25 Memory without Conscious Recollection: A Tutorial Review from a Neuropsychological Perspective

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ABSTRACT Four different types of implicit tests of memory are identified: (1) item-specific perceptual tests; (2) item-specific conceptual tests; (3) procedural, sensorimotor tests; and (4) procedural, ordered/rule-based tests. They all show the quality that memory is tested indirectly by changes in performance with experience without requiring that the subject refer directly or explicitly to the past in performing the tests. The review is concerned primarily with the first type of test, but it deals with each of the others as well. The effects of a variety of variables on performance are noted, as are the various deficits caused by damage to different neural structures. A number of theories of performance on perceptual item-specific tests are evaluated. We prefer a component of processing theory that states that performance on memory tests depends on the operation of potentially independent, but typically interactive, components that are assembled for use in a given task. Correspondences and dissociations between one memory test and another are determined by the extent to which the components involved in the test overlap or differ. In this proposal, we attempt to identify the components mediating performance on the various implicit tests at both a functional and structural level. Performance on different explicit tests also involves various components with the proviso that one component, associated with the functions of the hippocampus and related structures, is implicated in each test. Based on this assumption, and on Fodor's ideas concerning modules and central systems, a neuropsychological model of memory is proposed that accounts for the relationship between consciousness and memory on implicit and explicit tests.

25.1 INTRODUCTION

The relation between consciousness and memory was considered important by theorists as diverse in their interests as James and Freud, Ebbinghaus, Korsakoff, and Ribot, who were writing during what Rozin (1976) called the golden age of memory research at the end of the nineteenth century. The advent and success of behaviorism at the beginning of the twentieth century effectively banished the study of both memory and consciousness from experimental psychology, though both continued to play a critical role in psychodynamic theory and psychotherapy. It was only as cognitive psychology and neuropsychology replaced behavioral learning theory as the dominant doctrines for experimental psychology that it again became legitimate to study memory. Once released from the constricting and fundamentally flawed doctrines of learning theory, work on memory began to flourish. It was only a matter of time before the relation of consciousness to memory would once again occupy the interests of experimental psychologists.

The current interest in consciousness on memory derived from the mounting, converging evidence from studies of normal and amnesic people of striking dissociations in performance between tests of memory that require conscious recollection, such as recognition and recall, and on those that assess memory merely by noting if behavior is altered by experience (Milner 1966; Moscovitch 1982a). Memory tests that depend on conscious recollection have come to be known as *direct* or *explicit tests* (Graf and Schacter 1985; Richardson-Klavehn and Bjork 1988) because reference to a past episode is explicit in both the instructions and the subject's own reflections in performing the test. In contrast, *implicit tests* make no direct reference to the past but rather assess memory simply by noting changes in performance with experience or practice. The subject may not be aware of a relation between the study and test conditions or even that memory is being tested. In short, implicit tests are tests of nonconscious memory, or, more appropriately, they are tests of memory without conscious awareness of the past (see Moscovitch 1984 for other criteria that distinguish implicit from explicit tests of memory). To give a concrete example, memory for words or pictures may be tested implicitly by seeing whether identification latency is superior for studied than for nonstudied items. This contrasts with an explicit test, such as recognition, in which the subject must directly indicate those items he or she remembers studying. An ordinary life analogue of an implicit test might be the more rapid typing of a word one had typed earlier, the more rapid solution to an item in a crossword puzzle that one had previously solved, or the humming of a tune that one had heard earlier, without remembering the initial occurrence of any of these events.

This chapter will address two questions: What distinguishes performance on implicit tests of memory from that on explicit tests and, also, what distinguishes performance on one implicit test from that on another? Why is conscious awareness of the target as a memory associated with performance on explicit but not implicit tests?

The literature concerned with distinctions between explicit and implicit tests of memory has grown too large to allow this review to be anything more than selective (for detailed reviews see Richardson-Klavehn and Bjork 1988; Schacter 1987a; Moscovitch, Vriezen, and Goshen-Gottstein 1993; Roediger and McDermott 1993). Although the review will cover studies of normal and brain-damaged people, the focus will be on the neuropsychological literature, both because it is more manageable and because issues concerning neurological mechanisms and memory are addressed most clearly there. In that literature, the terms *declarative* and *nondeclarative* or *procedural memory* are often used interchangeably with the terms *explicit* and *implicit* (Squire 1992), but we prefer the latter terms because they carry fewer theoretical overtones.

We will begin by providing a classification of implicit tests of memory. Then we will concentrate on only one type, perceptual item-specific implicit tests, both because more is known about this test than any other and because it is in relation to this test that issues and theories on consciousness and memory are most clearly explicated. After indicating the characteristics of this test, we will consider briefly some of the theories that have been proposed to account for distinctions between performance on implicit and explicit tests with particular emphasis on how the theories deal with the issue of consciousness. Next we will present a neuropsychological model of memory that we think not only can accommodate the relevant data but also make predictions about the memory performance of various neurological populations. The model also offers an explanation as to why conscious awareness accompanies performance on some tests but not on others. We end by considering very briefly some of the other different types of implicit tests mentioned in the initial classification.

25.2 CLASSIFICATION OF IMPLICIT TESTS OF MEMORY

Implicit tests can be divided into two major categories: item specific and procedural. Item-specific tests are those that assess memory for a particular item, such as a certain word, face, or object. Memory for the item typically is inferred from changes in the efficiency or accuracy with which the item is processed when it is repeated or in the probability and efficiency that it is reproduced or elicited by appropriate cues. The change in item-specific processing efficiency is known as the repetition priming effect because the initial presentation of the item is assumed to prime it so that it is more readily accessible for later processing. Procedural tests, on the other hand, are not concerned with acquisition and retention of a particular item but rather with learning a general cognitive or sensorimotor skill, as is involved in tracking moving objects, reading peculiar scripts, or solving puzzles. Here, too, memory is inferred from changes in performance with practice (table 25.1).

Each of these two major categories can be divided into two further subtypes. Item-specific tests can be either perceptual or conceptual, the subtype being determined by the demand characteristics of the test and by the attributes of the cues to which responses are generated. On perceptual tests, the study material is reinstated in whole or in part, and perceptual identification of the target or some aspect of it is required. Conceptual tests, on the other hand, do not provide any perceptual information about the target. Instead, the target is generated in response to a semantic or conceptual cue. Performance on perceptual tests is affected by sensory variables, whereas that on conceptual tests is affected more by semantic variables.

Procedural tests can be either sensorimotor or ordered/rule-based. Implicit sensorimotor tests measure changes in some sensory, perceptual, or motor skill with mere repetition or practice, as is the case on pursuit-rotor or mirror-tracing tests. Ordered or rule-based implicit tests, such as solving puzzles like the Tower of Hanoi, involve the acquisition or application of sequential patterns or rules. In contrast to sensorimotor tests that are driven by external cues, ordered or rule-based tests involve a measure of internal organization based on strategic processes such as monitoring, planning, and developing and testing hypotheses.

