–word associative recognition, and possibly recency judgments must be interpreted cautiously because there are conditions under which they differ from other measures of recollection. Moreover, the current examination of the estimation methods indicates that in order to avoid biasing the parameter estimates provided by these methods it is important to carefully design studies to avoid ceiling effects.

The Relationship to Other Memory Theories

The original dual-process models were developed to account for results showing that at least two different processes or types of memory contributed to recognition performance. A number of other models have been developed that either are similar to or build directly on the major dual-process models. In many of these cases the models were designed with a specific experimental paradigm in mind, and they often do not make testable predictions about many of the experiments described above. Nevertheless, they often differ from the major dual-process models in important ways and thus may provide important theoretical contributions to the understanding of recollection and familiarity.

For example, Reder et al. (2000) developed a dual-process model to account for word frequency effects in recognition memory. They argue that familiarity reflects the assessment of the activation of word nodes, whereas recollection reflects the assessment of activation of nodes that represent specific events. Thus both processes rely on assessments of activation in a manner consistent with signal-detection theory. The model was found to account for the effects of word frequency seen in recognition memory, and to generate the novel prediction that was subsequently verified, that know responses would be greater for high than low frequency words (Reder et al., 2000). Another dual-process model that is quite consistent with many of the observed recognition results is that of Brainerd and colleagues (e.g., Brainerd, Reyna, & Mojardin, 1999). This model was developed to account for developmental changes in false recognition and assumes that recognition relies on two independent memory processes (i.e., verbatim memory and gist memory). True recognition is thought to rely on both verbatim memory and gist memory, whereas false recognition is thought to arise primarily on the basis of gist memory. Verbatim memory reflects item-specific information about the surface form of the studied items and gives rise to the experience of recollection, whereas gist memory reflects meaning and relational information and is experienced as familiarity. In agreement with this model, recollection and familiarity are found to operate independently, and recollection is generally found to be less susceptible to false alarms than familiarity.

Johnson and colleagues (e.g., Johnson, Hashtroudi, & Lindsay, 1993) have proposed a "source monitoring framework" that has a number of similarities with dual-process models. Memory judgments are assumed to reflect two types of memory processes (i.e., heuristic and systematic). The heuristic process reflects an assessment of the activation of memory records, such as "is the familiarity level of this item sufficiently great?" or "is the retrieved perceptual information sufficiently detailed?" In contrast, the systematic process reflects more complex judgments such as deciding if the memory is consistent with the subject's general knowledge. As with the dual-process models, one process (i.e., the heuristic process) is assumed to be relatively automatic in the sense that it is expected to be faster and less attention-demanding than the other process. The heuristic and systematic memory processes, however, do not appear to map perfectly onto recollection and familiarity in the sense that the heuristic process is not limited to assessments of memory strength information, but can also support complex associative information such as spatial and contextual information about the study event. Thus, recollection and familiarity may be more appropriately treated as two different types of heuristic processes.

Squire and colleagues (e.g., Squire, 1994; Squire & Zola, 1998) have proposed a model in which the medial temporal lobes function as a unified declarative memory system that supports both recognition and recall performance, whereas the frontal lobes play an additional executive role in tasks like free recall. Thus, two processes are involved in recall, whereas only one is involved in recognition. The model is consistent with the current results in the sense that it predicts that selective frontal lobe lesions should produce disproportionate deficits in recall compared to recognition. However, the model treats recognition as reflecting a single memory system and provides no principled way of accounting for the behavioral or neuropsychological dissociations observed between recollection and familiarity. For example, the model predicts that medial temporal lobe damage that disrupts recall must disrupt recognition to a similar extent, and the results from studies of patients with selective hippocampal damage disconfirm this prediction.

One potentially useful way of modeling recollection and familiarity is to use a multidimensional signal-detection approach (Macmillan & Creelman, 1991) in which the two processes are treated as orthogonal memory strength dimensions, such that studying an item leads to an increase in the recollective and familiarity strengths of that item (Rotello, Macmillan, & Reeder, 2001). Because recollection and familiarity are treated as separate dimensions, it should be possible to produce double dissociations between recollection and familiarity. Moreover, this type of model has recently been shown to be consistent with results from remember/know studies which have been problematic for single-process models (Rotello et al., 2001). Although it is not yet clear whether it can account for all the behavioral dissociations described above, it represents a potentially very useful method of describing recollection and familiarity. One critical limitation of this approach, however, is that it appears to be inconsistent with the types of ROCs that have been observed in associative recognition studies. That is, the core assumption of this type of model is that memory judgments are based solely on Gaussian strength distributions, and the ROCs observed in associative recognition tests show that this assumption is often violated.

A somewhat different approach is to assume that there are many different memory strength dimensions reflecting different types of recollected information such as “list 1 strength,” “list 2 strength,” “visual modality strength,” and so on. This approach has been shown to provide good fits to results from source memory and exclusion conditions (Banks, Chen, & Prull, 1999; Banks, 2000). However, it is not yet clear whether the model provides a principled way of accounting for behavioral dissociations that were described above. For example, if recognition judgments simply reflect the assessments of different strength dimensions then it is not clear why manipulations like response-deadline reduce the type of strength used in associative recognition judgments more than that used in item recognition judgments, nor why the strength information used to make item recognition judgments is found to decrease more rapidly than that supporting associative judgments. Moreover, if recognition simply reflects the assessment of a variety of recollective strength dimensions, then it is not clear why recollection relies on the hippocampus, whereas familiarity does not. The model also suffers from the same problem as the previous multidimentional signal-detection model in the sense that it is based solely on assessments of Gaussian strength distributions and thus runs into problems accounting for associative recognition ROCs.

One signal-detection model that may be able to overcome the problems associated with the Gaussian assumption is a model proposed by Kelley and Wixted (2001). In this model, recognition judgments are based on assessments of familiarity strength and recollection (or associative) strength. Both recollection and familiarity strength distributions are assumed to be Gaussian, but recollection is thresholded such that only some discrete proportion of old items are assumed to be recollected. This threshold aspect of the model allows it to produce ROCs that are more linear in shape (much in the same way that the Yonelinas model does), something that the other signal detection models cannot. Although there are a number of critical assumptions underlying this model that still need to be assessed, it has been shown to provide a good account of the results from a number of associative recognition experiments (Kelley & Wixted, 2001).

One assumption that is sometimes made about recollection is that it is only used when it is absolutely necessary (Hintzman & Curran, 1994; Rotello & Hiet, 2000). That is, because familiarity can be used to discriminate between old and new items, under standard recognition memory conditions performance is based exclusively on assessments of familiarity. Only in tests like associative recognition or tasks in which subjects are instructed to use recollection such as in exclusion conditions or remember/know conditions do subjects make use of recollection. There is, however, very little evidence to suggest that subjects refrain from using recollection in item recognition tests, whereas there is considerable evidence indicating that recollection does contribute to performance in these tests. The suggestion that recollection might not contribute to item recognition comes from response speeding studies. That is, the accuracy/response-time functions observed in conditions in which recollection is required are biphasic, suggesting that two processes are influencing performance. In contrast, in standard item recognition conditions the functions are monotonic, and thus it is possible to account for them using a single familiarity process. These results do not show that recollection is not contributing to item recognition, it merely shows that it is not necessarily the case that it does. Evidence that recollection does contribute to item recognition comes from several sources. First, if recollection was only used under test conditions where it was explicitly required, then overall recognition memory accuracy should be much greater under these conditions than under standard recognition conditions. Although there is evidence for a slight trend in this direction in exclusion and remember/know studies (Yonelinas, 1994; Khoe et al., 2000), these differences are quite small, suggesting that requiring recollection does not fundamentally alter the processes involved in recognition. Second, an examination of ROCs in item-recognition tests indicates that the shapes of the observed functions can be used to accurately predict performance on remember/know and associative memory tests (Yonelinas, 2001a, 2001b), indicating that the recollection process supporting remembering and associative recognition is playing a critical role in item recognition. Third, the ERP correlates of recollection and familiarity are still observed in standard recognition test conditions (Curran, 2000; Düzel et al., 2001), indicating that these two processes are initiated even in item recognition tests.

One potential criticism of the dual-process models is that they have not yet been specified at a computational level. A number of computational models of recognition have been proposed (e.g., SAM, TODAM, and MINERVA2), and these models can account for a large body of behavioral data (for review see Clark & Gronlund, 1996). In general, these models assume that recognition decisions are based on an assessment of a global measure of memory strength, thus they are single-factor models of recognition. However, because they can incorporate multiple types of memory information (e.g., items and associations), and they include a familiarity process, as well as a recall process, they can produce dissociations between different types of recognition memory tasks. For example, Ratcliff, Van Zandt, and McKoon (1995) showed that the SAM model could account for some results from the process-dissociation procedure using only the familiarity process. These findings are important in showing that it is possible to produce behavioral dissociations without using two separate memory retrieval mechanisms. However, they also noted that the model did not work in general as a way of accounting for process-dissociation results unless the recall process was assumed to contribute to recognition memory (for similar arguments see Clark & Gronlund, 1995; Hintzman & Curran, 1994; Yonelinas, 1994). The global memory models may provide a useful way of implementing recollection and familiarity on a computation level. However, one potential limitation is that they are not generally consistent with ROC results observed in associative recognition tasks because they base recognition memory on the assessment of a Gaussian signal detection like strength measure (Yonelinas, 1997, 1999; also see Ratcliff, Sheu, & Gronlund, 1992, for further problems with the global model accounts of ROCs). Moreover, as with the multidimensional signal-detection models, they do not provide much in the way of understanding the results from patient, ERP, or neuroimaging studies in the sense that, at least as they are currently formulated, they do not make testable predictions about neuroanatomical substrates of these processes.

A computational model that appears to overcome many of the difficulties associated with the global models is the Complementary Learning Systems model (e.g., McClelland, McNaughton, & O'Reilly, 1995; Norman & O'Reilly, 2001; O'Reilly & Rudy, 2001). The model is based on the assumption that the hippocampus and surrounding cortex support interactive but distinct mnemonic functions. The hippocampus supports recollection by developing minimum overlapping representations of prior episodes, whereas the surrounding cortex gradually tunes populations of cortical units to respond strongly to different stimuli in such a way that it can discriminate between familiar and new items. A review of the model goes beyond the scope of the current article (for a detailed discussion of the model see Norman & O'Reilly, 2001), but the results from preliminary simulations with that model are promising because they indicate that it can account for the differential importance of hippocampal versus the surrounding neocortex in recollection and familiarity, and successfully predicts behavioral properties of recollection that other models have not (e.g., producing linear and curvilinear ROCs). It is not yet clear whether the model is able to account for the full body of results discussed above; however, models such as this one are particularly promising because they aim to incorporate the behavioral and neuroanatomical knowledge about recollection and familiarity within the same theoretical framework.

Conclusions

Results collected using a variety of different measurement methods, across an extremely broad range of empirical paradigms, including behavioral, neuropsychological, and neuroimaging studies, have been useful in characterizing the functional nature and neuroanatomical substrates of recollection and familiarity. Familiarity is found to be a fast, signal-detection-like process that operates independently of recollection. It is found to be relatively automatic and somewhat more sensitive to perceptual manipulations than recollection, although it is not limited exclusively to perceptual information. Unlike recollection, familiarity does not readily support learning of novel associations, although it can support learning of novel items and novel associations if they are treated as single items. Familiarity is functionally distinct from perceptual implicit memory, but it shares a number of similarities with conceptual implicit memory. Recollection depends critically on the hippocampus and frontal lobes, whereas familiarity appears to rely on separate temporal lobe regions and may rely on separate frontal lobe regions.

The dual-process models have been critical in framing many of the questions that have guided empirical research in human memory over the past 30 years and have led to important discoveries about the nature of the processes that support memory performance. Although future studies are necessary to further delineate the neural substrates of these processes, and to further differentiate the subprocesses that are involved in recollection and familiarity, the existing research has provided a broad foundation on which to build an understanding of human memory.

APPENDIX

Raw Scores and Estimates of Recollection (R) and Familiarity (F) from the Process Estimation Studies

1) LEVELS OF PROCESSING	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Yonelinas (2001, Expt. 3)						
Shallow	0.19	0.03	0.32	0.18	0.16	0.21
Deep	0.54	0.03	0.27	0.18	0.51	0.40
Gardiner (1988, Expt. 1)						
Shallow	0.45	0.01	0.16	0.01	0.44	0.28
Deep	0.66	0.01	0.17	0.01	0.65	0.49
Rajaram (1993, Expt. 1)						
Shallow	0.32	0.02	0.30	0.14	0.30	0.30
Deep	0.66	0.02	0.20	0.14	0.64	0.45
Gregg & Gardiner (1994)						
Shallow	0.31	0.05	0.34	0.23	0.26	0.24
Deep	0.61	0.01	0.27	0.16	0.60	0.52

APPENDIX—*continued*

1) LEVELS OF PROCESSING	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Gardiner, Java, et al. (1996, Expt. 1)						
Shallow	0.15	0.03	0.20	0.11	0.12	0.12
Deep	0.72	0.03	0.18	0.11	0.69	0.53
Gardiner, Java, et al. (1996, Expt. 2)						
Shallow	0.13	—	0.25	—	0.13	0.29
Deep	0.42	—	0.24	—	0.42	0.41
Gardiner, Ramponi, et al. (1999, Expt. 1)						
Shallow	0.30	0.02	0.16	0.06	0.29	0.16
Deep	0.51	0.02	0.12	0.06	0.50	0.18
Khoe et al. (2000, Expt. 1)						
Shallow	0.16	0.05	0.39	0.28	0.11	0.17
Deep	0.29	0.05	0.39	0.28	0.24	0.25
Java et al. (1997, Expt. 2)						
Shallow	0.50	0.04	0.22	0.12	0.46	0.32
Deep	0.71	0.04	0.10	0.03	0.67	0.31
Perfect et al. (1995, Expt. 2A)						
Shallow	0.37	0.28	0.02	0.05	0.09	−0.04
Deep	0.68	0.18	0.02	0.01	0.50	0.05