Table 25.1 Classification of Implicit and Explicit Tests

Type of Test	Characterization	Some Variables and Factors That Influence Performance	Typical Tests Used to Assess Memory	Probable Neural Substrate
Implicit				
Item Specific				
Perceptual	Identification or classification of particular stimuli based on sensory cues	Perceptual (e.g., modality, representational format), retention interval	Identification of fragmented words or pictures (e.g., fragment completion or perceptual identification)	Perceptual input modules (representational systems) in posterior neocortex
Conceptual	Generation, production, or classification of targets in response to conceptual or semantic cues	Semantic (e.g., levels of processing), number of trials, proactive interference, (attention?)	Exemplar generation to category cues	Interpretative central systems in lateral temporal, parietal, and possibly frontal lobes
Procedural				
Sensorimotor	Acquisition and improvement of motor or sensory skills	Number of trials, feedback	Pursuit rotor, mirror drawing, general skill component of reading transformed script, classical conditioning	Basal ganglia, cerebellum
Ordered/Rule-based	Learning to solve problems based on rules or organized response contingencies	Number of trials, feedback, hierarchical organization, monitoring	Tower of Hanoi, (serial reaction time test?)	Dorsolateral and midlateral frontal lobes
Explicit				
Associative	Conscious recollection of episodes in which the cue is sufficient for retrieval	Semantic (e.g., levels of processing), retention interval, stimulus duration and repetition, interference, attention	Simple recognition or cued recall	Hippocampus and related limbic structures in medial temporal lobes and diencephalion
Strategic	Conscious recollection of episodes in which extra-cue strategic factors are critical	Organizational variables (e.g., clustering), attention, cognitive resources	Free recall, particularly of categorized lists, memory for temporal order, conditional associative learning	Dorsolateral and ventromedial frontal lobes and cingulate cortex

Admittedly, the proposed classification is rather crude and will need to be refined as more is learned about the tests currently in use and as new ones are developed. Although classifiable as primarily one type or another, few tests are so pure that they comprise only one element. The classificatory scheme suggests ideal prototypes against which impure tests can be compared and thus provides a framework for task analysis. That the classification captures important distinctions among the various tests is indicated by its good correspondence to memory deficits associated with damage to different structures. Thus, although the classification is based on operational, psychological criteria, it maps well onto the neural substrates that mediate performance on the various types of tests.

It is important not to confuse the operational definition of each test with the processes that are involved in performing it. A test that is ostensibly perceptual may be influenced by conceptual processes, and vice versa. Ultimately the success of the classification will be judged by the consistency between the operational definition and the underlying process, but for the time being, it is necessary to keep the two separate.

This issue takes on special force in determining the phenomenological status of implicit memory tests. A test may honor all the relevant operational criteria to make it implicit, but if recollective processes are involved in performing it, its inclusion as an implicit test is meaningless. If it is to be a true test of memory without conscious awareness, an implicit test, must, by definition, also satisfy a processing criterion: that retrieval of the relevant information did not involve conscious recollection. To deal with this problem, a number of different methods have been developed to help decide whether conscious recollection is a critical factor on implicit tests. Discussions of the problem and a critical assessment of some of the methods can be found in Jacoby (chap. 26, this volume; 1991), Mayes (1992) Roediger and McDermott (1993), and Schacter, Bowers, and Booker (1989). Although it is necessary to remain vigilant, there is little evidence to indicate that performance on implicit tests is sufficiently contaminated by conscious recollection to invalidate them (Roediger and McDermott 1993). Besides, the most powerful techniques have not been applied widely enough to provide information about many variables. Consequently, unless there is evidence to the contrary, we will accept at face value the results reported in the literature. Considering that our review focuses on neurological patients whose conscious recollection is severely compromised, we are on safe ground in taking this position.

25.3 PERCEPTUAL ITEM-SPECIFIC TESTS

A variety of perceptual tests have been used to assess memory without awareness. What they all have in common is that they measure the individual's ability to supply or identify an item primarily on the basis of perceptual information. Typically, the item is degraded so that features, such as letters, or parts thereof, are either eliminated or blurred, and accuracy of identification is the dependent measure. For example, one of the most commonly used tests is stem completion in which the first letters of a word are presented (e.g., *Str-*) and the subject is required to complete the stem with the first word that comes to mind. Priming effects are obtained when percent completion of studied words is above the baseline guessing rate and exceeds that of nonstudied words. Fragment completion is similar, except that a word fragment is presented (e.g., *_t_i_g*, for *string*) instead of the stem. Another test is word identification in which the test item is visually degraded by presenting it at very brief exposures, by masking it, or by deleting parts of it. Here, too, memory of studied items is inferred if they can be identified better than nonstudied items.

Sometimes the test items are presented in their full, nondegraded form, and latency to identify them is the dependent measure. This is the case in lexical decision tasks, in which subjects are asked to determine whether letter strings form legitimate words, or in naming tasks, in which subjects are asked to read aloud words in normal or transformed script. Shorter response latencies to studied than nonstudied items are taken as evidence of retention.

All of the tests mentioned so far are visual (for a list of tests, see Roediger and McDermott 1993). Auditory analogues of some of these tests, such as stem completion and perceptual identification, also have been used with neurologically intact people (Bassilli, Smith, and MacLeod 1989; Jackson and Morton 1984) but very seldom with brain-damaged patients (but see Schacter 1992; Johnson, Kim, and Risse 1985). When they are used, the results are consistent with those on visual tests.

Words

Most of the literature on implicit tests, like the literature on explicit tests, is concerned with memory for visually presented words. Amnesic patients consistently show normal priming when the studied items are single words, even though their memory for the same words is severely impaired when it is tested explicitly. This pattern of results is observed when the implicit test is stem completion (Diamond and Rozin 1984; Graf, Squire, and Mandler 1984; Squire, Shimamura, and Graf 1987; Warrington and Weiskrantz 1968, 1970), perceptual identification (Warrington and Weiskrantz 1974; Cermak, Chandler, and Wolbarst 1985; Cermak et al. 1991), word fragment completion (Tulving, Hayman, and MacDonald 1991), and lexical decision (Glass and Butters 1985; Gordon 1988; Moscovitch 1982b, 1985; Smith and Oscar-Berman 1990; Verfaellie et al. 1991). Latency to read words in a normal (Moscovitch, Winocur, and McLachlan 1986; Musen and Squire 1991) or geometrically transformed script is also reduced with repetition in amnesic patients (Cohen and Squire 1980; Squire, Cohen, and Zouzoumis 1984; Moscovitch, Winocur, and McLachlan 1986; Nichelli et al. 1988; Verfaellie, Bauer, and Bowers 1991) though sometimes not to the same extent as in normal people (Cohen and Squire 1980; Martone et al. 1984), who presumably can benefit from their explicit memory of the items. Using the galvanic skin response as implicit memory measure, Rees-Nishio (1984; cited in Moscovitch 1985) found that in amnesics, as in normal people, amplitude of the response to studied words was higher than to nonstudied words, especially when the words were emotional. Explicit recognition of the same words was at chance for the amnesic patients. Similar results have recently been reported by Verfaellie, Bauer, and Bowers (1991) and by Diamond (cited in Mayes 1992, p. 252).

Priming can be measured not only in terms of facilitated performance due to ease of processing but also in terms of biasing of judgment that is the result of an attribution process based on increased perceptual fluency. Witherspoon and Allen (1985) have found that when presentation of degraded words was repeated, normal subjects tended to judge the duration of the second presentation to be longer than that of words that were seen only once. It seems likely that subjects misattributed the ease of processing on the second presentation to length of presentation rather than to familiarity. Amnesic patients of mixed etiology have also been shown to display this effect, in a magnitude that equals that of normal people (Paller et al. 1991).

Objects and Faces

A similar pattern of results is obtained when pictures, rather than words, are the stimuli. Perceptual identification of degraded line drawings of familiar objects improves in amnesic patients if they previously had seen the intact drawing, even though their explicit memory for the drawing is severely impaired (Milner, Corkin, and Teuber 1968; Warrington and Weiskrantz 1968, 1970). The amnesic patients' improvement on perceptual identification did not always match that of normal, control subjects (Mayes, Meudell, and Neary 1978; Mortensen 1980; Squire, Wetzel, and Slater 1978; Wetzel and Squire 1982), suggesting that normal subjects may have used their explicit memory of the items to improve their performance.

More recently, perceptual repetition priming of visual objects has been obtained in amnesic patients using a speeded naming task. Mitchell and Brown (1988) showed that picture-naming latencies in normal subjects were reduced if they had identified the picture at study. Using this task with amnesic patients, Cave and Squire (1992) found normal repetition effects.

Priming of familiar faces by amnesic patients has been reported by Paller et al. (1992) who adapted Roberts's (1988) technique of presenting pictures of pairs of faces that were of the same person or of two different persons. Subjects were asked to judge whether the faces were the same or different. The pairs comprised either of two views of one famous person or views of two different famous persons. Decision times in amnesic patients, as in normal controls, were shorter when the faces were repeated than when they were viewed on the first presentation.

Characteristics of Implicit Tests of Memory

Unlike explicit tests, which are sensitive to semantic manipulations, performance on perceptual implicit tests is affected much more by perceptual variables (Kirsner and Dunn 1985).

Modality Specificity Repetition priming effects on perceptual implicit tests are far greater when study and test materials are presented in the same modality than in different modalities. Cross-modal repetition reduces the priming effect considerably both when the test is visual (Roediger and McDermott 1993; Moscovitch, Vriezen, and Goshen-Gottstein 1993) and when the test is auditory (Schacter 1992; Schacter and Church 1992). The modalities tested have been exclusively auditory and visual, with most of the tests being conducted in the visual modality, though some auditory tests have been reported (Jackson and Morton 1984; Schacter 1992; Bassilli, Smith, and MacLeod 1989). Though small by comparison to unimodal priming, cross-modal priming is nonetheless significant in many studies on normal people (Kirsner, Dunn, and Standen 1989; Roediger et al. 1992), leading some investigators to argue that abstract, semantic processes can contribute to performance on perceptual implicit tests. Because theoretical conceptions about the nature of the processes mediating priming hinge on this issue, it is important to determine whether the cross-modal effects are associated with recollective processes that can contaminate performance on implicit tests or whether cross-modal priming is a natural concomitant of the implicit test itself. Although more studies are needed, the evidence favors the former interpretation. When the influence of recollective processes is greatly diminished, as in a patient with pure alexia (Schacter et al. 1990), even the small cross-modal priming effect is eliminated. Graf, Shimamura, and Squire (1985), however, found normal cross-modal priming in amnesic patients. A similar conclusion is reached by Jacoby (personal communication) based on a study in which he applied his process dissociation procedure (Jacoby 1991; chap. 26, this volume) to a test of fragment completion. He found that cross-modal priming was associated exclusively with conscious, controlled processes in memory and not with automatic memory processes that were truly implicit.

Format Specificity Even when stimuli are presented in the same modality at study and test, priming is diminished considerably if they are presented in different formats, such as words on one occasion and pictures on the next (Weldon 1991; Weldon and Roediger 1987; for review, see Kirsner and Dunn 1985; Roediger and McDermott 1993), or the voices and names of people at study and their faces at test (Young, chap. 6, this volume; Jones 1993). Changing the language between study and test will also reduce repetition effects for written words (Kirsner and Dunn 1985). These greatly diminished cross-format priming effects on implicit tests are all the more striking when one considers that they are either weak or absent on explicit tests, or, if present, they may act in the opposite direction, as is the case even when word recognition for names of pictures is better if pictures, rather than words, were presented at study (Paivio 1986; Madigan 1983). As with cross-modality effects, some small, but consistent, cross-format effects are found, but these, too, may be attributable to the slight contaminating effects of conscious recollection on implicit tests. As yet, this conjecture has not been put to any rigorous test using the more powerful methods that have recently been developed.

Item Specificity By comparison to the effects of cross-format priming, repetition priming effects are attenuated slightly, if at all, if the format is kept constant but only the physical features of the item vary between study and test. In normal people, repetition priming effects of line drawings of objects are maintained across transformations of size, reflection, and foreshortening, if critical features are visible (Biederman and Cooper 1991; E. E. Cooper, Biederman, and Hummel 1992; L. Cooper et al. Moore 1992; Jolicoeur 1985; Jolicoeur and Milliken 1989). Similar effects have been observed in amnesic patients (Cave and Squire 1992) and in memory-impaired patients with Alzheimer's disease (Gabrieli et al. 1990). These same changes lead to poorer performance on explicit tests in normal people (Kolers, Duchnicky, and Sundstroem 1985; Jolicoeur, and Milliken 1989; L. Cooper et al. 1992). Repetition priming effects for faces also survive changes in viewpoint, though the effect is somewhat greater than when viewpoint is kept constant (Ellis et al. 1987; Young, chap. 6, this volume). For words, changes in font, size, spacing, and script have little effect on repetition priming for words on tests of lexical decision, naming, and perceptual identification (Carr, Brown, and Charalombous 1989). Although alteration in surface features between study and test has little effect on repetition priming, it can be reduced considerably by changing exemplars from one presentation to another, say, from one kind of clown to another that looks quite different (Bartram 1974; Clarke and Morton 1983; Jacoby, Woloshyn, and Kelley 1989; E. E. Cooper, Biederman, and Hummel 1992).

Based on these studies, the following rule of thumb seems to apply. Repetition priming effects can tolerate changes in surface features so long as the structurally invariant properties of the item are similar at study and at test. In other words, repetition priming is dependent on maintaining a common structural description of the item across repetitions. Repetition priming is item specific not with respect to a generic item but with regard to the particular item that is presented.