PDP	Inclusion		Exclusion			
	Old	New	Old	New	R	F
Yonelinas (2001, Expt. 3)						
Shallow	0.52	0.19	0.18	0.11	0.26	0.09
Deep	0.77	0.19	0.14	0.11	0.55	0.16
Toth (1996, Expt. 3)						
Shallow	0.56	0.22	0.33	0.26	0.27	0.21
Deep	0.91	0.22	0.30	0.26	0.65	0.61
Wagner et al. (1997)						
Shallow	0.57	0.16	0.18	0.10	0.33	0.14
Deep	0.88	0.16	0.22	0.10	0.60	0.42
Komatsu et al. (1994, Expt. 1)						
Shallow	0.74	0.27	0.35	0.23	0.35	0.29
Deep	0.90	0.27	0.27	0.23	0.60	0.41
Wagner, Stebbins et al. (1998, Expt. 1)						
Shallow	0.54	0.27	0.28	0.17	0.16	0.11
Deep	0.76	0.27	0.31	0.17	0.35	0.26

ROC	Confidence						
	>1	>2	>3	>4	>5	R	F
Yonelinas (2001, Expt. 3)							
Shallow	0.42	0.54	0.63	0.76	0.89	0.26	0.24
Deep	0.68	0.76	0.83	0.90	0.95	0.50	0.37
New	0.10	0.18	0.28	0.45	0.71	—	—
Yonelinas, Kroll, et al. (1998)							
Shallow	0.86	0.77	0.56	0.43	0.31	0.27	0.25
Deep	0.93	0.86	0.73	0.63	0.49	0.44	0.36
New	0.66	0.44	0.16	0.09	0.03	—	—

APPENDIX—*continued*

2) GENERATE/READ	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Gardiner, Java, et al. (1996, Expt. 3)						
Read	0.14	—	0.25	—	0.14	0.29
Generate	0.38	—	0.28	—	0.38	0.45
Gardiner (1988, Expt. 2)						
Read	0.30	0.07	0.17	0.09	0.23	0.15
Generate	0.54	0.07	0.16	0.09	0.47	0.25
Gardiner, Ramponi, et al. (1999, Expt. 2)						
Read	0.11	0.03	0.17	0.09	0.08	0.10
Generate	0.21	0.03	0.18	0.09	0.19	0.14
Wippich (1992, Expt. 1)						
Read	0.17	0.02	0.24	0.12	0.15	0.17
Generate	0.40	0.02	0.31	0.12	0.38	0.39
Curran & Hildebrandt (1999)						
Read	0.43	0.02	0.22	0.05	0.41	0.33
Generate	0.52	0.02	0.22	0.05	0.50	0.41
Donaldson et al. (1996)						
Read	0.31	0.02	0.41	0.14	0.29	0.45
Generate	0.76	0.02	0.21	0.14	0.74	0.73

PDP	Inclusion		Exclusion			
	Old	New	Old	New	R	F
Jacoby (1991, Expt. 3)						
Read	0.48	0.18	0.37	0.22	0.15	0.24
Generate	0.80	0.18	0.29	0.22	0.55	0.44
Jennings & Jacoby (1993, Expt. 2)						
Read	0.65	—	0.52	—	0.13	0.60
Generate	0.84	—	0.30	—	0.54	0.65
Verfiellie & Treadwell (1993)						
Read	0.45	0.17	0.33	0.19	0.14	0.20
Generate	0.67	0.17	0.34	0.19	0.35	0.34
Dodson & Johnson (1996, Expt. 1)						
Read	0.43	0.27	0.33	0.25	0.07	0.10
Generate	0.81	0.27	0.33	0.25	0.46	0.35
Wagner, Stebbins, et al. (1998, Expt. 1)						
Read	0.72	0.27	0.35	0.19	0.29	0.26
Generate	0.88	0.27	0.13	0.19	0.67	0.16

3) DIVIDED ATTENTION AT STUDY	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Yonelinas (2001, Expt. 1)						
Full	0.45	0.02	0.38	0.26	0.43	0.43
Divided	0.29	0.02	0.45	0.26	0.27	0.37
Yonelinas (2001, Expt. 2a)						
Full	0.57	0.01	0.26	0.14	0.56	0.46
Divided	0.39	0.01	0.32	0.14	0.38	0.38
Yonelinas (2001, Expt. 2b)						
Full	0.23	0.02	0.40	0.26	0.21	0.25
Divided	0.15	0.02	0.42	0.26	0.13	0.23
Yonelinas (2001, Expt. 2c)						
Full	0.36	0.03	0.34	0.24	0.33	0.28
Divided	0.21	0.03	0.37	0.24	0.18	0.22

APPENDIX—*continued*

3) DIVIDED ATTENTION AT STUDY

Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Parkin, Gardiner, & Rosser (1995, Expt. 1)						
Full	0.54	0.04	0.28	0.10	0.50	0.50
Divided	0.38	0.08	0.28	0.15	0.30	0.29
Mangels, Picton, & Craik (2001)						
Full	0.63	0.01	0.24	0.12	0.62	0.54
Divided	0.17	0.02	0.34	0.20	0.16	0.20
Gardiner & Parkin (1990)						
Full	0.50	0.01	0.20	0.04	0.49	0.36
Divided	0.27	0.01	0.22	0.08	0.26	0.22

PDP	Inclusion		Exclusion			
	Old	New	Old	New	R	F
Jacoby & Kelly (1991)						
Full	0.77	—	0.35	—	0.42	0.59
Divided	0.68	—	0.48	—	0.20	0.60
Gruppuso et al. (1995, Expt. 3)						
Full	0.84	0.03	0.50	0.03	0.34	0.72
Divided	0.76	0.05	0.53	0.05	0.23	0.63

ROC	Confidence						
	>1	>2	>3	>4	>5	R	F
Yonelinas (2001, Expt. 1)							
Full	0.49	0.65	0.76	0.84	0.92	0.49	0.43
Divided	0.31	0.47	0.62	0.75	0.89	0.31	0.36
New	0.02	0.05	0.13	0.28	0.56	—	—
Yonelinas (2001, Expt. 2A)							
Full	0.69	0.77	0.83	0.89	0.94	0.56	0.51
Divided	0.51	0.63	0.71	0.80	0.89	0.39	0.42
New	0.04	0.08	0.15	0.25	0.46	—	—
Yonelinas (2001, Expt. 2B)							
Full	0.38	0.50	0.63	0.75	0.88	0.25	0.26
Divided	0.27	0.42	0.57	0.69	0.83	0.16	0.23
New	0.06	0.14	0.28	0.43	0.61	—	—
Yonelinas (2001, Expt. 2C)							
Full	0.49	0.60	0.70	0.80	0.91	0.34	0.27
Divided	0.33	0.45	0.58	0.71	0.87	0.17	0.23
New	0.09	0.16	0.27	0.45	0.38	—	—

4) STUDY DURATION

Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Yonelinas, Dobbins, et al. (1996, Expt. 2)						
1×	0.32	0.05	0.31	0.28	0.27	0.16
2×	0.46	0.05	0.29	0.28	0.41	0.24
Gardiner & Radomski (1999)						
1×	0.24	0.06	0.22	0.12	0.19	0.17
3×	0.46	0.06	0.27	0.09	0.41	0.40
Jacoby et al. (1999, Expt. 1)						
1×	0.40	—	0.35	—	0.40	0.58
3×	0.59	—	0.35	—	0.59	0.85

APPENDIX—*continued*

4) STUDY DURATION

Remember/Know	Remember Old	Remember New	Know Old	Know New	R	F
Jacoby et al. (1999, Expt. 2)						
1×	0.34	—	0.34	—	0.34	0.52
3×	0.61	—	0.29	—	0.61	0.74
Kinoshita (1997, Expt. 1)						
1×	0.51	0.05	0.19	0.09	0.46	0.30
2×	0.71	0.05	0.15	0.09	0.66	0.43
Dewhurst & Anderson (1999, Expt. 1)						
1 s	0.53	0.04	0.15	0.14	0.49	0.16
4 s	0.71	0.04	0.12	0.14	0.67	0.27
8 s	0.74	0.04	0.11	0.14	0.70	0.28
Hirshman & Henzler (1998)						
.5 S	0.16	0.08	0.34	0.24	0.08	0.14
2 S	0.31	0.08	0.38	0.24	0.23	0.28
Gardiner, Kaminski, et al. (1996, Expt. 1)						
1×	0.30	0.13	0.29	0.18	0.17	0.21
2×	0.29	0.04	0.38	0.16	0.25	0.37
4×	0.33	0.02	0.52	0.11	0.31	0.66
Gardiner, Kaminski et al. (1996, Expt. 2)						
1×	0.25	0.08	0.32	0.09	0.17	0.33
2×	0.27	0.03	0.46	0.13	0.24	0.50
4×	0.42	0.01	0.38	0.07	0.41	0.58
Gardiner, Kaminski et al. (1996, Expt. 2)						
1×	0.22	0.04	0.27	0.13	0.18	0.21
3×	0.41	0.05	0.33	0.13	0.36	0.41
Hirshman et al. (2002)						
.5 s	0.18	0.09	0.31	0.26	0.10	0.09
1.2 s	0.26	0.09	0.31	0.26	0.17	0.13
2.5 s	0.35	0.09	0.32	0.26	0.27	0.21

PDP	Inclusion Old	Inclusion New	Exclusion Old	Exclusion New	R	F
Jacoby (1999, Expt. 4)						
1×	0.59	0.17	0.33	0.16	0.25	0.28
3×	0.81	0.17	0.32	0.16	0.49	0.45
Yonelinas (1994, Expt. 3)						
1×	0.51	0.24	0.40	0.24	0.11	0.21
3×	0.64	0.24	0.42	0.24	0.22	0.30

ROC	Confidence >1	>2	>3	>4	>5	R	F
Yonelinas et al. (1996, Expt. 2)							
1×	0.87	0.75	0.61	0.47	0.34	0.28	0.19
2×	0.92	0.83	0.73	0.62	0.49	0.43	0.24
New	0.71	0.50	0.31	0.14	0.05	—	—

5) MASSED VERSUS DISTRIBUTED

Remember/Know	Remember Old	Remember New	Know Old	Know New	R	F
Parkin, Gardiner, & Rosser (1995)						
Massed	0.35	0.04	0.40	0.18	0.31	0.43
Distributed	0.54	0.04	0.34	0.18	0.50	0.55

APPENDIX—*continued*

5) MASSED VERSUS DISTRIBUTED	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Parkin & Russo (1993)						
Massed	0.51	0.06	0.26	0.17	0.45	0.35
Distributed	0.66	0.06	0.19	0.17	0.60	0.38
Dewhurst & Anderson (1999, Expt. 1)						
Massed	0.67	0.05	0.11	0.10	0.62	0.23
Distributed	0.65	0.03	0.14	0.17	0.62	0.22

PDP	Inclusion		Exclusion			
	Old	New	Old	New	R	F
Benjamin & Craik (2001, Expt. 1)						
Massed	0.56	0.10	0.37	0.10	0.20	0.35
Distributed	0.66	0.10	0.37	0.10	0.30	0.42
Benjamin & Craik (2001, Expt. 2)						
Massed	0.50	0.08	0.22	0.08	0.28	0.23
Distributed	0.62	0.08	0.20	0.08	0.42	0.26

6) BENZODIAZEPINES	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Mintzer & Griffiths (2000)						
Placebo	0.67	0.04	0.18	0.05	0.63	0.49
Triazolam (low)	0.48	0.09	0.22	0.09	0.39	0.32
Triazolam (high)	0.43	0.14	0.26	0.15	0.29	0.28
Curran, Gardiner, et al. (1993)						
Placebo	0.68	0.03	0.15	0.08	0.65	0.39
Lorazapam	0.44	0.03	0.26	0.08	0.41	0.38
Bishop & Curran (1995)						
Placebo	0.52	0.00	0.24	0.00	0.52	0.50
Lorazapam	0.34	0.01	0.33	0.01	0.34	0.49
Hirshman et al. (2001)						
Placebo	0.26	0.09	0.31	0.26	0.18	0.14
Midazolam	0.15	0.12	0.25	0.20	0.04	0.06

7) RESPONSE DEADLINE	Inclusion		Exclusion			
PDP	Old	New	Old	New	R	F
Yonelinas & Jacoby (1994, Expt. 3)						
Slow	0.75	0.15	0.36	0.15	0.39	0.44
Fast	0.68	0.15	0.38	0.15	0.30	0.39
Yonelinas & Jacoby (1995)						
Slow	0.76	0.30	0.42	0.30	0.35	0.34
Fast	0.67	0.33	0.53	0.33	0.14	0.29
Toth (1997, Expt. 3)						
Slow	0.76	0.21	0.25	0.27	0.57	0.34
Fast	0.70	0.22	0.37	0.24	0.35	0.34
Benjamin & Craik (2001, Expt. 1)						
Slow	0.68	0.05	0.32	0.05	0.37	0.45
Fast	0.54	0.15	0.42	0.15	0.13	0.32

APPENDIX—*continued*

8) DIVIDED ATTENTION AT TEST	Inclusion		Exclusion			
Remember/Know	Old	New	Old	New	R	F
Gruppuso et al. (1995, Expt. 3)						
Full	0.77	0.04	0.46	0.04	0.32	0.62
Divided	0.75	0.05	0.64	0.05	0.12	0.67
Dodson & Johnson (1996, Expt. 1)						
Full	0.61	0.23	0.27	0.25	0.36	0.18
Divided	0.63	0.31	0.39	0.25	0.18	0.20

9) PERCEPTUAL MATCHING—WORDS	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Rajaram (1993, Expt. 1)						
Same modality	0.49	0.02	0.25	0.14	0.47	0.35
Different modality	0.49	0.02	0.25	0.14	0.47	0.35
Gegg & Gardiner (1994, Expt. 1)						
Same modality	0.42	0.03	0.34	0.17	0.39	0.41
Different modality	0.50	0.03	0.26	0.17	0.47	0.35
Gegg & Gardiner (1994, Expt. 2: slow encoding condition)						
Same modality	0.66	0.06	0.17	0.08	0.60	0.41
Different modality	0.69	0.12	0.12	0.07	0.57	0.31
Gegg & Gardiner (1994, Expt. 2: perceptual fast encoding condition)						
Same modality	0.11	0.03	0.52	0.18	0.08	0.40
Different modality	0.10	0.05	0.27	0.09	0.05	0.21