Possible exceptions to this rule of thumb are reported in the literature, but they may be peculiar to word stem and fragment completion (Roediger 1990; Tulving and Schacter 1990) tests for words and to identification of degraded pictures (Snodgrass 1989; Snodgrass and Feenan 1990; Srinivas 1993). A possible reason is that because the stimuli are degraded or fragmented along arbitrary lines, the gestalt of the target is broken, and more specific, precise information is needed to recover it from memory. Changes in surface features are less critical when items are presented intact at both study and test, as they are on tests of naming and lexical decision. In addition, as was the case for modality and format specificity, it is possible that conscious recollection may contribute to hyperspecificity in normal people. This suggestion is supported by Kinoshita and Wayland's 1993 finding that the effects of surface features on repetition priming that are observed in normal people are eliminated in amnesic patients.

Insensitivity to Semantic Manipulations Manipulations of semantic variables at study, such as the level to which an item is processed, is known to have profound effects on performance on explicit tests of memory (Craik and Lockhart 1972). The semantically deeper the level is, the better is the memory. By contrast, it is now well established that these variables have little influence on perceptual, item-specific implicit tests of memory in normal people (Roediger 1990; Roediger and McDermott 1993; Schacter 1987b) and in amnesic patients (Graf, Shimamura, and Squire 1985). As before, a relatively slight, but consistent, level of processing effect can be noted on many implicit tests, but here, too, the evidence suggests that it is due to contamination by conscious recollective processes. The level of processing effect is not observed in amnesic patients (Graf, Shimamura, and Squire 1985), and it is eliminated in normal people who are truly unaware of the relation between study and test items on the stem completion test (Bowers and Schacter 1990; but see Howard, Fry, and Brune 1991).

These studies indicate that a class of implicit tests is truly item specific and perceptual, not only in terms of operational definition but also with regard to the processes and representations involved in performing the tests. Semantic representations and processes seem not to be implicated. As we shall see, the neural mechanisms mediating these effects are also involved in perception and are distinct from those mediating performance on explicit tests and other types of implicit tests. To appreciate fully the nature of perceptual repetition priming effects, it is necessary to examine two other properties that are not directly linked to the issue of whether the processes involved are perceptual or semantic.

Duration Initial reports indicated that repetition priming effects on tests of word stem completion were short-lived, lasting no more than a couple of hours in both normal and amnesic people (Rozin 1976; Diamond and Rozin 1984; Squire, Shimamura, and Graf 1987). The same was assumed to be true of other implicit tests, such as perceptual identification and lexical decision.

It quickly became apparent, however, that the longevity of repetition priming effects depends on the test and the material involved. If the word stems used have one or two, as opposed to many, possible completions, then the repetition priming effect can be extended by hours and even days (Graf, Shimamura, and Squire 1985; Warrington and Weiskrantz 1978). Similarly, when fragment completion tests that have only one possible solution are used as the implicit test, repetition priming effects were first reported to be undiminished even after a week (Tulving, Schacter, and Stark 1982) and can last as long as a year in normal people (Sloman et al. 1988) and in at least in one amnesic patient with closed head injury (Tulving, Hayman, and MacDonald 1991). Exactly why limiting the number of solutions should prolong repetition priming effects is not known, but one possibility is that priming is related to the extent that a fragment uniquely specifies the memory representation that it activates.

Long-lasting perceptual repetition priming effects have also been found on other tests using verbal and nonverbal material. On lexical decision tasks, repetition priming effects have been reported at lags of at least 3 days in normal people (Scarborough, Gerard, and Cortese 1979) and at least twenty-nine items in amnesics (Moscovitch 1985). In speeded reading of geometrically transformed script, effects have been reported over intervals lasting hours (Martone et al. 1984), days (Cohen and Squire 1980), and weeks (Moscovitch, Winocur, and McLachlan 1986) in amnesic people and over a year in normal subjects (Kolers 1976). On picture naming tasks, repetition priming effects were found that lasted at least a week in amnesics (Cave and Squire 1992) and more than 6 weeks in normal people (Mitchell and Brown 1988). Galvanic skin response (GSR) to exposure of previously seen words also lasted a week in normal and amnesic people (Rees-Nishio 1984, reported in Moscovitch 1985; Verfaellie et al. 1991). Similarly long-lasting repetition priming effects have been observed on tests of perceptual identification of words (Jacoby and Dallas 1981) and meaningless patterns (Musen and Treisman 1990). Together, these results suggest that some relatively long-lasting neural changes must underlie the observed perceptual repetition priming effects (see also Milner, Corkin, and Teuber 1968; Warrington and Weiskrantz 1968, 1970).

Having emphasized the longevity of repetition priming effects, it is important not to leave the impression that repetition priming effects do not decay with time and that they necessarily last longer than memory assessed by explicit tests. Studies of normal subjects have shown that repetition priming effects show a reduction during the first few seconds or minutes after the initial presentation of the item and then asymptote for relatively long intervals that range from hours to years, depending on the test (Sloman et al. 1988; Moscovitch and Bentin 1993 and references therein; Roediger and McDermott 1993). Performance on explicit tests, such as recognition, do not show as precipitous a decline in the first few minutes but have a more pronounced decay rate over the next few hours or days. What is important to keep in mind, however, is that recognition also rarely falls to chance, even when the retention interval is longer than a year (Kolers 1976; see Moscovitch and Bentin 1993 for other references).

The likelihood that long-term retention on perceptual, item-specific implicit tests is mediated by processes associated with conscious recollection is remote given that similar retention functions are observed in amnesic patients as in normal people. The reverse is considered more likely: that implicit memory processes contribute, surreptitiously, to performance on what is ostensibly an explicit test of recognition. As yet, it has not been possible to determine empirically whether this is correct, though our reading of the circumstantial evidence does not favor this interpretation, primarily because performance on recognition can be reduced to chance in amnesic patients whose performance on implicit tests for the very same items is normal (Hirst 1989; Moscovitch and Bentin 1993).

Novelty: Unfamiliar Words Early reports on repetition priming effects for novel stimulus material indicated that they were difficult or impossible to obtain for nonsense words (Moscovitch 1982b, 1985; Rozin 1976; Diamond and Rozin 1984; Schacter 1985) and for unfamiliar faces, at least if they were exposed only once at study (Bentin and Moscovitch 1988; but see Paller et al. 1992). When positive results were reported on tests of perceptual identification (Cermak, Chandler, and Walbarst 1985, 1988; Gabrieli and Keane 1988) or lexical decision (Gordon 1988; Smith and Oscar-Berman 1990; Verfaellie, Bauer, and Bowers 1991) in normal and amnesic people, the effects were not always consistent (Moscovitch 1985; Scarborough, Cortese, and Scarborough 1977).

As with duration, as better techniques were developed, it became apparent that the absence of a nonword priming effect is attributable more to the nature of the task than to some intrinsic property of nonconscious memory. Consider the instruction to complete a stem with the first item that comes to mind. The possibility of producing a correct nonword ending is virtually nil if the person has no explicit memory for the studied items. A word, rather than a nonword, is the most likely response. As support for this argument, Bowers and Schacter (1990, 1992) and Haist, Musen, and Squire (1991) showed that when the possibility of using explicit memory is reduced in normal people, through deception and by embedding very few target items in a very large set of lures, then their performance comes to resemble that of amnesics.

When lexical search is not a prominent feature of the task, as it is in stem completion, then repetition priming effects for nonwords are reported in both normal and amnesic patents, although the effects are not always consistent. Borrowing a technique from Moscovitch, Winocur, and Mahachlan (1986), Musen and Squire (1991) measured the time subjects took to read a list of nonwords. Reading times improved for lists of repeated but not of newly presented nonwords. This item-specific repetition effect was substantial—as great in amnesic patients as in normal control subjects—and was independent of their explicit recognition of the items. This finding has now been replicated in normal young people and in a population of old people (Light and Lavoie 1993).

Novelty: Unfamiliar Objects, Faces, and Melodies Evidence for perceptual repetition priming effects is stronger, and more consistent, when nonverbal stimuli are used. To our knowledge, there is only one study on implicit tests of novel, item-specific auditory information in amnesic patients. Johnson, Kim, and Risse (1985) demonstrated that a group of Korsakoff patients showed a normally enhanced preference for Korean tunes that they had recently heard. In contrast, their explicit memory for these tunes was severely impaired.

In the vast majority of studies, visual stimuli are used. In two similar studies, Gabrieli et al. (1990) and Musen and Squire (1992) showed that normal people and amnesic patients, including H.M., could retain a simple, meaningless visual pattern they had studied and reproduce it when given a matrix of dots to connect either spontaneously or in response to a subsequent brief exposure of the stimulus. Performance on this implicit test was independent of their explicit recognition of the pattern.

In an implicit test using novel faces, Johnson, Kim, and Risse (1985) found that preference ratings for faces varied according to whether the "story" presented with each face was positive or negative, even though their explicit memory for the stories and the faces was severely impaired. Paller et al. (1992) also reported normal priming in amnesic patients in a same-different face-matching task. Reaction times were faster to faces that had been seen once previously than to faces that were viewed for the first time.

The most extensive studies on perceptual, item-specific tests of memory for novel objects have been conducted by Schacter et al. (1990, 1991). In their studies, subjects are asked to examine novel, potentially three-dimensional line drawings that can represent objects that are structurally possible (can exist in the real world) whereas others are structurally impossible (like some figures by the artist Escher). When the drawings are exposed very briefly at test, the accuracy of determining whether the drawings are possible is higher for previously studied drawings of possible objects, and the effect is independent of the subjects' explicit recognition of the drawings. No repetition priming effect was observed for impossible objects in either normal or amnesic people.

Overall, there is converging evidence from studies of normal and amnesic people that perceptual repetition priming effects can be obtained for different types of novel items on various implicit tests.

Forming New Associations: Associative Repetition Priming Previous attempts to find associative repetition priming effects yielded inconclusive results. McKoon and Ratcliff (1979, 1986) reported finding associative repetition priming effects in a sequential, lexical decision task in normal people, but many investigators failed to replicate their findings (see reviews in Lewandowsky, Kirsner, and Bainbridge 1989; Moscovitch, Vriezen, and Goshen-Gottstein 1993). Graf and Schacter (1985) reported that word stem completion is greater when the stem presented at test is paired with a word with which it was associated at study than with a new word. Moreover, the effect was modality specific, consistent with the idea that it was mediated by input modules. Unfortunately, this associative priming effect was not found reliably in severely amnesic patients (Cermak, Bleich, and Blackford 1988; Mayes and Gooding 1989; Schacter and Graf 1986; Shimamura and Squire 1989) or in normal people who were truly unaware of the relation between study and test pairs (Bowers and Schacter 1990, 1992; but see Howard, Fry, and Brune 1991). Although some amnesic patients demonstrated the effect, the overall impression from these studies is that associative priming in stem completion has an explicit memory component.

Speeded reading may be a better implicit test of memory than stem completion because its rapid pace may not allow the intrusion of explicit retrieval strategies. Using speeded reading, Moscovitch, Winocur, and McLachlan (1986) had subjects study pairs of randomly associated words and at test had the subjects read lists of studied pairs, new pairs, or old words in new pairings.

All items were slightly visually degraded at test to slow reading speed and allow the priming effect to emerge. They found that reading speed was fastest for the studied pairs when the results from amnesic patients and normal people were combined, indicating that repetition priming effects can be found for newly formed associations. They obtained a similar but even stronger effect using sentences in which words could be interchanged to produce, at test, sentences that contained old words in new combinations (recombined sentences). Reading speed was fastest for the old, intact sentences than for recombined sentences. Musen and Squire (1993), however, could not obtain associative repetition priming in the word-pair experiment unless multiple learning trials were provided. It should be noted that their scoring and testing procedure differed somewhat from Moscovitch, Winocur, and McLachlan's and that they never attempted to replicate the sentence study that produced the stronger effect (but see Musen, Shimamura, and Squire 1990 for a comparable study on sentences with comparable results). In a subsequent experiment using perceptual identification as the measure, Musen and Squire did find a weak associative priming effect but only when the results from amnesic and normal control subjects were combined. Since then, however, Light and Lavoie (1993), using a similar but more sensitive procedure, have reported a strong associative repetition priming effect in normal young and old people.

The partial successes of the previous studies and the indication that priming of new associations is perceptual prompted Goshen-Gottstein and Moscovitch (1992) to design a new procedure for obtaining reliable associative repetition priming effects. As before, subjects studied simultaneously presented written pairs of randomly associated words. At test, old pairs, new pairs, and recombined pairs were again presented simultaneously, and subjects had to indicate whether both members of the pair were words. On negative trials, at least one member of the pair was a pronounceable but meaningless letter string.

This modified lexical decision task produced reliable associative repetition priming effects in normal people (table 25.2). Reaction times were about 50 ms faster for old than for recombined pairs, and the latter were about 70 ms faster than for new pairs. Changing modalities between study and test, from auditory to visual, eliminated the repetition priming effect, indicating that it was domain specific, resembling priming for single items in this regard. Most important, using this procedure, we have now obtained reliable repetition effects in amnesic patients with confirmed bilateral, medial temporal lobe lesions and in patients with right temporal lobectomy that included large hippocampal excisions.

Table 25.2 Reaction Times (in ms) to Lexical Decision for High- and Low-Frequency Pair Types

	Intact	Recombined	Control
High frequency	899	922	977
Low frequency	975	1053	1149

Speed of Acquisition Numerous studies have shown that perceptual repetition priming effects can be obtained after a single, brief exposure to the stimulus, and in many, but not all, cases the effect often is not augmented by increasing exposure duration and by multiple presentations. Sometimes the exposure duration can be as short as 100 ms (Hirshman and Mulligan 1991), or so brief that the subject is not even aware that a stimulus has been presented. Even such brief exposures are sufficient to produce small but long-lasting, perceptual repetition priming effects (for recent evidence and references, see Challis and Sidhu 1993; Hirshman and Mulligan 1991; Moscovitch and Bentin 1993; Roediger and McDermott 1993).