10) PERCEPTUAL MATCHING—DRAWINGS	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Yonelinas & Jacoby (1995, Expt. 2)						
Same size	0.45	0.08	0.36	0.36	0.37	0.26
Different size	0.30	0.08	0.41	0.36	0.22	0.19
Yonelinas & Jacoby (1995, Expt. 3)						
Same size	0.37	0.03	0.41	0.36	0.34	0.28
Different size	0.27	0.03	0.40	0.36	0.24	0.18
Rajaram (1996, Expt. 2)						
Same size	0.49	0.03	0.28	0.08	0.46	0.47
Difference size	0.39	0.03	0.33	0.08	0.36	0.46
Rajaram (1996, Expt. 3)						
Same reflection	0.54	0.03	0.30	0.11	0.51	0.54
Different reflection	0.49	0.03	0.33	0.11	0.46	0.53

	Inclusion		Exclusion			
	Old	New	Old	New	R	F
PDP						
Yonelinas & Jacoby (1995, Expt. 1)						
Same size	0.68	0.42	0.42	0.42	0.26	0.15
Different size	0.55	0.42	0.45	0.42	0.10	0.08

APPENDIX—*continued*

11) THE PICTURE SUPERIORITY EFFECT	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Rajaram (1993, Expt. 2)						
Words	0.51	0.01	0.18	0.01	0.50	0.36
Pictures	0.81	0.08	0.09	0.08	0.73	0.39
Dewhurst & Conway (1994, Expt. 1)						
Words	0.31	0.02	0.28	0.02	0.29	0.39
Pictures	0.77	0.10	0.15	0.10	0.67	0.54
Wagner et al. (1997, Expt. 4)						
Words	0.26	0.03	0.27	0.14	0.23	0.22
Pictures	0.82	0.03	0.13	0.14	0.79	0.58
Rajaram (1996, Expt. 1)						
Words	0.43	0.02	0.24	0.12	0.41	0.30
Pictures	0.80	0.02	0.13	0.10	0.78	0.55
Dewhurst & Conway (1994, Expt. 1)						
Words	0.31	0.02	0.28	0.10	0.29	0.30
Pictures	0.77	0.02	0.15	0.10	0.75	0.55
Dewhurst & Conway (1994, Expt. 2)						
Words (visualize object)	0.76	0.01	0.17	0.07	0.75	0.64
Pictures	0.58	0.01	0.21	0.07	0.57	0.43
Dewhurst & Conway (1994, Expt. 3)						
Words (visualize object)	0.64	0.00	0.29	0.02	0.64	0.79
Pictures (write word)	0.79	0.00	0.14	0.02	0.79	0.65
Dewhurst & Conway (1994, Expt. 3)						
Words (visualize + write)	0.64	0.00	0.29	0.02	0.64	0.79
Pictures (visualize + write)	0.79	0.00	0.14	0.02	0.79	0.65

	Inclusion		Exclusion			
PDP	Old	New	Old	New	R	F
Wagner et al. (1997)						
Words	0.67	0.13	0.28	0.12	0.38	0.33
Pictures	0.93	0.13	0.22	0.12	0.70	0.61

12) INTERMEDIATE-TERM DELAYS (number of intervening items) PDP	Inclusion		Exclusion			
	Old	New	Old	New	R	F
Yonelinas & Levy (2001, Expt. 1)						
8	0.68	0.27	0.42	0.27	0.27	0.30
16	0.67	0.27	0.41	0.27	0.26	0.28
32	0.62	0.27	0.33	0.27	0.29	0.20
Yonelinas & Levy (2001, Expt. 2)						
8	0.69	0.22	0.46	0.22	0.22	0.38
16	0.59	0.22	0.42	0.22	0.17	0.28
32	0.55	0.22	0.33	0.22	0.22	0.20

13) LONG-TERM DELAYS (number of intervening hours) Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Hockley & Consoli (1999, Expt. 1)						
0.03	0.53	0.05	0.22	0.16	0.48	0.30
0.5	0.54	0.10	0.20	0.19	0.44	0.22
24	0.28	0.11	0.27	0.24	0.17	0.11

APPENDIX—*continued*

13) LONG-TERM DELAYS (number of intervening hours) Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Hockley & Consoli (1999, Expt. 2)						
0.03	0.53	0.06	0.21	0.13	0.47	0.31
48	0.22	0.11	0.30	0.24	0.11	0.11
168	0.21	0.13	0.30	0.28	0.08	0.06
Gardner & Java (1991, Expt. 1)						
0.166	0.49	0.00	0.26	0.05	0.49	0.46
1	0.42	0.01	0.24	0.06	0.41	0.35
24	0.27	0.03	0.27	0.06	0.24	0.31
168	0.25	0.05	0.23	0.08	0.20	0.22
Gardiner & Java (1991, Expt. 2)						
168	0.24	0.05	0.25	0.10	0.19	0.22
672	0.19	0.02	0.21	0.09	0.17	0.17
4032	0.15	0.02	0.17	0.09	0.13	0.11
Gardiner (1988, Expt. 2)						
1	0.52	0.04	0.15	0.03	0.48	0.27
168	0.32	0.10	0.19	0.14	0.22	0.12
Knowlton & Squire (1995, Expt. 1)						
0.166	0.46	0.02	0.21	0.04	0.44	0.35
168	0.24	0.11	0.25	0.16	0.14	0.14
Knowlton & Squire (1995, Expt. 2)						
0.166	0.47	0.01	0.14	0.02	0.46	0.24
168	0.23	0.04	0.18	0.07	0.19	0.16
Knowlton & Squire (1995, Expt. 3)						
0.166	0.34	0.03	0.19	0.04	0.31	0.24
168	0.18	0.02	0.20	0.07	0.16	0.17

14) FLUENCY MANIPULATIONS (because the manipulations influenced both old and new items the effects were averaged across old and new items) Remember/Know	Remember		Know			
	Old	New	Old	New	R (old + new)	F (old + new)
Rajaram & Geraci (2000)						
Control	0.43	0.03	0.24	0.07	0.23	0.25
Fluent	0.41	0.04	0.30	0.13	0.23	0.32
Rajaram (1993, Expt. 3)						
Control	0.42	0.05	0.18	0.13	0.24	0.22
Fluent	0.43	0.05	0.24	0.18	0.24	0.31
Kinoshita (1997, Expt. 1)						
Control	0.61	0.04	0.15	0.08	0.32	0.23
Fluent	0.61	0.07	0.20	0.10	0.34	0.31
LeCompte (1995, Expt. 2)						
Control	0.45	0.14	0.25	0.20	0.30	0.34
Fluent	0.39	0.16	0.31	0.28	0.28	0.42

	Inclusion		Exclusion			
	Old	New	Old	New	R (old + new)	F (old + new)
PDP						
LeCompte (1995, Expt. 1)						
Control	0.63	0.24	0.53	0.25	0.05	0.40
Fluent	0.66	0.32	0.55	0.33	0.05	0.45

APPENDIX—*continued*

15) FALSE RECOGNITION (Deese Paradigm)	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Roediger & McDermott (1995)						
Studied	0.49	0.02	0.23	0.09	0.47	0.36
Critical lure	0.48	0.03	0.29	0.13	0.45	0.41
Schacter, Verfaellie, et al. (1996)						
Studied	0.49	0.10	0.18	0.16	0.39	0.17
Critical lure	0.55	0.14	0.17	0.22	0.41	0.12
Schacter, Verfaellie, et al. (1997, Expt. 1)						
Studied	0.29	0.05	0.29	0.14	0.24	0.27
Critical lure	0.17	0.05	0.26	0.20	0.12	0.09
Schacter, Verfaellie, et al. (1997, Expt. 2)						
Studied	0.35	0.03	0.30	0.11	0.31	0.35
Critical lure	0.15	0.04	0.22	0.10	0.12	0.15
Israel & Schacter (1997, Expt. 1)						
Studied	0.60	0.08	0.14	0.05	0.52	0.30
Critical lure	0.19	0.06	0.14	0.10	0.13	0.06
Israel & Schacter (1997, Expt. 1)						
Studied	0.67	0.06	0.12	0.09	0.61	0.26
Critical lure	0.36	0.08	0.15	0.10	0.28	0.12
Mintzer & Griffiths (2000)						
Studied	0.53	0.09	0.22	0.10	0.44	0.36
Critical lure	0.45	0.10	0.26	0.11	0.35	0.35
Gallo et al. (2001, Expt. 2)						
Studied	0.43	0.05	0.16	0.10	0.38	0.17
Critical lure	0.36	0.07	0.20	0.12	0.29	0.19
Gallo et al. (2001, Expt. 3)						
Studied	0.35	0.05	0.20	0.09	0.30	0.20
Critical lure	0.25	0.06	0.24	0.14	0.19	0.17
Anastasi et al. (2000, Expt. 3)						
Studied	0.30	0.04	0.21	0.11	0.26	0.19
Critical lure	0.23	0.12	0.25	0.18	0.11	0.12
Miller & Gazzaniga (1998)						
Studied	0.42	0.02	0.25	0.09	0.41	0.33
Critical lure	0.24	0.02	0.27	0.09	0.23	0.26
Norman & Schacter (1997)						
Studied	0.54	0.01	0.26	0.07	0.53	0.48
Critical lure	0.36	0.01	0.36	0.07	0.35	0.48

16) SHIFTING RESPONSE CRITERION	Remember		Know			
(Recollection and familiarity are estimated for old items only; false alarms are not incorporated into the parameter estimates) Remember/Know	Old	New	Old	New	R (Old)	F (Old)
Postma (1999)						
Liberal instructions	0.52	0.03	0.31	0.14	0.52	0.65
Strict instructions	0.38	0.02	0.30	0.03	0.38	0.48
Strack & Forster (1995, Expt. 1)						
50% old instruction	0.37	0.02	0.33	0.23	0.37	0.52
30% old instruction	0.30	0.03	0.26	0.10	0.30	0.38
Strack & Forster (1995, Expt. 2)						
Liberal instructions	0.26	0.05	0.42	0.23	0.26	0.56
Strict instructions	0.25	0.00	0.11	0.02	0.25	0.14
Hirshman & Henzer (1998)						
70% instructions	0.28	0.11	0.43	0.35	0.28	0.59
30% instructions	0.19	0.05	0.29	0.13	0.19	0.36

APPENDIX—*continued*

16) SHIFTING RESPONSE CRITERION **(Recollection and familiarity are estimated for old items only; false alarms are not incorporated into the parameter estimates)** **Remember/Know**	Remember		Know			
	Old	New	Old	New	R (Old)	F (Old)
Yonelinas (2001, Expt. 1)						
Confidence >1	0.37	0.02	0.54	0.55	0.37	0.85
Confidence >2	0.37	0.02	0.43	0.27	0.37	0.68
Confidence >3	0.37	0.01	0.32	0.12	0.37	0.51
Confidence >4	0.36	0.01	0.19	0.04	0.36	0.30
Confidence >5	0.35	0.01	0.05	0.01	0.35	0.08
Yonelinas, Dobbins, et al. (1997)						
Confidence >1	0.39	—	0.51	—	0.39	0.83
Confidence >2	0.39	—	0.40	—	0.39	0.66
Confidence >3	0.39	—	0.28	—	0.39	0.46
Confidence >4	0.39	—	0.16	—	0.39	0.25
Confidence >5	0.37	—	0.05	—	0.37	0.07
Gardiner, Richardson-Klavehn, et al. (1997)						
50% instructions	0.36	0.03	0.23	0.09	0.36	0.35
30% instructions	0.32	0.03	0.22	0.12	0.32	0.31

PDP	Inclusion		Exclusion			
	Old	New	Old	New	R (Old)	F (Old)
Dodson & Johnson (1997)						
66% heard	0.63	0.25	0.35	0.22	0.26	0.46
33% heard	0.61	0.25	0.32	0.27	0.32	0.47
Yonelinas (1994, Expt. 1)						
Confidence >1	0.96	0.66	0.61	0.66	0.36	0.94
Confidence >2	0.86	0.32	0.39	0.32	0.46	0.73
Confidence >3	0.74	0.12	0.26	0.12	0.48	0.50
Confidence >4	0.60	0.04	0.13	0.04	0.47	0.24
Confidence >5	0.42	0.01	0.04	0.01	0.38	0.06
Yonelinas (1994, Expt. 2)						
Confidence >1	0.96	0.65	0.61	0.65	0.35	0.94
Confidence >2	0.83	0.20	0.37	0.20	0.47	0.69
Confidence >3	0.74	0.08	0.24	0.08	0.50	0.47
Confidence >4	0.61	0.03	0.12	0.03	0.49	0.24
Confidence >5	0.41	0.00	0.04	0.00	0.37	0.06
Yonelinas (1994, Expt. 3)						
Confidence >1	0.84	0.62	0.71	0.62	0.13	0.82
Confidence >2	0.70	0.40	0.55	0.40	0.15	0.64
Confidence >3	0.57	0.24	0.41	0.24	0.16	0.49
Confidence >4	0.45	0.13	0.29	0.13	0.16	0.35
Confidence >5	0.28	0.05	0.14	0.05	0.14	0.16

17) WORD FREQUENCY	Remember		Know			
Remember/Know	Old	New	Old	New	R	F
Gardiner & Java (1990, Expt. 1)						
High	0.31	0.05	0.16	0.09	0.26	0.14
Low	0.43	0.04	0.17	0.07	0.39	0.23
Kinoshita (1995, Expt. 1)						
High	0.17	0.01	0.10	0.08	0.16	0.03
Low	0.31	0.01	0.11	0.08	0.30	0.08

APPENDIX—*continued*

17) WORD FREQUENCY

Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Kinoshita (1995, Expt. 3)						
High	0.17	0.06	0.32	0.22	0.11	0.15
Low	0.28	0.05	0.27	0.14	0.23	0.23
Strack & Forester (1995, Expt. 1)						
High	0.25	0.02	0.30	0.16	0.23	0.24
Low	0.42	0.03	0.29	0.17	0.39	0.33
Guttentag & Carroll (1997, Expt. 1)						
High	0.35	0.04	0.27	0.19	0.31	0.22
Low	0.50	0.04	0.23	0.13	0.46	0.32
Gardiner, Richardson-Klavehn, et al. (1997)						
High	0.28	0.03	0.22	0.10	0.26	0.20
Low	0.39	0.03	0.22	0.11	0.37	0.26
Bowler et al. (1998)						
High	0.41	0.19	0.12	0.02	0.22	0.18
Low	0.52	0.05	0.11	0.04	0.47	0.19
Joordens & Hockley (2000, Expt. 1A)						
High	0.48	0.06	0.25	0.14	0.42	0.34
Low	0.58	0.04	0.22	0.09	0.54	0.41
Joordens & Hockley (2000, Expt. 1B)						
High	0.44	0.07	0.22	0.11	0.37	0.26
Low	0.53	0.06	0.19	0.08	0.48	0.31
Reder et al. (2000, Expt. 1)						
High	0.70	0.02	0.22	0.12	0.68	0.61
Low	0.80	0.01	0.16	0.04	0.79	0.76
Reder et al. (2000, Expt. 2)						
High	0.80	0.02	0.16	0.11	0.78	0.69
Low	0.90	0.01	0.08	0.04	0.89	0.76
Reder et al. (2000, Expt. 3)						
High	0.15	0.03	0.33	0.24	0.12	0.14
Low	0.35	0.01	0.31	0.15	0.34	0.33
Hirshman et al. (2001)						
High	0.18	0.09	0.36	0.33	0.09	0.08
Low	0.34	0.08	0.26	0.19	0.26	0.19

PDP	Inclusion		Exclusion			
	Old	New	Old	New	R	F
Komatsu et al. (1994)						
High	0.83	0.38	0.41	0.29	0.33	0.27
Low	0.81	0.15	0.21	0.16	0.62	0.38
Guttentag & Carroll (1997, Expt. 1)						
High	0.62	0.23	0.30	0.23	0.32	0.21
Low	0.73	0.17	0.25	0.17	0.48	0.31

ROC	Confidence						
	>1	>2	>3	>4	>5	R	F
Arndt & Reder (2002, Expt. 1)							
High (Old)	0.92	0.76	0.59	0.44	0.29	0.24	0.21
Low (Old)	0.91	0.77	0.68	0.57	0.43	0.40	0.34
High (New)	0.83	0.51	0.27	0.12	0.04	—	—
Low (New)	0.62	0.28	0.14	0.07	0.03	—	—

APPENDIX—*continued*

17) WORD FREQUENCY

ROC	Confidence >1	>2	>3	>4	>5	R	F
Arndt & Reder (2002, Expt. 2)							
High (Old)	0.91	0.76	0.59	0.45	0.31	0.25	0.15
Low (Old)	0.88	0.75	0.64	0.55	0.45	0.42	0.21
High (New)	0.82	0.57	0.36	0.19	0.05	—	—
Low (New)	0.67	0.37	0.20	0.11	0.03	—	—

18) AMNESIA

Remember/Know	Remember Old	Remember New	Know Old	Know New	R	F
Knowlton & Squire (1995)						
Controls	0.46	0.02	0.21	0.04	0.44	0.35
Amnesics	0.17	0.09	0.16	0.10	0.08	0.08
Schacter, Verfaellie, et al. (1996)						
Controls	0.71	0.06	0.13	0.12	0.65	0.32
Amnesics	0.28	0.14	0.23	0.20	0.14	0.08
Schacter, Verfaellie, et al. (1997)						
Controls	0.49	0.00	0.30	0.10	0.49	0.49
Amnesics	0.20	0.07	0.30	0.12	0.14	0.25
Blaxton & Theodore (1997, Expt. 1)						
Controls	0.29	0.15	0.45	0.17	0.14	0.43
Amnesics	0.25	0.12	0.41	0.29	0.14	0.22
Blaxton & Theodore (1997, Expt. 2)						
Controls	0.35	0.10	0.27	0.11	0.25	0.28
Amnesics	0.26	0.13	0.32	0.13	0.13	0.29

PDP	Inclusion Old	Inclusion New	Exclusion Old	Exclusion New	R	F
Verfaellie & Treadwell (1993)						
Controls	0.56	0.17	0.34	0.19	0.25	0.26
Amnesics	0.47	0.32	0.41	0.27	0.01	0.12

ROC	Confidence >1	>2	>3	>4	>5	R	F
Yonelinas et al. (1997)							
Controls (Old)	0.89	0.81	0.65	0.53	0.40	0.36	0.30
Amnesics (Old)	0.98	0.91	0.80	0.62	0.38	0.07	0.21
Controls (New)	0.66	0.44	0.16	0.09	0.03	—	—
Amnesics (New)	0.93	0.79	0.61	0.41	0.18	—	—

19) AGING (studies in which estimates of recollection were below .60)

Remember/Know	Remember Old	Remember New	Know Old	Know New	R	F
Parkin & Walker (1992, Expt. 1)						
Young	0.52	0.01	0.25	0.04	0.51	0.48
Old	0.20	0.01	0.46	0.09	0.19	0.48

APPENDIX—*continued*

19) AGING (studies in which estimates of recollection were below .60) Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Parkin & Walker (1992, Expt. 2)						
Young	0.37	0.02	0.43	0.05	0.35	0.63
Old	0.12	0.02	0.55	0.07	0.10	0.55
Perfect et al. (1995, Expt. 1)						
Young	0.53	0.05	0.23	0.05	0.48	0.44
Old	0.18	0.07	0.53	0.03	0.11	0.61
Java (1996)						
Young	0.16	0.00	0.08	0.01	0.16	0.09
Old	0.10	0.00	0.08	0.01	0.10	0.08
Norman & Schacter (1997, Expt. 1)						
Young	0.54	0.01	0.26	0.07	0.53	0.48
Old	0.53	0.08	0.22	0.08	0.46	0.37
Friedman & Trott (2000)						
Young	0.50	0.02	0.22	0.06	0.48	0.38
Old	0.43	0.07	0.23	0.06	0.36	0.34

PDP	Inclusion		Exclusion			
	Old	New	Old	New	R	F
Jennings & Jacoby (1993, Expt. 2)						
Young	0.79	—	0.37	—	0.42	0.63
Old	0.70	—	0.45	—	0.25	0.60
Jacoby (1999, Expt. 4)						
Young	0.77	0.15	0.25	0.18	0.56	0.39
Old	0.66	0.17	0.39	0.16	0.26	0.36
Raybash & Hoyer (1996)						
Young	0.72	0.19	0.33	0.18	0.38	0.35
Old	0.66	0.20	0.41	0.20	0.25	0.35
Caldwell & Masson (2001, Expt. 1)						
Young	0.63	0.27	0.18	0.26	0.44	0.06
Old	0.48	0.26	0.29	0.28	0.21	0.10
Benjamin & Craik (2001, Expt. 2)						
Young	0.56	0.07	0.21	0.07	0.35	0.25
Old	0.54	0.14	0.44	0.14	0.10	0.35

20) AGING (studies in which estimates of recollection exceeded .60) Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Perfect et al. (1995, Expt. 2b)						
Young	0.88	0.01	0.10	0.02	0.87	0.81
Old	0.25	0.03	0.39	0.08	0.22	0.44
Schacter et al. (1997, Expt. 1)						
Young	0.80	0.02	0.07	0.09	0.78	0.26
Old	0.69	0.04	0.08	0.11	0.65	0.15
Schacter et al. (1997, Expt. 2: scores are collapsed across conditions in which recollection ≥.69)						
Young	0.62	0.04	0.22	0.17	0.58	0.41
Old	0.43	0.19	0.16	0.15	0.24	0.10
Perfect & Dasgupta (1997)						
Young	0.74	0.02	0.17	0.06	0.72	0.59
Old	0.48	0.08	0.23	0.10	0.40	0.33

APPENDIX—*continued*

20) AGING (studies in which estimates of recollection exceeded .60) Remember/Know	Remember		Know			
	Old	New	Old	New	R	F
Perfect et al. (1995, Expt. 2A: scores are collapsed across conditions in which recollection ≥.67)						
Young	0.54	0.01	0.33	0.03	0.54	0.68
Old	0.52	0.03	0.14	0.03	0.49	0.26
Mark & Rugg (1998)						
Young	0.64	—	0.19	—	0.64	0.53
Old	0.64	—	0.21	—	0.64	0.58

	Inclusion		Exclusion			
	Old	New	Old	New	R	F
PDP						
Jennings & Jacoby (1997)						
Young	0.95	0.09	0.09	0.10	0.87	0.60
Old	0.90	0.17	0.29	0.15	0.59	0.54

REFERENCES

Aggleton, J. P., & Brown, M. W. (1999). Episodic memory, amnesia, and the hippocampal-anterior thalamic axis. *Behavioral and Brain Sciences*, **22**(3), 425–444.

Aggleton, J. P., McMackin, D., Carpenter, K., Hornak, J., Kapur, N., Halpin, S., Wiles, C. M., Kamel, H., Brennan, P., Carton, S., & Gaffan, D. (2000). Differential cognitive effects of colloid cysts in the third ventricle that spare or compromise the fornix. *Brain*, **123**(1), 800–815.

Aggleton, J. P., & Shaw, C. (1996). Amnesia and recognition memory: A re-analysis of psychometric data. *Neuropsychologia*, **34**(1), 51–62.

Anastasi, J. S., Rhodes, M. G., & Burns, M. C. (2000). Distinguishing between memory illusions and actual memories using phenomenological measurements and explicit warnings. *American Journal of Psychology*, **113**(1), 1–26.

Anderson, N. D., Craik, F. I., & Naveh-Benjamin, M. (1998). The attentional demands of encoding and retrieval in younger and older adults. 1. Evidence from divided attention costs. *Psychology and Aging*, **13**(3), 405–423.

Arndt, J., & Reder, L.M. (2002). Word frequency and receiver-operating characteristic curves in recognition memory: Evidence for a dual-process interpretation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, in press.

Asthana, B., & Nagrani, S. (1984). Recall and recognition as a function of levels of processing. *Psycho-Lingua*, **14**(2), 85–94.

Atkinson, R. C., Hertmann, D. J., & Wescourt, K. T. (1974). Search processes in recognition memory. In R. L. Solso (Ed.), *Theories in cognitive psychology: The Loyola symposium* (pp. 101–146). Potomac, MD: Erlbaum.

Atkinson, R. C., & Juola, J. F. (1973). Factors influencing speed and accuracy of word recognition. In S. Kornblum (Ed.), *Fourth international symposium on attention and performance* (pp. 583–611). New York: Academic Press.

Atkinson, R. C., & Juola, J. F. (1974). Search and decision processes in recognition memory. In D. H. Krantz, R. C. Atkinson, R. D. Luce, & P. Suppes (Eds.), *Contemporary developments in mathematical psychology: Vol. 1. Learning, memory & thinking*. San Francisco: Freeman.

Baddeley, A., Vargha-Khadem, F., & Mishkin, M. (2001). Preserved recognition in a case of developmental amnesia: Implications for the acquisition of semantic memory? *Journal of Cognitive Neuroscience*, **13**(3), 357–369.

Balota, D. A., Burgess, G. C., Cortese, M. J., & Adams, D. A. (2002). The word-frequency mirror effect in young, old, and early-stage Alzheimer's disease: Evidence for two processes in episodic recognition memory. *Journal of Memory and Language*, **46**(1), 199–226.

Banks, W. P. (1970). Signal Detection Theory and human memory. *Psychological Bulletin*, **74**(2), 81–99.

Banks, W. P. (2000). Recognition and source memory as multivariate decision processes. *Psychological Science*, **11**(4), 267–273.

Banks, W. P., Chen, Y.-P., & Prull, M. W. (1999). Memory and awareness: Is memory information stratified into conscious and unconscious components? In E. Bradford, H. Challis, E. Boris, & M. Velichkovsky (Eds.), *Stratification in cognition and consciousness* (pp. 129–172). Amsterdam:

Benjamin, A. S., & Craik, F. I. M. (2001). Parallel effects of aging and time pressure on memory for source: Evidence from the spacing effect. *Memory & Cognition*, **29**(5), 691–697.

Bentin, S., Moscovitch, M., & Nirhod, O. (1998). Levels of processing and selective attention effects on encoding in memory. *Acta Psychologica*, **98**(2–3), 311–341.

Bishop, K. I., & Curran, H. V. (1995). Psychopharmacological analysis of implicit and explicit memory: A study with lorazepam and the benzodiazepine antagonist flumazenil. *Psychopharmacology*, **121**(2), 267–278.

Bishop, K. I., & Curran, H. V. (1998). An investigation of the effects of benzodiazepine receptor ligands and of scopolamine on conceptual priming. *Psychopharmacology*, **140**(3), 345–353.

Blaxton, T. A. (1992). Dissociations among memory measures in memory-impaired subjects: Evidence for a processing account of memory. *Memory & Cognition*, **20**(5), 549–562.

Blaxton, T. A., & Theodore, W. H. (1997). The role of the temporal lobes in recognizing visuospatial materials: Remembering versus knowing. *Brain and Cognition*, **35**(1), 5–25.

Bornstein, B. H., & LeCompte, D. C. (1995). A comparison of item and source forgetting. *Psychonomic Bulletin & Review*, **2**(2), 254–259.

Brewer, J. B., Zhao, Z., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. E. (1998). Making memories: Brain activity that predicts how well visual experience will be remembered. *Science*, **281**(5380), 1185–1187.

Buchner, A., Erdfelder, E., & Vaterrodt-Pluennecke, B. (1995). Toward unbiased measurement of conscious and unconscious memory processes within the process dissociation framework. *Journal of Experimental Psychology: General*, **124**(2), 137–160.

Buckner, R. L., Logan, J., Donaldson, D. I., & Wheeler, M. E. (2000). Cognitive neuroscience of episodic memory encoding. *Acta Psychologica*, **105**(2–3), 127–139.

Buckner, R. L., Corbetta, M., Schatz, J., Raichle, M. E., & Peterson, S. F. (1993). Preserved speech abilities and compensation following prefrontal damage. *Proceedings of the National Academy of Science of the USA*, **93,** 1249–1253.

Cabeza, R., Anderson, N. D., Houle, S., Mangels, J. A., & Nyberg, L. (2000). Age-related differences in neural activity during item and temporal-order memory retrieval: A positron emission tomography study. *Journal of Cognitive Neuroscience*, **12**(1), 197–206.

Cabeza, R., Grady, C. L., Nyberg, L., & McIntosh, A. R. (1997). Age-related differences in neural activity during memory encoding and retrieval: A positron emission tomography study. *Journal of Neuroscience*, **17**(1), 391–400.

Cabeza, R., McIntosh, A. R., Tulving, E., Nyberg, L., & Grady, C. L. (1997). Age-related differences in effective neural connectivity during encoding and recall. *NeuroReport*, **8**(16), 3479–3483.