Summary

The foregoing review indicates that repetition priming effects that index performance on perceptual item-specific implicit tests are modality specific, format specific, and item specific. Also, studies on amnesic patients and on normal people indicate that conscious recollection has little or no effect on performance. In short, in a deep sense, the tests are true to their name: perceptual, item specific, and implicit. In addition, perceptual repetition priming effects are long-lasting; they can be obtained for novel and preexisting items and for newly formed associations; and the memories that mediate their effects can be formed rapidly in only one trial. The relevance of these findings to theories of repetition priming will be examined in the next section.

25.4 THEORIES OF PERFORMANCE ON PERCEPTUAL ITEM-SPECIFIC IMPLICIT TESTS OF MEMORY

A number of different types of theories have been proposed to account for perceptual repetition priming effects and their dissociation from performance on explicit tests of memory. We will sketch some of the main ones, noting their strengths and deficiencies, and propose a conceptual framework based on components consisting of modules and central systems.

Activation/Elaboration

When perceptual repetition priming effects were first reported in normal and in amnesic people, they were interpreted as arising from the temporary activation of preexisting, abstract representation in semantic memory (Graf, Mandler, and Haden 1982; Graf and Mandler 1984; Morton 1969; Mandler 1980; Rozin 1976; Diamond and Rozin 1984). On the other hand, the formation, retention, and recovery of long-term memories that support performance on explicit tests depend on elaboration that involves processing the stimulus information meaningfully, forming associations to it, generating images, and so on. Very soon, evidence that repetition priming was modality specific forced the abandonment of the notion that the activated representations were abstract in favor of the idea that they were modality specific (Jackson and Morton 1984). The more recent finding that repetition priming is long-lived and can be obtained for novel material and associations effectively disconfirms the two remaining postulates of the theory: namely, that the activation is temporary and that only preexisting representations can be primed. As Roediger and McDermott (1993) rightly note, these setbacks have induced proponents of the theory to modify it so that it has come to resemble transfer-appropriate-processing theories (Graf, chap. 27, this volume).

Transfer-Appropriate-Processing Theories

The transfer-appropriate-processing approach states that the degree of transfer between study and test depends on the overlap between the processes instituted on both occasions (Morris, Bransford and Franks 1977; Bransford et al. 1989; Kolers 1973; Kolers and Roediger 1984). The less the overlap is, the greater is the likelihood of finding dissociations. The dissociations and independence between implicit and explicit tests of memory arise because implicit tests are primarily mediated by data-driven perceptual processes and explicit tests are driven by conceptual processes (Blaxton 1989; Roediger 1990; Roediger, Weldon, and Challis 1989). The idea that performance on implicit tests is data driven is consistent with the finding that perceptual priming effects are sensitive to manipulations of physical features but are relatively unaffected by semantic variables. Using this interpretation, proponents of the transfer-appropriate-processing approach have also accounted for dissociations among various implicit tests of memory, so long as one is conceptual and the other perceptual (Blaxton 1989; Roediger 1990). Independence between two purportedly data-driven tests might cause difficulties for this approach (Hayman and Tulving 1989; Witherspoon and Moscovitch 1989), but there is always the recourse that finer distinctions among the processes can be made.

Despite its success (Roediger and McDermott 1993), a major deficiency with this approach is that it does not capture fully the difference between conscious recollection and memory without awareness at either the phenomenological or the empirical level. The division into conceptual and data-driven processes is not adequate for this purpose. If most explicit tests of memory are conceptually driven, then no dissociations should be found in amnesics or normal people between explicit and implicit tests that are conceptually driven; yet there is evidence from both populations that contradicts this prediction (Gardner et al. 1973; Tulving, Hayman, and MacDonald 1991; Graf, Shimamura, and Squire 1985; Roediger 1990; but see Blaxton 1992). In addition, by concentrating on processes to the exclusion of structure, the approach effectively forfeits the opportunity to relate its data and theory to neurology. Except for the rare study (Blaxton 1992), the neuropsychological field has been relinquished to the system theorists.

Memory Systems Theories

At first only two memory systems were postulated—one for dealing with explicit tests and one for implicit tests—though the organization and characteristics of the systems varied from theory to theory (Schacter 1987a; Squire 1992). As more was learned about memory without awareness and as dissociations were found among implicit tests, in both normal people (Witherspoon and Moscovitch 1989) and neurological patients (Butters, Heindel, and Salmon 1990; Heindel et al. 1989), proponents of the memory systems approach began to fractionate implicit memory into various subsystems (Butters, Heindel, and Salmon 1990; Heindel et al. 1989; Keane et al. 1991; Squire 1992; Tulving and Schacter 1990; Schacter 1992). This trend is considered disturbing by critics of memory systems theories because they fear that systems theorists have abandoned strict criteria for proposing memory systems (Sherry and Schacter 1987) for the more expedient option of postulating a system every time new dissociations are discovered.

We think that systems theorists would concede that the main deficiency of their approach is that it has difficulty in dealing with dissociations within its major divisions, but it is premature to accuse them of being unprincipled. The subsystems are still linked to the processes they are presumed to mediate and to the neural substrates whose damage leads to deficits that implicate only the affected subsystem.

Using these guidelines, systems theorists have made impressive advances in identifying at both a functional and a neurological level a collection of subsystems that mediate performance on perceptual-item-specific implicit tests of memory. This collection, called a perceptual representation system (PRS) by Schacter and Tulving (Schacter 1990a, 1992; Tulving and Schacter 1990), consists of separate, domain-specific processing units that are involved in deriving and storing a structural, presemantic representation of stimulus input. The output from these systems can activate nonconscious procedural systems, which can influence behavior without awareness, or the output can be delivered to a conscious awareness system (CAS) (Schacter 1989), which would lead to the phenomenological awareness of the perceived material. Reactivation of the stored, domain-specific structural representations results in perceptual repetition priming effects and accounts nicely for the perceptual, nonsemantic aspects of those effects. Performance on other implicit tests, such as conceptual or sensorimotor, is believed to be mediated by other systems (Butters, Heindel, and Salmon 1990; Heindel et al. 1989). As for performance on explicit tests, systems theorists consider that it is mediated by yet another system that processes rich, multimodal, contextual information and is centered on the hippocampus and related structures in the medial temporal lobe and diencephalon (Squire 1992). As with perceptual representation systems, rich memory traces become available to consciousness by interacting with the CAS (Schacter 1989).

In many ways, the new version of the systems theorists, consisting of many subdivisions within a larger system, is similar to the components of processing theory that Moscovitch and Umiltà developed at about the same time (Moscovitch 1989, 1992a, 1992b; Moscovitch and Umiltà 1990, 1991; Witherspoon and Moscovitch 1989). There are, however, some important differences, which we will note after presenting the theory.

Components of Processing Theory

The central idea is that memory is not unitary but depends on the operation of potentially independent, but typically interactive, components that are assembled for use in a given task. Dissociations in performance on different tests of memory are determined by the extent to which they recruit different components, leaving open the possibility that some components may be more critical than others.