Cabeza, R., & Nyberg, L. (2000). Imaging cognition. II. An empirical review of 275 PET and fMRI studies. *Journal of Cognitive Neuroscience*, **12**(1), 1–47.

Caldwell, J. I., & Masson, M. E. J. (2001). Conscious and unconscious influences of memory for object location. *Memory & Cognition*, **29**(2), 285–295.

Cameron, T. E., & Hockley, W. E. (2000). The revelation effect for item and associative recognition: Familiarity versus recollection. *Memory & Cognition*, **28**(2), 176–183.

Carlesimo, G. A. (1994). Perceptual and conceptual priming in amnesic and alcoholic patients. *Neuropsychologia*, **32**(8), 903–921.

Cave, C., & Squire, L.R. (1991). Equivalent impairment of spatial and nonspatial memory following damage to the human hippocampus, *Hippocampus*, **1,** 329–340.

Cermak, L. S., Verfaellie, M., Lanzoni, S., Mather, M., & Chase, K. A. (1996). Effect of spaced repetitions on amnesia patients' recall and recognition performance. *Neuropsychology*, **10**(2), 219–227.

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

Chalfonte, B. L., Verfaellie, M., Johnson, M. K., & Reiss, L. (1996). Spatial location memory in amnesia: Binding item and location information under incidental and intentional encoding conditions. *Memory*, **4**(6), 591–614.

Challis, B. H., & Sidhu, R. (1993). Dissociative effect of massed repetition on implicit and explicit measures of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **19**(1), 115–127.

Clark, S. E. (1992). Word frequency effects in associative and item recognition. *Memory & Cognition*, **20**(3), 231–243.

Clark, S. E. (1995). The generation effect and the modeling of associations in memory. *Memory & Cognition*, **23**(4), 442–455.

Clark, S. E. (1999). Recalling to recognize and recognizing recall. In E. Chizuko Izawa (Ed.), *On human memory: Evolution, progress, and reflections on the 30th anniversary of the Atkinson–Shiffrin model* (pp. 215–243). Mahwah, NJ: Erlbaum.

Clark, S. E., & Burchett, R. E. R. (1994). Word frequency and list composition effects in associative recognition and recall. *Memory & Cognition*, **22**(1), 55–62.

Clark, S. E., & Gronlund, S. D. (1996). Global matching models of recognition memory: How the models match the data. *Psychonomic Bulletin & Review*, **3**(1), 37–60.

Craik, F. I. M., & Jennings, J. M. (1992). Human memory. In E. Fergus, I. M., Craik, E. Timothy, & A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 51–110). Hillsdale, NJ: Erlbaum.

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The effects of divided attention on encoding and retrieval processes in human memory. *Journal of Experimental Psychology: General*, **125**(2), 159–180.

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, **11**(6), 671–684.

Craik, F. I., & McDowd, J. M. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **13**(3), 474–479.

Curran, H. V., Gardiner, J. M., Java, R. I., & Allen, D. (1993). Effects of lorazepam upon recollective experience in recognition memory. *Psychopharmacology*, **110**(3), 374–378.

Curran, H. V., & Hildebrandt, M. (1999). Dissociative effects of alcohol on recollective experience. *Consciousness and Cognition*, **8**(4), 497–509.

Curran, T. (2000). Brain potentials of recollection and familiarity. *Memory & Cognition*, **28**(6), 923–938.

Curran, T., & Hintzman, D. L. (1995). Violations of the independence assumption in process dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **21**(3), 531–547.

Curran, T., & Hintzman, D. L. (1997). Consequences and causes of correlations in process dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(2), 496–504.

Curran, T., Schacter, D. L., Norman, K. A., & Galluccio, L. (1997). False recognition after a right frontal lobe infarction: memory for general and specific information. *Neuropsychologia*, **35**(7), 1035–1049.

Dehn, D. M., & Engelkamp, J. (1997). Process dissociation procedure: Double dissociations following divided attention and speeded responding. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, **50**(2), 318–336.

Dewhurst, S. A., & Anderson, S. J. (1999). Effects of exact and category repetition in true and false recognition memory. *Memory & Cognition*, **27**(4), 664–673.

Dewhurst, S. A., & Conway, M. A. (1994). Pictures, images, and recollective experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**(5), 1088–1098.

Dobbins, I.G. (2001). The systematic discrepancy between Á for overall recognition and remembering: A dual-process account. *Psychonomic Bulletin & Review*, **8**(3), 587–599.

Dobbins, I. G., Khoe, W., Yonelinas, A. P., & Kroll, N. E. A. (2000). Predicting individual false alarm rates and signal detection theory: A role for remembering. *Memory & Cognition*, **28**(8), 1347–1356.

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

Donaldson, W., MacKenzie, T. M., & Underhill, C. F. (1996). A comparison of recollective memory and source monitoring. *Psychonomic Bulletin & Review*, **3**(4), 486–490.

Donaldson, D. I., & Rugg, M. D. (1998). Recognition memory for new associations: Electrophysiological evidence for the role of recollection. *Neuropsychologia*, **36**(5), 377–395.

Donaldson, W. (1996). The role of decision processes in remembering and knowing. *Memory & Cognition*, **24**(4), 523–533.

Dosher, B. A. (1984). Discriminating preexperimental (semantic) from learned (episodic) associations: A speed/accuracy study. *Cognitive Psychology*, **16**(4), 519–555.

Duchek, J. M., & Heely, J. H. (1989). A dissociative word-frequency × levels-of-processing interaction in episodic recognition and lexical decision tasks. *Memory & Cognition*, **17**(2), 148–162.

Düzel, E., Vargha-Khadem, F., Heinze, H. J., & Mishkin, M. (2001). Brain activity evidence for recognition without recollection after early hippocampal damage. *Proceedings of the National Academy of Sciences of the USA*, **98**(14), 8101–8106.

Düzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H. J., & Tulving, E. (1997). Event-related brain potential correlates of two states of conscious awareness in memory. *Proceedings of the National Academy of Sciences of the USA*, **94**(11), 5973–5978.

Eichenbaum, H., Otto, T., & Cohen, N. J. (1994). Two functional components of the hippocampal memory system. *Behavioral & Brain Sciences*, **17**(3), 449–517.

Eldridge, L. L., Knowlton, B. J., Furmanski, C. S., Bookheimer, S. Y., & Engel, S. A. (2000). Remembering episodes: A selective role for the hippocampus during retrieval. *Nature Neuroscience*, **3**(11), 1149–1152.

Fabiani, M., & Friedman, D. (1997). Dissociations between memory for temporal order and recognition memory in aging. *Neuropsychologia*, **35**(2), 129–141.

Fletcher, P. C., Shallice, T., & Dolan, R. J. (1998). The functional roles of prefrontal cortex in episodic memory. I. Encoding. *Brain*, **121**(7), 1239–1248.

Friedman, D., & Trott, C. (2000). An event-related potential study of encoding in young and older adults. *Neuropsychologia*, **38**(5), 542–557.

Friedman, D., Ritter, W., & Snodgrass, J. G. (1996). ERPs during study as a function of subsequent direct and indirect memory testing in young and old adults. *Cognitive Brain Research*, **4**(1), 1–13.

Gabrieli, J. D. E. (1998). Cognitive neuroscience of human memory. *Annual Review of Psychology*, **49,** 87–115.

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Memory & Cognition*, **16**(4), 309–313.

Gardiner, J. M., & Gregg, V. H. (1997). Recognition memory with little or no remembering: Implications for a detection model. *Psychonomic Bulletin & Review*, **4**(4), 474–479.

Gardiner, J. M., & Java, R. I. (1990). Recollective experience in word and nonword recognition. *Memory & Cognition*, **18**(1), 23–30.

Gardiner, J. M., & Java, R. I. (1991). Forgetting in recognition memory with and without recollective experience. *Memory & Cognition*, **19**(6), 617–623.

Gardiner, J. M., Java, R. I., & Richardson-Klavehn, A. (1996). How level of processing really influences awareness in recognition memory. *Canadian Journal of Experimental Psychology*, **50**(1), 114–122.

Gardiner, J. M., Kaminska, Z., Dixon, M., & Java, R. I. (1996). Repetition of previously novel melodies sometimes increases both remember and know responses in recognition memory. *Psychonomic Bulletin & Review*, **3**(3), 366–371.

Gardiner, J. M., & Parkin, A. J. (1990). Attention and recollective experience in recognition memory. *Memory & Cognition*, **18**(6), 579–583.

Gardiner, J. M., & Radomski, E. (1999). Awareness of recognition memory for Polish and English folk songs in Polish and English folk. *Memory*, **7**(4), 461–470.

Gardiner, J. M., & Richardson-Klavehn, A. (2000). Remembering and knowing. In E. E. Tulving, E. Fergus, & I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 229–244). New York: Oxford Univ. Press.

Gardiner, J. M., Ramponi, C., & Richardson-Klavehn, A. (1999). Response deadline and subjective awareness in recognition memory. *Consciousness and Cognition*, **8**(4), 484–496.

Gardiner, J. M., Richardson-Klavehn, A., & Ramponi, C. (1997). On reporting recollective experiences and "direct access to memory systems." *Psychological Science*, **8**(5), 391–394.

Gardner, H., Boller, F., Moreines, J., & Butters, N. (1973). Retrieving information from Korsakoff patients: Effects of categorical cues and reference to the task. *Cortex*, **9**(2), 165–175.

Gershberg, F. B. (1997). Implicit and explicit conceptual memory following frontal lobe damage. *Journal of Cognitive Neuroscience*, **9**(1), 105–116.

Gershberg, F. B., & Shimamura, A. P. (1995). Impaired use of organizational strategies in free recall following frontal lobe damage. *Neuropsychologia*, **33**(10), 1305–1333.

Gillund, G., & Shiffrin, R. M. (1984). A retrieval model for both recognition and recall. *Psychological Review*, **91**(1), 1–67.

Giovanello, K., & Verfaellie, M. (2001). The relationship between recall and recognition in amnesia: Effects of matching recognition between patients with amnesia and controls. *Neuropsychology*, **15**(4), 444–451.

Glanzer, M., & Adams, J. K. (1985). The mirror effect in recognition memory. *Memory and Cognition*, **13**(1), 8–20.

Glanzer, M., Kim, K., Hilford, A., & Adams, J. K. (1999). Slope of the receiver-operating characteristic in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(2), 500–513.

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

Grady, C. L., McIntosh, A. R., Horwitz, B., & Maisog, J. M. (1995). Age-related reductions in human recognition memory due to impaired encoding. *Science*, **269**(5221), 218–221.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior*, **23**(5), 553–568.

Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11**(2), 386–396.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **10**(1), 164–178.

Greenblatt, D. J., Shader, R. I., & Abernethy, D. R. (1983). Drug therapy. I. Current status of benzodiazepines. *New England Journal of Medicine*, **309**(6), 354–358.

Gregg, V. H., & Gardiner, J. M. (1994). Recognition memory and awareness: A large effect of study-test modalities on "know" responses following a highly perceptual orienting task. *European Journal of Cognitive Psychology*, **6**(2), 131–147.

Gregg, V. H., Montgomery, D. C., & Castano, D. (1980). Recall of common and uncommon words from pure and mixed lists. *Journal of Verbal Learning and Verbal Behavior*, **19**(2), 240–245.

Gronlund, S. D., & Ratcliff, R. (1989). Time course of item and associative information: Implications for global memory models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **15**(5), 846–858.

Gronlund, S. D., Edwards, M. B., & Ohrt, D. D. (1997). Comparison of the retrieval of item versus spatial position information. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(5), 1261–1274.

Gruppuso, V., Lindsay, D. S., & Kelley, C. M. (1997). The process-dissociation procedure and similarity: Defining and estimating recollection and familiarity in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(2), 259–278.

Guttentag, R. E., & Carroll, D. (1994). Identifying the basis for the word frequency effect in recognition memory. *Memory*, **2**(3), 255–273.

Guttentag, R. E., & Carroll, D. (1997). Recollection-based recognition: Word frequency effects. *Journal of Memory and Language*, **37**(4), 502–516.

Haist, F., Shimamura, A. P., & Squire, L. R. (1992). On the relationship between recall and recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **18**(4), 691–702.

Hamann, S. B. (1990). Level-of-processing effects in conceptually driven implicit tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **16**(6), 970–977.

Hamann, S. B., & Squire, L. R. (1997). Intact perceptual memory in the absence of conscious memory. *Behavioral Neuroscience*, **111**(4), 850–854.

Hanley, J. R., Davies, A. D. M., Downes, J. J., & Mayes, A. R. (1994). Impaired recall of verbal material following rupture and repair of an anterior communicating artery aneurysm. *Cognitive Neuropsychology*, **11**(5), 543–578.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General*, **108**(3), 356–388.

Hashtroudi, S., Parker, E. S., Luis, J. D., & Reisen, C. A. (1989). Generation and elaboration in older adults. *Experimental Aging Research*, **15**(1–2), 73–78.

Haug, H., & Eggers, R. (1991). Morphometry of the human cortex cerebri and corpus striatum during aging. *Neurobiology of Aging*, **12**(4), 336–338.

Henke, K., Buck, A., Weber, B., & Wieser, H. G. (1997). Human hippocampus establishes associations in memory. *Hippocampus*, **7**(3), 249–256.

Henson, R. N. A., Rugg, M. D., Shallice, T., & Dolan, R. J. (2000). Confidence in recognition memory for words: Dissociating right prefrontal roles in episodic retrieval. *Journal of Cognitive Neuroscience*, **12**(6), 913–923.

Henson, R. N. A., Rugg, M. D., Shallice, T., Josephs, O., & Dolan, R. J. (1999). Recollection and familiarity in recognition memory: An event-related functional magnetic resonance imaging study. *Journal of Neuroscience*, **19**(10), 3962–3972.

Hintzman, D. L., & Caulton, D. A. (1997). Recognition memory and modality judgments: A comparison of retrieval dynamics. *Journal of Memory and Language*, **37**(1), 1–23.

Hintzman, D. L., Caulton, D. A., & Levitin, D. J. (1998). Retrieval dynamics in recognition and list discrimination: Further evidence of separate processes of familiarity and recall. *Memory and Cognition*, **26**(3), 449–462.

Hintzman, D. L., & Curran, T. (1994). Retrieval dynamics of recognition and frequency judgments: Evidence for separate processes of familiarity and recall. *Journal of Memory and Language*, **33**(1), 1–18.

Hirshman, E. (1998). On the utility of the signal detection model of the remember–know paradigm. *Consciousness and Cognition*, **7**(1), 103–107.

Hirshman, E., Fisher, J., Henthorn, T., Arndt, J., & Passannante, A. (2002). Midazolam amnesia and dual-process models of the word-frequency mirror effect. *Jounal of Memory and Language*, in press.

Hirshman, E., & Henzler, A. (1998). The role of decision processes in conscious recollection. *Psychological Science*, **9**(1), 61–65.

Hirshman, E., & Master, S. (1997). Modeling the conscious correlates of recognition memory: Reflections on the remember-know paradigm. *Memory and Cognition*, **25**(3), 345–351.

Hirst, W., Johnson, M. K., Phelps, E. A., & Volpe, B. T. (1988). More on recognition and recall in amnesics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **14**(4), 758–762.

Hirst, W., Phelps, E. A., Johnson, M. K., & Volpe, B. T. (1988). Amnesia and second language learning. *Brain and Cognition*, **8**(1), 105–116.

Hirst, W., & Volpe, B. T. (1984). Encoding of spatial relations with amnesia. *Neuropsychologia*, **22**(5), 631–634.

Hockley, W. E. (1991). Recognition memory for item and associative information: A comparison of forgetting rates. In E. William, E. Hockley, & E. S. Lewandowsky (Eds.), *Relating theory and data: Essays on human memory in honor of Bennet B. Murdock* (pp. 227–248). Hillsdale, NJ: Erlbaum.

Hockley, W. E. (1992). Item versus associative information: Further comparisons of forgetting rates. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **18**(6), 1321–1330.

Hockley, W. E., & Consoli, A. (1999). Familiarity and recollection in item and associative recognition. *Memory and Cognition*, **27**(4), 657–664.

Holdstock, J. S., Mayes, A. R., Cezayirli, E., Isaac, C. L., Aggleton, J. P., & Roberts, N. (2000). A comparison of egocentric and allocentric spatial memory in a patient with selective hippocampal damage. *Neuropsychologia*, **38**(4), 410–425.

Huppert, F. A., & Piercy, M. (1976). Recognition memory in amnesic patients: Effects of temporal context and familiarity of material. *Cortex*, **12**(1), 3–20.

Huppert, F. A., & Piercy, M. (1978). The role of trace strength in recency and frequency judgments by amnesic and control subjects. *Quarterly Journal of Experimental Psychology*, **30**(2), 347–354.

Hurst, W., & Volpe, B. T. (1982). Temporal order judgments with amnesia. *Brain and Cognition*, **1**(3), 294–306.

Iidaka, T., Anderson, N. D., Kapur, S., Cabeza, R., & Craik, F. I. M. (2000). The effect of divided attention on encoding and retrieval in episodic memory revealed by positron emission tomography. *Journal of Cognitive Neuroscience*, **12**(2), 267–280.

Iidaka, T., Sadato, N., Yamada, H., & Yonekura, Y. (2000). Functional asymmetry of human prefrontal cortex in verbal and non-verbal episodic memory as revealed by fMRI. *Cognitive Brain Research*, **9**(1), 73–83.

Incisa della Rocchetta, A., & Milner, B. (1993). Strategic search and retrieval inhibition: The role of the frontal lobes. *Neuropsychologia*, **31**(6), 503–524.

Inoue, C., & Bellezza, F. S. (1998). The detection model of recognition using know and remember judgments. *Memory and Cognition*, **26**(2), 299–308.

Isaac, C. L., & Mayes, A. R. (1999). Rate of forgetting in amnesia. I. Recall and recognition of prose. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(4), 942–962.

Israel, L., & Schacter, D. L. (1997). Pictorial encoding reduces false recognition of semantic associates. *Psychonomic Bulletin and Review*, **4**(4), 577–581.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, **30**(5), 513–541.

Jacoby, L. L. (1998). Invariance in automatic influences of memory: Toward a user's guide for the process-dissociation procedure. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **24**(1), 3–26.

Jacoby, L. L. (1999). Ironic effects of repetition: Measuring age-related differences in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(1), 3–22.

Jacoby, L. L., Begg, I. M., & Toth, J. P. (1997). In defense of functional independence: Violations of assumptions underlying the process-dissociation procedure? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(2), 484–495.

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

Jacoby, L. L., Jones, T. C., & Dolan, P. O. (1998). Two effects of repetition: Support for a dual-process model of knowledge judgments and exclusion errors. *Psychonomic Bulletin and Review*, **5**(4), 705–709.

Jacoby, L. L., & Kelley, C. M. (1992). Unconscious influences of memory: Dissociations and automaticity. In E. A. D. Milner, & E. M. D. Rugg (Eds.), *The neuropsychology of consciousness* (pp. 201–233). San Diego, CA: Academic Press.

Jacoby, L. L., Kelley, C. M., & Dywan, J. (1989). Memory attributions. In E. Henry, L. Roediger III, E. Fergus, & I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 391–422). Hillsdale, NJ: Erlbaum.

Jacoby, L. L., & Shrout, P. E. (1997). Toward a psychometric analysis of violations of the independence assumption in process dissociation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(2), 505–510.

Jacoby, L. L., Toth, J. P., & Yonelinas, A. P. (1993). Separating conscious and unconscious influences of memory: Measuring recollection. *Journal of Experimental Psychology: General*, **122**(2), 139–154.

Jacoby, L. L., & Whitehouse, K. (1989). An illusion of memory: False recognition influenced by unconscious perception. *Journal of Experimental Psychology: General*, **118**(2), 126–135.

Jacoby, L. L., & Witherspoon, D. (1982). Remembering without awareness. *Canadian Journal of Psychology*, **36**(2), 300–324.

Jacoby, L. L., Yonelinas, A. P., & Jennings, J. M. (1997). The relation between conscious and unconscious (automatic) influences: A declaration of independence. In E. Jonathan, D. Cohen, & W. Schooler (Eds.), *Scientific approaches to consciousness* (pp. 13–47). Hillsdale, NJ: Erlbaum.

Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia*, **27**(8), 1043–1056.

Janowsky, J. S., Shimamura, A. P., Kritchevsky, M., & Squire, L. R. (1989). Cognitive impairment following frontal lobe damage and its relevance to human amnesia. *Behavioral Neuroscience*, **103**(3), 548–560.

Java, R. I. (1996). Effects of age on state of awareness following implicit and explicit word-association tasks. *Psychology and Aging*, **11**(1), 108–111.

Java, R. I., Gregg, V. H., & Gardiner, J. M. (1997). What do people actually remember (and know) in "remember/know" experiments? *European Journal of Cognitive Psychology*, **9**(2), 187–197.

Java, R. I., Kaminska, Z., & Gardiner, J. M. (1995). Recognition memory and awareness for famous and obscure musical themes. *European Journal of Cognitive Psychology*, **7**(1), 41–53.

Jennings, J. M., & Jacoby, L. L. (1993). Automatic versus intentional uses of memory: Aging, attention, and control. *Psychology and Aging*, **8**(2), 283–293.

Jennings, J. M., & Jacoby, L. L. (1997). An opposition procedure for detecting age-related deficits in recollection: Telling effects of repetition. *Psychology and Aging*, **12**(2), 352–361.

Jetter, W., Poser, U., Freeman, R. B., & Markowitsch, H. J. (1986). A verbal long term memory deficit in frontal lobe damaged patients. *Cortex*, **22**(2), 229–242.

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

Johnson, M. K., & Kim, J. K. (1985). Recognition of pictures by alcoholic Korsakoff patients. *Bulletin of the Psychonomic Society*, **23**(6), 456–458.

Johnson, M. K., Kounios, J., & Reeder, J. A. (1994). Time-course studies of reality monitoring and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**(6), 1409–1419.

Johnson, M. K., O'Connor, M., & Cantor, J. (1997). Confabulation, memory deficits, and frontal dysfunction. *Brain and Cognition*, **34**(2), 189–206.

Juola, J. F., Fischler, I., Wood, C. T., & Atkinson, R. C. (1971). Recognition time for information stored in long-term memory. *Perception and Psychophysics*, **10**(1), 8–14.

Jurado, M. A., Junque, C., Pujol, J., & Oliver, B. (1997). Impaired estimation of word occurrence frequency in frontal lobe patients. *Neuropsychologia*, **35**(5), 635–641.

Kelley, C. M., & Jacoby, L. L. (2000). Recollection and familiarity: Process-dissociation. In E. E. Tulving, E. Fergus, & I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 215–228). New York, NY: Oxford Univ. Press.

Kelley, R., & Wixted, J. T. (2001). On the nature of associative information in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **27**(3), 701–722.

Khoe, W., Kroll, N. E. A., Yonelinas, A. P., Dobbins, I. G., & Knight, R. T. (2000). The contribution of recollection and familiarity to yes-no and forced-choice recognition tests in healthy subjects and amnesics. *Neuropsychologia*, **38**(10), 1333–1341.

Kinoshita, S. (1995). The word frequency effect in recognition memory versus repetition priming. *Memory and Cognition*, **23**(5),1 569–580.

Kinoshita, S. (1997). Masked target priming effects on feeling-of-knowing and feeling-of-familiarity judgments. *Acta Psychologica*, **97**(2), 183–199.

Kintsch, W. (1967). Memory and decision aspects of recognition learning. *Psychological Review*, **74**(6), 496–504.

Klimesch, W., Doppelmayr, A., Yonelinas, A. O., Kroll, N. E. A., Lazzara, M., Rohm, D., & Gruber, W. (2001). Theta synchronization during episodic retrieval: Neural correlates of conscious awareness. *Cognitive Brain Research*, 1.

Knowlton, B. J., & Squire, L. R. (1995). Remembering and knowing: Two different expressions of declarative memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **21**(3), 699–710.

Komatsu, S., Graf, P., & Uttl, B. (1995). Process dissociation procedure: Core assumptions fail, sometimes.

European Journal of Cognitive Psychology, **7**(1), 19–40.

Kopelman, M. D. (1986). Recall of anomalous sentences in dementia and amnesia. *Brain and Language*, **29**(1), 154–170.

Kopelman, M. D. (1989). Remote and autobiographical memory, temporal context memory and frontal atrophy in Korsakoff and Alzheimer patients. *Neuropsychologia*, **27**(4), 437–460.

Kopelman, M. D., & Stanhope, N. (1998). Recall and recognition memory in patients with focal frontal, temporal lobe, and diencephalic lesions. *Neuropsychologia*, **36**(8), 785–795.

Lazzara, M. M., Yonelinas, A. P., Kroll, N. E. A., Kishiyama, M. M., Sauve, M. J., Zusman, E., & Knight, R. T. (2001). *Conceptual priming and familiarity-based recognition in amnesia*. New York: The Cognitive Neuroscience Society.

LeCompte, D. C. (1995). Recollective experience in the revelation effect: Separating the contributions of recollection and familiarity. *Memory & Cognition*, **23**(3), 324–334.

Lepage, M., Ghaffar, O., Nyberg, L., & Tulving, E. (2000). Prefrontal cortex and episodic memory retrieval mode. *Proceedings of the National Academy of Sciences of the USA*, **97**(1), 506–511.

Levine, B., Black, S. E., Cabeza, R., Sinden, M., McIntosh, A. R., Toth, J. P., Tulving, E., & Stuss, D. T. (1998). Episodic memory and the self in a case of isolated retrograde amnesia. *Brain*, **121**(10), 1951–1973.

Levine, B., Freedman, M., Dawson, D., Black, S., & Stuss, D. T. (1999). Ventral frontal contribution to self-regulation: Convergence of episodic memory and inhibition. *Neurocase*, **5**(3), 263–275.

Light, L. L., & Prull, M. (1995). Aging, divided attention, and repetition priming. *Swiss Journal of Psychology*, **54**(2), 87–101.

Light, L. L., Prull, M. W., La Voie, D. J., & Healy, M. R. (2000). Dual-process theories of memory in old age. In E. Timothy, J. Perfect, E. Elizabeth, & A. Maylor (Eds.), *Models of cognitive aging* (pp. 238–300). New York:

Loftus, G. R. (1978). On interpretation of interactions. *Memory & Cognition*, **6**(3), 312–319.

MacAndrew, S. B. G., Jones, G. V., & Mayes, A. R. (1994). No selective deficit in recall in amnesia. *Memory*, **2**(3), 241–254.

Macmillan, N. A., & Creelman, C. D. (1991). *Detection theory: A user's guide*. New York:

Mandler, G. (1979). Organization and repetition: Organizational principles with special reference to rote learning. In L. G. Nilsson (Ed.), *Perspectives on memory research* (pp. 293–327). Hillsdale, NJ: Erlbaum.

Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review*, **87**(3), 252–271.

Mandler, G. (1991). Your face looks familiar but I can't remember your name: A review of dual process theory. In E. William, E. Hockley, & E. S. Lewandowsky (Eds.), *Relating theory and data: Essays on human memory in honor of Bennet B. Murdock* (pp. 207–225). Hillsdale, NJ: Erlbaum.

Mandler, G., Graf, P., & Kraft, D. (1986). Activation and elaboration effects in recognition and word priming. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, **38**(4-A), 645–662.

Mandler, G., Pearlstone, Z., & Koopmans, H. S. (1969). Effects of organization and semantic similarity on recall and recognition. *Journal of Verbal Learning and Verbal Behavior*, **8**(3), 410–423.

Mangels, J. A. (1997). Strategic processing and memory for temporal order in patients with frontal lobe lesions. *Neuropsychology*, **11**(2), 207–221.

Mangels, J. A., Picton, T. W., & Craik, F. I. M. (2001). Attention and successful episodic encoding: An event-related potential study. *Cognitive Brain Research*, **11**(1), 77–95.

Manns, J. R., & Squire, L. R. (1999). Impaired recognition memory on the Doors and People Test after damage limited to the hippocampal region. *Hippocampus*, **9**(5), 495–499.

Mark, R. E., & Rugg, M. D. (1998). Age effects on brain activity associated with episodic memory retrieval: An electrophysiological study. *Brain*, **121**(5), 861–873.

Martin, A., Wiggs, C. L., & Weisberg, J. (1997). Modulation of human medial temporal lobe activity by form, meaning and experience. *Hippocampus*, **7**(6), 587–593.