The components approach, therefore, accepts as its initial assumption what systems theorists were led to conclude after their simple models failed: that each system is divisible into separate components. Insofar as components have certain processes associated with them, they can incorporate many of the data gathered by proponents of the transfer-appropriate-processing theorists. Like systems theory, the components approach does not hold that components are isolable, free-floating units. The function the component serves in behavior is determined not only by its internal organization but probably also by a network of connections to other components, which together form a functional unit or system. A single component can belong to a number of different systems. The unit of analysis is not the large-scale system but the smaller components and their interactions with each other. The components approach, therefore, provides a middle ground between systems and processing theories of memory.

The particular version of a component of processing approach to memory that Moscovitch and Umiltà advocate is based on Fodor's (1983) proposal that modules and central systems are the constituents of mind (and brain). Although Moscovitch and Umiltà took exception with some of Fodor's ideas and modified them accordingly, they retained what they believed were his core assumptions and suggested how his criterion of modularity can be translated at a neuropsychological level (for details, see Moscovitch and Umiltà 1990, 1991).

Modules are computational devices that have propositional content and satisfy all of the following three criteria: domain specificity, informational encapsulation or cognitive impenetrability, and shallow output. Domain specificity entails that the type of information modules accept for processing is restricted or circumscribed. Informational encapsulation implies that modules are resistant to the effects of higher-order knowledge on processing and are cognitively impenetrable to probes of their content or operation. Only the module's shallow output is available for conscious inspection. Shallow output is output that has no meaning beyond the value assigned to it by the module; interlevel representations that led to the shallow output are not available for conscious inspection.

Thus, a module, no matter how complex its inner workings, is essentially a "stupid," closed computational device that delivers its shallow output to interpretative central systems where meaning and relevance are assigned and where strategies and plans can be devised to guide thought and action. None of the criteria of modularity applies to central systems (but see Moscovitch and Umiltà 1990 for some provisos). Unlike modules, central systems integrate information from superficially dissimilar domains and are open to top-down influences. The output of central systems is deep or meaningful, and the interlevel representations that give rise to the final output may be available to consciousness. These characteristics of modules and central systems will become critical in our analysis of the relationship between consciousness and memory.

Registration: The Rapid Formation of Records by Neocortical Structures

According to the components' approach, performance on item-specific, implicit tests of memory is mediated by the very structures involved in picking up and interpreting incoming stimulus information: the perceptual input modules and semantic central systems. The perceptual input modules pick up and transform stimulus events into structural, presemantic representations. The shallow output of these modules is delivered to central system structures for early semantic interpretation. In processing this information, the input modules and interpretative central systems are modified, thereby leaving, respectively, a perceptual and semantic record (Kirsner and Dunn 1985) of their activity. The altered neuronal circuitry (which may involve strengthening old synapses and creating new connections) that underlies the records preserves information about the stimulating event and enables subsequently related events to be processed more quickly. Reactivation of perceptual and semantic records is the basis for perceptual and conceptual repetition priming effects, respectively. The formation of long-term records is called registration, a term I (Moscovitch 1992) proposed so as to distinguish this process from consolidation, which involves the formation of long-term, episodic memories that are involved in conscious recollection.

As is apparent, perceptual input modules are similar to the system theorists' perceptual representation systems. Both share the characteristic of being domain specific and of representing presemantic, structural information. As such, both account for evidence that perceptual repetition priming effects are modality and format specific. Being caused by reactivation of perceptual records, the repetition priming effect must preserve the form of representation characteristic of the module or PRS that is being altered. For that reason as well, semantic variables have little influence on perceptual repetition priming effects since the perceptual record is not semantic. Because perceptual input modules and PRS are necessary for the structural identification of objects, sounds, words, and so forth, they must by necessity be modifiable by experience to represent the myriad of items we encounter in our lives. This quality is manifested in the rapid registration of novel information which accounts for repetition priming effects for unfamiliar items.

The idea that perceptual records retain information of the activity of modules is consistent with one of the main assumptions of transfer-appropriate-processing theory and provides a bridge between structurally based, representational theories and processing theories of repetition priming. To account for dissociations within a particular domain, such as between two types of repetition priming tests for words (Witherspoon and Moscovitch 1989), it is necessary to postulate that, in addition to the record of the item, the processes involved in gaining access to it must differ across tasks. These processes or procedures must also be modified with experience independent of the item and reactivated as needed (McAndrews and Moscovitch 1990; Schwartz and Hashtroudi 1991; Moscovitch 1992a, p. 265).

Anatomical Localization of Perceptual Input Modules and PRS

Evidence from patients with agnosia, dyslexia, and dementia indicates that modules and PRS are not mere hypothetical constructs but are localizable to structures in the posterior neocortex, in what Luria (1966) called secondary zone structures. Thus, damage to those structures leads to modular deficits: visual word form deficits (word form dyslexia) are associated with left extrastriate, occipital cortex lesions (Warrington and Shallice 1980); phonological or auditory word form deficits (pure word deafness) with left, superior posterior temporal lesions (Kohn and Friedman 1986; Saffran and Marin 1977); face recognition deficits (prosopagnosia) with right or bilateral lingual and fusiform cortex lesions (Sergent, MacDonald, and Zuck, chap. 8, this volume; Young, chap. 6, this volume) and object recognition deficits (visual object agnosia) with temperoparietal lesions, possibly bilaterally (Warrington and Taylor 1978; see McCarthy and Warrington 1990 for review). Recent positron emission tomography (PET) studies conducted on normal people and using subtraction techniques have corroborated the evidence from lesion studies that the aforementioned regions are critical for performance on the perceptual tasks believed to be mediated by the various modules (Peterson et al. 1989).

Additional evidence, however, is needed to confirm that the structures in the posterior neocortex support perceptual repetition priming effects. These effects should be present in patients whose input modules are sufficiently intact to pick up information and absent, or greatly reduced, in patients with damage to those modules. Though incomplete, the evidence is generally consistent with this prediction.

One source of evidence comes from a variety of different patient groups who show normal perceptual repetition priming effects despite poor performance on explicit tests of memory, other types of implicit tests, or both. Thus, perceptual repetition priming effects are well preserved in amnesic patients with damage to the hippocampus and surrounding cortex in the medial temporal lobes, as well as to related limbic structures in the diencephalon (Moscovitch, Vriezen, and Goshen-Gottstein 1993; Shimamura 1986; Squire 1992).

Similarly, patients with Alzheimer's disease whose pathology spares the sensory or parasensory areas of the posterior neocortex perform well on most perceptual, item-specific tests of memory but poorly on conceptual tests and on explicit tests (Keane et al. 1991; Moscovitch, Vriezen, and Goshen-Gottstein 1993). Patients with Parkinson's or Huntington's disease, which affect the basal ganglia and, indirectly, the frontal cortex (Butters, Heindel, and Salmon 1990; Heindel et al. 1989) and patients with frontal lesions (Shimamura, personal communication) are not impaired on perceptual, item-specific tests, though their performance on procedural tests of memory is often compromised (Butters, Heindel, and Salmon 1990; Heindel et al. 1989; Shallice 1982).