Mayes, A. R. (1988). Amnesia and memory for contextual information. In E. Graham, M. Davies, E. Donald, & M. Thomson (Eds.), *Memory in context: Context in memory* (pp. 193–213). New York:

Mayes, A. R., Baddeley, A. D., Cockburn, J., & Meudell, P. R. (1989). Why are amnesic judgments of recency and frequency made in a qualitatively different way from those of normal people? *Cortex*, **25**(3), 479–488.

Mayes, A. R., Isaac, C. L., Holdstock, J. S., Hunkin, N. M., Montaldi, D., Downes, J. J., MacDonald, C., Cezayirli, E., & Roberts, J. N. (2001). Memory for single items, word pairs, and temporal order of different kinds in a patient with selective hippocampal lesions. *Cognitive Neuropsychology*, **18**(2), 97–123.

Mayes, A. R., Meudell, P. R., & Pickering, A. (1985). Is organic amnesia caused by a selective deficit in remembering contextual information? *Cortex*, **21**(2), 167–202.

Mayes, A. R., van Eijk, R., Gooding, P.A., Isaac, C. L., & Holdstock, J. S. (1999). What are the functional deficits produced by hippocampal and perirhinal cortex lesions? *Behavior Brain Sciences*, **22,** 460–461.

McBride, D. M., & Dosher, B. A. (1999). Forgetting rates are comparable in conscious and automatic memory: A process-dissociation study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(3), 583–607.

McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, **102**(3), 419–437.

McElree, B., Dolan, P. O., & Jacoby, L. L. (1999). Isolating the contributions of familiarity and source information to item recognition: A time course analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(3), 563–582.

McIntyre, J. S., & Craik, F. I. (1987). Age differences in memory for item and source information. *Canadian Journal of Psychology*, **41**(2), 175–192.

Mecklinger, A., von Cramon, D. Y., & Matthes–von Cramon, G. (1998). Event-related potential evidence for a specific recognition memory deficit in adult survivors of cerebral hypoxia. *Brain*, **121**(10), 1919–1935.

Meudell, P. R., Mayes, A. R., Ostergaard, A., & Pickering, A. (1985). Recency and frequency judgments in alcoholic amnesics and normal people with poor memory. *Cortex*, **21**(4), 487–511.

Miller, B., & Gazzaniga, M.S. (1998). Creating false memories for visual scenes. *Neuropsychologia*, **36**(6), 513–520.

Milner, B. (1968). Visual recognition and recall after right temporal-lobe excision in man, *Neuropsychologia*, **6,** 191–209.

Milner, B., Corsi, P., & Leonard, G. (1991). Frontal-lobe contribution to recency judgments. *Neuropsychologia*, **29**(6), 601–618.

Mintzer, M. Z., & Griffiths, R. R. (2000). Acute effects of triazolam on false recognition. *Memory & Cognition*, **28**(8), 1357–1365.

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

Mulligan, N. W. (1999). The effects of perceptual interference at encoding on organization and order: Investigating the roles of item-specific and relational information. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(1), 54–69.

Mulligan, N. W., & Hirshman, E. (1997). Measuring the bases of recognition memory: An investigation of the process-dissociation framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(2), 280–304.

Mulligan, N. W., & Stone, M. (1999). Attention and conceptual priming: Limits on the effects of divided attention in the category-exemplar production task. *Journal of Memory and Language*, **41**(2), 253–280.

Mulligan, N., & Hirshman, E. (1995). Speed–accuracy trade-offs and the dual process model of recognition memory. *Journal of Memory and Language*, **34**(1), 1–18.

Murdock, B. B. (1974). *Human memory: Theory and data*. Hillsdale, NJ: Erlbaum.

Murdock, B. B. (1965). Signal-Detection Theory and short-term memory. *Journal of Experimental Psychology*, **70**(5), 443–447.

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **26**(5), 1170–1187.

Naveh-Benjamin, M., & Craik, F. I. M. (1995). Memory for context and its use in item memory: Comparisons of younger and older persons. *Psychology & Aging*, **10**(2), 284–293.

Nolde, S. F., Johnson, M. K., & D'Esposito, M. (1998). Left prefrontal activation during episodic remembering: An event-related fMRI study. *NeuroReport*, **9**(15), 3509–3514.

Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory & Cognition*, **25**(6), 838–848.

Norman, K. A., & O'Reilly, R. C. (2001). *Modeling hippocampal and neocortical contributions to recognition memory: A complementary learning systems approach*. Technical report 01-02. Boulder, Co: University of Colorado.

Nunn, J. A., Graydon, F. J. X., Polkey, C. E., & Morris, R. G. (1999). Differential spatial memory impairment after right temporal lobectomy demonstrated using temporal titration. *Brain*, **122**(1), 47–59.

Nyberg, L., Cabeza, R., & Tulving, E. (1996). PET studies of encoding and retrieval: The HERA model. *Psychonomic Bulletin & Review*, **3**(2), 135–148.

Ochsner, K. N. (2000). Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of Experimental Psychology: General*, **129**(2), 242–261.

O'Reilly, R. C., & Rudy, J. W. (2001). Conjunctive representations in learning and memory: Principles of cortical and hippocampal function. *Psychological Review*, **108**(2), 311–345.

Paivio, A., & Csapo, K. (1969). Concrete Image and Verbal Memory Codes. *Journal of Experimental Psychology*, **80**(2, Pt. 1), 279–285.

Paller, K. A., Kutas, M., & McIsaac, H. K. (1998). An electrophysiological measure of priming of visual word-form. *Consciousness and Cognition*, **7**(1), 54–66.

Paller, K. A., McCarthy, G., & Wood, C. C. (1988). ERPs predictive of subsequent recall and recognition performance. *Biological Psychology*, **26**(1–3), 269–276.

Parkin, A. J. (1997). The neuropsychology of false memory. *Learning & Individual Differences*, **9**(4), 341– 357.

Parkin, A. J., Bindschaedler, C., Harsent, L., & Metzler, C. (1996). Pathological false alarm rates following damage to the left frontal cortex. *Brain and Cognition*, **32**(1), 14–27.

Parkin, A. J., Gardiner, J. M., & Rosser, R. (1995). Functional aspects of recollective experience in face recognition. *Consciousness and Cognition*, **4**(4), 387–398.

Parkin, A. J., & Hunkin, N. M. (1993). Impaired temporal context memory on anterograde but not retrograde tests in the absence of frontal pathology. *Cortex*, **29**(2), 267–280.

Parkin, A. J., Rees, J. E., Hunkin, N. M., & Rose, P. E. (1994). Impairment of memory following discrete thalamic infarction. *Neuropsychologia*, **32**(1), 39–51.

Parkin, A. J., & Russo, R. (1993). On the origin of functional differences in recollective experience. *Memory*, **1**(3), 231–237.

Parkin, A. J., & Walter, B. M. (1992). Recollective experience, normal aging, and frontal dysfunction. *Psychology and Aging*, **7**(2), 290–298.

Parkin, A. J., Ward, J., Bindschaedler, C., Squires, E. J., & Powell, G. (1999). False recognition following frontal lobe damage: The role of encoding factors. *Cognitive Neuropsychology*, **16**(3–5), 243–265.

Parks, T. E. (1966). Signal-Detectability Theory of recognition-memory performance. *Psychological Review*, **73**(1), 44–58.

Perfect, T. J., & Dasgupta, Z. R. R. (1997). What underlies the deficit in reported recollective experience in old age? *Memory & Cognition*, **25**(6), 849–858.

Perfect, T. J., Mayes, A. R., Downes, J. J., & Van Eijk, R. (1996). Does context discriminate recollection from familiarity in recognition memory? *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, **49**(3), 797–813.

Perfect, T. J., Williams, R. B., & Anderton-Brown, C. (1995). Age differences in reported recollective experience are due to encoding effects, not response bias. *Memory*, **3**(2), 169–86.

Pickering, A. D., Mayes, A. R., & Fairbairn, A. F. (1989). Amnesia and memory for modality information. *Neuropsychologia*, **27**(10), 1249–1259.

Polster, M. R. (1993). Drug-induced amnesia: Implications for cognitive neuropsychological investigations of memory. *Psychological Bulletin*, **114**(3), 477–493.

Polster, M. R., McCarthy, R. A., O'Sullivan, G., & Gray, P. A. (1993). Midazolam-induced amnesia: Implications for the implicit/explicit memory distinction. *Brain and Cognition*, **22**(2), 477–493.

Postma, A. (1999). The influence of decision criteria upon remembering and knowing in recognition memory. *Acta Psychologica*, **103**(1–2), 65–76.

Qin, J., Raye, C. L., Johnson, M. K., & Mitchell, K. J. (2001). Source ROCs are (typically) curvilinear: Comment on Yonelinas (1999). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **27**(4), 1110–1115.

Quamme, J.R., & Yonelinas, A.P. (2001). *A role for familiarity in associative recognition*. Presented at the 42nd annual meeting of the Psychonomic Society, Orlando, Florida.

Rabinowitz, J. C., Mandler, G., & Patterson, K. E. (1977). Determinants of recognition and recall: Accessibility and generation. *Journal of Experimental Psychology: General*, **106**(3), 302–329.

Rajaram, S. (1993). Remembering and knowing: Two means of access to the personal past. *Memory and Cognition*, **21**(1), 89–102.

Rajaram, S. (1996). Perceptual effects on remembering: Recollective processes in picture recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **22**(2), 365–377.

Rajaram, S. (1998). The effects of conceptual salience and perceptual distinctiveness on conscious recollection. *Psychonomic Bulletin & Review*, **5**(1), 71–78.

Rajaram, S., & Geraci, L. (2000). Conceptual fluency selectively influences knowing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **26**(4), 1070–1074.

Ranganath, C., & Paller, K. A. (1999). Frontal brain activity during episodic and semantic retrieval: Insights from event-related potentials. *Journal of Cognitive Neuroscience*, **11**(6), 598–609.

Ratcliff, R., & Murdock, B. B. (1976). Retrieval processes in recognition memory. *Psychological Review*, **83**(3), 190–214.

Ratcliff, R., Sheu, C., & Gronlund, S. D. (1992). Testing global memory models using ROC curves. *Psychological Review*, **99**(3), 518–535.

Ratcliff, R., Van Zandt, T., & McKoon, G. (1995). Process dissociation, single-process theories, and recognition memory. *Journal of Experimental Psychology: General*, **124**(**4**), 352–374.

Raye, C. L., Johnson, M. K., Mitchell, K. J., Nolde, S. F., & D'Esposito, M. (2000). fMRI investigations of left and right PFC contributions to episodic remembering. *Psychobiology*, **28**(2), 197–206.

Raz, N., Gunning-Dixon, F.M., Head, D., Dupuis, J.H., & Acker, J.D. (1998). Neuroanatomical correlates of cognitive aging: Evidence from structural magnetic resonance imaging. *Neuropsychology*, **12**(1), 95–114.

Reder, L. M., Nhouyvanisvong, A., Schunn, C. D., Ayers, M. S., Angstadt, P., & Hiraki, K. (2000). A mechanistic account of the mirror effect for word frequency: A computational model of remember–know judgments in a continuous recognition paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **26**(2), 294–320.

Reed, J. M., & Squire, L. R. (1997). Impaired recognition memory in patients with lesions limited to the hippocampal formation. *Behavioral Neuroscience*, **111**(4), 667–675.

Roediger, H. L., III, & McDermott, K. B. (1993). Implicit memory in normal human subjects. *Handbook of Neuropsychology*, **8**(8), 63–131.

Roediger, H. L., & McDermott, K. B. (1994). The problem of differing false-alarm rates for the process dissociation procedure: Comment on Verfaellie and Treadwell (1993). *Neuropsychology*, **8**(2), 284–288.

Roediger, H. L., & 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.

Rotello, C. M., Macmillan, N. A., & Reeder, J.A. (2001). *A two-dimensional signal detection model of remember–know judgments*. Presented at the 42nd Annual Meeting of the Psychonomic Society, Florida.

Rotello, C. M., Macmillan, N. A., & Van Tassel, G. (2000). Recall-to-reject in recognition: Evidence from ROC curves. *Journal of Memory and Language*, **43**(1), 67–88.

Rugg, M. D. (1995). Memory and consciousness: A selective review of issues and data. *Neuropsychologia*, **33**(9), 1131–1141.

Rugg, M. D., Cox, C. J., Doyle, M. C., & Wells, T. (1995). Event-related potentials and the recollection of low and high frequency words. *Neuropsychologia*, **33**(4), 471–484.

Rugg, M. D., Fletcher, P. C., Frith, C. D., Frackowiak, R. S. J., & Dolan, R. J. (1996). Differential activation of the prefrontal cortex in successful and unsuccessful memory retrieval. *Brain*, **119**(6), 2073–2083.

Rugg, M. D., Henson, N. A. (2001). Episodic Memory Retrieval and (event related) functional neuroimaging perspective. In A. E. Parker, E. L. Wilding, & E. L. Bussey (Eds.), *The cognitive neuroscience of memory encoding and retrieval*. Hove, UK: Psychology Press.

Rugg, M. D., Mark, R. E., Walla, P., Schloerscheidt, A. M., Birch, C. S., & Allan, K. (1998). Dissociation of the neural correlates of implicit and explicit memory. *Nature*, **392**(6676), 595–598.

Rugg, M. D., Schloerscheidt, A. M., & Mark, R. E. (1998). An electrophysiological comparison of two indices of recollection. *Journal of Memory and Language*, **39**(1), 47–69.

Rugg, M. D., Roberts, R. C., Potter, D. D., Pickles, C. D., & Nagy, M. E. (1991). Event-related potentials related to recognition memory: Effects of unilateral temporal lobectomy and temporal lobe epilepsy. *Brain*, **114**, 2313–2332.

Russo, R., Cullis, A. M., & Parkin, A. J. (1998). Consequences of violating the assumption of independence in the process dissociation procedure: A word fragment completion study. *Memory & Cognition*, **26**(4), 617–632.

Rybash, J. M., & Hoyer, W. J. (1996). Process dissociation procedure reveals age differences in unconscious influences on memory for possible and impossible objects. *Aging, Neuropsychology, & Cognition*, **3**(4), 251–263.

Schacter, D. L., Chiu, C. Y. P., & Ochsner, K. N. (1993). Implicit memory: A selective review. *Annual Review of Neuroscience*, **16**, 159–182.

Schacter, D. L., Harbluk, J. L., & 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., Kaszniak, A. W., Kihlstrom, J. F., & Valdiserri, M. (1991). The relation between source memory and aging. *Psychology and Aging*, **6**(4), 559–568.

Schacter, D. L., Koutstaal, W., Johnson, M. K., Gross, M. S., & Angell, K. E. (1997). False recollection induced by photographs: A comparison of older and younger adults. *Psychology and Aging*, **12**(2), 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., Savage, C. R., Alpert, N. M., Rauch, S. L., & Albert, M. S. (1996). The role of hippocampus and frontal cortex in age-related memory changes: A PET study. *NeuroReport*, **7**(6), 1165–1169.

Schacter, D. L., Verfaellie, M., & Anes, M. D. (1997). Illusory memories in amnesic patients: Conceptual and perceptual false recognition. *Neuropsychology*, **11**(3), 331–342.

Schacter, D. L., Verfaellie, M., & Pradere, D. (1996). The neuropsychology of memory illusions: False recall and recognition in amnesic patients. *Journal of Memory and Language*, **35**(2), 319–334.

Schonfield, D., & Robertson, B. A. (1966). Memory storage and aging. *Canadian Journal of Psychology*, **20**(2), 228–236.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing. II. Perceptual learning, automatic attending and a general theory. *Psychological Review*, **84**(2), 127–190.

Shimamura, A. P. (1986). Priming effects in amnesia: Evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, **38**(4-A), 619–644.

Shimamura, A. P., & Squire, L. R. (1984). Paired-associate learning and priming effects in amnesia: A neuropsychological study. *Journal of Experimental Psychology: General*, **113**(4), 556–570.

Shimamura, A. P., & Squire, L. R. (1987). A neuropsychological study of fact memory and source amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **13**(3), 464–473.

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory*, **4**(6), 592–604.

Slotnick, S. D., Klein, S. A., Dodson, C. S., & Shimamura, A. P. (2000). An analysis of signal detection and threshold models of source memory. *Journal of Experimental Psychology: Human Learning and Memory*, **28**(6), 1499–1517.

Smith, M. E. (1993). Neurophysiological manifestations of recollective experience during recognition memory judgments. *Journal of Cognitive Neuroscience*, **5**(1), 1–13.

Smith, M. E., & Halgren, E. (1989). Dissociation of recognition memory components following temporal lobe lesions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **15**(1), 50–60.

Squire, L. R. (1982). Comparisons between forms of amnesia: Some deficits are unique to Korsakoff's Syndrome. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **8**(6), 560–571.

Squire, L. R. (1994). Declarative and nondeclarative memory: Multiple brain systems supporting learning and memory. In E. Daniel, L. Schacter, & E. E. Tulving (Eds.), *Memory systems 1994* (pp. 203–231). Cambridge, MA: Harvard Univ. Press.

Squire, L.R., & Zola, M.S., (1998). Episodic memory, semantic memory and amnesia. *Hippocampus*, **8,** 205–211.

Srinivas, K., & Roediger, H. L. (1990). Classifying implicit memory tests: Category association and anagram solution. *Journal of Memory and Language*, **29**(4), 389–412.

Srinivas, K., & Verfaellie, M. (2000). Orientation effects in amnesics' recognition memory: Familiarity-based access to object attributes. *Journal of Memory and Language*, **43**(2), 274–290.

Stark, C. E. L., & Squire, L. R. (2000). Recognition memory and familiarity judgments in severe amnesia: No evidence for a contribution of repetition priming. *Behavioral Neuroscience*, **114**(3), 459–467.

Strack, F., & Foerster, J. (1995). Reporting recollective experiences: Direct access to memory systems? *Psychological Science*, **6**(6), 352–358.

Strange, B. A., Otten, L. J., Josephs, O., Rugg, M. D., Dolan, R. J. (2002). Dissociating human perirhinal, hippocampal, and parahippocampal roles during verbal encoding. *The Journal of Neuroscience*, **22**(2), 523–528.

Swets, J. A. (1986). Form of empirical ROCs in discrimination and diagnostic tasks: Implications for theory and measurement of performance. *Psychological Bulletin*, **99**(2), 181–198.

Tendolkar, I., Doyle, M. C., & Rugg, M. D. (1997). An event-related potential study of retroactive interference in memory. *NeuroReport*, **8**(2), 501–506.

Tendolkar, I., Schoenfeld, A., Golz, G., Fernández, G., Kühl, K. P., Ferszt, R., & Heinze, H. J. (1999). Neural correlates of recognition memory with and without recollection in patients with Alzheimer's disease and healthy controls. *Neuroscience Letters*, **263**(1), 45–48.

Toth, J. P. (1996). Conceptual automaticity in recognition memory: Levels-of-processing effects on familiarity. *Canadian Journal of Experimental Psychology*, **50**(1), 123–138.

Trott, C. T., Friedman, D., Ritter, W., & Fabiani, M. (1997). Item and source memory: Differential age effects revealed by event-related potentials. *NeuroReport*, **8**(15), 3373–3378.

Trott, C. T., Friedman, D., Ritter, W., Fabiani, M., & Snodgrass, J. G. (1999). Episodic priming and memory for temporal source: Event-related potentials reveal age-related differences in prefrontal functioning. *Psychology and Aging*, **14**(3), 390–413.

Troyer, A. K., Winocur, G., Craik, F. I. M., & Moscovitch, M. (1999). Source memory and divided attention: Reciprocal costs to primary and secondary tasks. *Neuropsychology*, **13**(4), 467–474.

Tulving, E. (1982). Synergistic ecphory in recall and recognition. *Canadian Journal of Psychology*, **36**(2), 130–147.

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

Tulving, E., & Markowitsch, H. J. (1998). Episodic and declarative memory: Role of the hippocampus. *Hippocampus*, **8**(3), 198–204.

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science*, **247**(4940), 301–306.

Vaidya, C. J., Gabrieli, J. D. E., Keane, M. M., & Monti, L. A. (1995). Perceptual and conceptual memory processes in global amnesia. *Neuropsychology*, **9**(4), 580–591.

Vargha-Khadem, F., Gadian, D.G., Watkins, K.E., et al. (1997). Differential effects of early hippocampal pathology on episodic and semantic memory. *Science*, **277**(5324), 376–380.

Verfaellie, M., & Cermak, L. S. (1999). Perceptual fluency as a cue for recognition judgments in amnesia. *Neuropsychology*, **13**(2), 198–205.

Verfaellie, M., Cermak, L. S., Letourneau, L., & Zuffante, P. (1991). Repetition effects in a lexical decision task: The role of episodic memory in the performance of alcoholic Korsakoff patients. *Neuropsychologia*, **29**(7), 641–657.

Verfaellie, M., & Treadwell, J. R. (1993). Status of recognition memory in amnesia. *Neuropsychology*, **7**(1), 5–13.

Volpe, B. T., Holtzman, J. D., & Hirst, W. (1986). Further characterization of patients with amnesia after cardiac arrest: Preserved recognition memory. *Neurology*, **36**(3), 408–411.

Wagemans, J., Notebaert, W., & Boucart, M. (1998). Lorazepam but not diazepam impairs identification of pictures on the basis on specific contour fragments. *Psychopharmacology*, **138**(3–4).

Wagner, A. D., & Gabrieli, J. D. E. (1998). On the relationship between recognition familiarity and perceptual fluency: Evidence for distinct mnemonic processes. *Acta Psychologica*, **98**(2–3).

Wagner, A. D., Gabrieli, J. D. E., & Verfaellie, M. (1997). Dissociations between familiarity processes in explicit recognition and implicit perceptual memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **23**(2).

Wagner, A. D., Koutstaal, W., & Schacter, D. L., (1999). When encoding yields remembering: Insights from event-related neuroimaging. *Philosophical Transcripts of the Royal Society of London, Biological Sciences*, **354**(1387), 1307–1324.

Wagner, A. D., Poldrack, R. A., Eldridge, L. L., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. E. (1998). Material-specific lateralization of prefrontal activation during episodic encoding and retrieval. *Neuroreport*, **9**(16).

Wagner, A. D., Stebbins, G. T., Masciari, F., Fleischman, D. A., & Gabrieli, J. D. E. (1998). Neuropsychological dissociation between recognition familiarity and perceptual priming in visual long-term memory. *Cortex*, **34**(4).

Watkins, M. J., & Peynircioglu, Z. F. (1990). The revelation effect: When disguising test items induces recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **16**(6).

Watkins, M. J., LeCompte, D. C., & Kim, K. (2000). Role of study strategy in recall of mixed lists of common and rare words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **26**(1).

Weingartner, H., Eckardt, M., Molchan, S. E., & Sunderland, T. (1992). Measurement and interpretation of changes in memory in response to drug treatments. *Psychopharmacology Bulletin*, **28**(4).

Westerman, D. L. (2001). The role of familiarity in item recognition, associative recognition, and plurality recognition on self-paced and speeded tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **27**(3), 723–732.

Weyerts, H., Tendolkar, I., Smid, H. G. O. M., & Heinz, H. J. (1997). ERPs to encoding and recognition in two different inter-item association tasks. *Neuroreport*, **8**(7).

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1995). Frontal lobe damage produces episodic memory impairment. *Journal of the International Neuropsychological Society*, **1**(6).

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: The frontal lobes and autonoetic consciousness. *Psychological Bulletin*, **121**(3).

Whittlesea, B. W. A. (1993). Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **19**(6).

Whittlesea, B. W. A., & Williams, L. D. (1998). Why do strangers feel familiar, but friends don't? A discrepancy-attribution account of feelings of familiarity. *Acta Psychologica*, **98**(2–3).

Whittlesea, B. W. A., & Williams, L. D. (2000). The source of feelings of familiarity: The discrepancy-attribution hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **26**(3).

Whittlesea, B. W., Jacoby, L. L., & Girard, K. (1990). Illusions of immediate memory: Evidence of an attributional basis for feelings of familiarity and perceptual quality. *Journal of Memory and Language*, **29**(6).

Wickelgren, W. A. (1979). Chunking and consolidation: A theoretical synthesis of semantic networks, configuring in conditioning, S-R versus cognitive learning, normal forgetting, the amnesic syndrome, and the hippocampal arousal system. *Psychological Review*, **86**(1).

Wilding, E. L. (1999). Separating retrieval strategies from retrieval success: An event-related potential study of source memory. *Neuropsychologia*, **37**(4).

Wilding, E. L., & Rugg, M. D. (1996). An event-related potential study of recognition memory with and without retrieval of source. *Brain*, **119**(3).

Wilding, E. L., & Rugg, M. D. (1997). Event-related potentials and the recognition memory exclusion task. *Neuropsychologia*, **35**(2).

Wilding, E. L., Doyle, M. C., & Rugg, M. D. (1995). Recognition memory with and without retrieval of context: An event-related potential study. *Neuropsychologia*, **33**(6).

Winnick, W. A., & Daniel, S. A. (1970). Two kinds of response priming in tachistoscopic recognition. *Journal of Experimental Psychology*, **84**(1).

Wippich, W. (1992). Implicit and explicit memory without awareness. *Psychological Research*, **54**(3).

Yonelinas, A. P. (1994). Receiver-operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**(6), 1341–1354.

Yonelinas, A. P. (1997). Recognition memory ROCs for item and associative information: The contribution of recollection and familiarity. *Memory & Cognition*, **25**(6), 747–763.

Yonelinas, A. P. (1999). Recognition memory ROCs and the dual-process signal-detection model: Comment on Glanzer, Kim, Hilford, and Adams (1999). *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(2), 514–521.

Yonelinas, A. P. (1999). The contribution of recollection and familiarity to recognition and source-memory judgments: A formal dual-process model and an analysis of receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(6), 1415–1434.

Yonelinas, A. P. (2001a). Consciousness, control, and confidence: The 3 Cs of recognition memory. *Journal of Experimental Psychology: General*, **130**(3), 361–379.

Yonelinas, A.P. (2001b). Components of episodic memory: the contribution of recollection and familiarity. *Philosophical Transcripts of the Royal Society of London, Biological Sciences*, **356**(1413), 1363–1374.

Yonelinas, A. P., Dobbins, I., Szymanski, M. D., Dhaliwal, H. S., & King, L. (1996). Signal-detection, threshold, and dual-process models of recognition memory: ROCs and conscious recollection. *Consciousness and Cognition*, **5**(4), 418–441.

Yonelinas, A. P., Hopfinger, J. B., Buonocore, M. H., Kroll, N. E. A., & Baynes, K. (2001). Hippocampal, parahippocampal and occipital-temporal contributions to associative and item recognition memory: An fMRI study. *Neuroreport*, **12**(2), 359–363.

Yonelinas, A. P., & Jacoby, L. L. (1994). Dissociations of processes in recognition memory: Effects of interference and of response speed. *Canadian Journal of Experimental Psychology*, **48**(4), 516–534.

Yonelinas, A. P., & Jacoby, L. L. (1995). The relation between remembering and knowing as bases for recognition: Effects of size congruency. *Journal of Memory and Language*, **34**(5), 622–643.

Yonelinas, A. P., & Jacoby, L. L. (1996a). Noncriterial recollection: Familiarity as automatic, irrelevant recollection. *Consciousness and Cognition*, **5**(1–2), 131–141.

Yonelinas, A. P., & Jacoby, L. L. (1996b). Response bias and the process-dissociation procedure. *Journal of Experimental Psychology: General*, **125**(4), 422–434.

Yonelinas, A. P., Kroll, N. E. A., Dobbins, I. G., & Soltani, M. (1999). Recognition memory of faces: When familiarity supports associative recognition judgments. *Psychonomic Bulletin & Review*, **6**(4), 654–661.

Yonelinas, A. P., Kroll, N. E. A., Dobbins, I., Lazzara, M., & Knight, R. T. (1998). Recollection and familiarity deficits in amnesia: Convergence of remember-know, process dissociation, and receiver operating characteristic data. *Neuropsychology*, **12**(3), 323–339.

Yonelinas, A. P., & Levy, B. J., (2002). Dissociating familiarity from recollection in human recognition memory: Different rates of forgetting over short retention intervals. *Psychonomic Bulletin & Review*, in press.

Yonelinas, A. P., Regehr, G., & Jacoby, L. L. (1995). Incorporating response bias in a dual-process theory of memory. *Journal of Memory and Language*, **34**(6), 821–835.

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