A valuable potential source of evidence are functional neuroimaging studies of repetition priming effects in normal people. As yet, only one PET study using the subtractive technique (Peterson et al. 1989) has been published showing that repetition priming effects in word stem completion are associated with reduced activation in the extrastriate cortex in a region corresponding to the visual word form system (Squire et al. 1991). Of concern, however, is that the target area is in the right hemisphere, rather than left, where the visual word form system had been identified in both lesion and PET studies (Peterson et al. 1990; Warrington and Shallice 1980). Squire et al. (1991) argue that the homologous region on the right side stores information about sensory features of words. This suggestion is consistent with evidence from tachistoscopic visual half-field studies (Marsolek, Kosslyn, and Squire 1992) and dichotic listening studies (Schacter 1992) that repetition priming effects that are sensitive to changes in surface features are associated only with left field/right hemisphere presentation. These right hemisphere modules that are sensory sensitive are the mates of corresponding left hemisphere visual word form and phonological word form modules that code information about format-invariant graphemic and phonological features of words, respectively. The evidence for corresponding, but different, left and right modules is in line with studies of left and right hemisphere reading (Moscovitch 1976, 1981; Rabinowicz and Moscovitch 1984; Coslett and Saffran 1989; Patterson, Vargha-Khadem, and Polkey 1989; Zaidel and Peters 1981; Coltheart 1980) and speech perception (Schacter 1992; Zaidel 1985). Nonetheless, because there has been some difficulty in replicating the PET (Raichle, personal communication) and visual half-field studies (Tulving, personal communication), the results must be treated with caution until further work confirms them.

Perception without Awareness Leads to Memory without Awareness

The most interesting evidence in favor of the modularity hypothesis of repetition priming comes from agnosic patients whose modules or PRS are sufficiently intact to process information but who are not consciously aware of the information they processed (Moscovitch and Umiltà 1990, 1991; Schacter, McAndrews, and Moscovitch 1988). In other words, these are patients who show evidence of preserved perception on implicit, but not explicit, tests of knowledge. If the mere pick-up of information by the module is sufficient to modify it and leave a perceptual record of the stimulating event, then normal repetition priming effects should be evident in patients who have implicit, perceptual knowledge but not in patients whose implicit, as well as explicit, knowledge is absent.

These hypotheses have been fully confirmed in prosopagnosic patients who show evidence of face perception without awareness (De Haan, Young, and Newcombe 1987; Bauer 1984; Tranel, Damasio, and Damasio 1985) and whose damage presumably spares the lingual and fusiform cortex (Sergent, MacDonald, and Zuck, chap. 8, this volume; Young, chap. 6, this volume). Such patients have strong priming effects for familiar and unfamiliar faces (Greve and Bauer 1990; De Haan, Bauer, and Greve 1992; Sergent, MacDonald, and Zuck, chap. 8, this volume; Young, chap. 6, this volume). On the other hand, prosopagnosic patients who cannot distinguish between familiar and unfamiliar faces even on implicit tests of knowledge (Young, this volume) also do not show repetition priming effects for faces (De Haan, Young, and Newcombe 1987; Sergent, MacDonald, and Zuck, chap. 8, this volume).

With regard to the visual word form module, Schacter et al. (1990) reported normal repetition priming effects in a dyslexic, letter-by-letter reader who has a viable visual word form system. Although she could not read explicitly words that were presented briefly, her identification of tachistoscopically presented words improved dramatically if she had been previously exposed to them. Repetition priming in this patient is observed only if presentation at study is visual rather than auditory, consistent with the idea that modules or PRS are domain specific. No repetition priming studies have yet been reported in patients, such as surface dyslexics, whose word form module is damaged but who can read using another route.

These findings on different types of agnosic patients are consistent with evidence of substantial and long-lasting perceptual repetition effects in studies of normal people in which the stimulus is so degraded that the subject is often not aware of it and his or her explicit recognition of it is at chance (Kunst-Wilson and Zajonc 1980; Merikle and Reingold 1991; Seamon, Brody, and Kauff 1983; for a summary of studies see Moscovitch and Bentin 1993). Similarly, reducing awareness by engaging attention with a demanding concurrent task at study has relatively little influence on perceptual, item-specific implicit tests of memory but a marked influence on explicit tests (Eich 1984; Jacoby, Woloshyn, and Kelley 1989; Parkin, Reid, and Russo 1990). Most impressive of all are a number of reports that repetition priming can be observed for items that are picked up even while the individual is anesthetized (Kilstrohm et al. 1990; Kilstrohm and Conture 1992; Bonke, Fitch, and Millar 1990).

These demonstrations in normal people use repetition priming as evidence for perception without awareness. It is informative and important that independent evidence of perception without awareness be provided in studies of normal people as it was in studies of brain-damaged patients.

25.5 WHY REPETITION PRIMING EFFECTS ARE NOT ASSOCIATED WITH CONSCIOUS RECOLLECTION OF THE TARGET EVENT

Having reviewed the empirical and theoretical literature on implicit tests of memory, we can now turn to the central question regarding the relationship between consciousness and memory: Why should the "memory" that is registered by input modules or PRS not be made conscious? Why can't perceptual records retain their properties yet still give rise to memory with conscious awareness when they are reactivated? There seems to be nothing inherently contradictory about this, yet it does not occur. Not unexpectedly, the answers to these questions are influenced by the theories that the authors hold.

Processing Theories

As Roediger and McDermott (1993) admit, "The transfer appropriate processing approach has virtually nothing to say about the important issue of consciousness in intentional and incidental retrieval" (p. 118). This statement may be too strong, but insofar as it has something to say about consciousness, it concerns the processes that can be used to distinguish conscious from nonconscious retrieval of memories. (See, for example, Jacoby, chap. 26, this volume; Graf, chap. 27, this volume.) Processing theorists have made important contributions for devising techniques that provide markers of consciousness but have shied away from the question of why conscious awareness accompanies some memories but not others.

Systems and Content Theories

According to some systems theorists, like Schacter (1989, 1990b) whose views we partially share (Moscovitch 1989; Schacter, McAndrews, and Moscovitch 1988), there is a system for consciousness, the CAS, just as there are systems for perception. For any mental event to become conscious, it must first gain access to the CAS. Thus, when a record in a PRS or input module is reactivated, it produces an output that is consciously experienced as a percept, not a memory, when it contacts the CAS. To explain why it is not experienced as a memory, Schacter provides an explanation in terms of the content of the record. Because "access of an activated representation to CAS does not provide any *contextual information* [our italics] about the occurrence of a recent event, [it] therefore does not provide a basis for explicit remembering" (p. 367). In other words, explicit remembering involves not just consciousness but some added content: the context in which the target item that gave rise to the percept occurred. Yet Schacter's own work on source amnesia or forgetting contradicts this statement: normal people and amnesic patients can have explicit memory for the target without memory for the context (Schacter, Harbluk, and McLachlan 1984; Schacter 1987b). Moreover, it is not inconceivable that one will find that performance on implicit tests might be influenced by context (Oliphant 1983; MacLeod 1989; Masson and Freedman 1990; Goshen-Gottstein and Moscovitch 1992; Graf, chap. 27, this volume; Lewandowsky, Kirsner, and Bainbridge 1989). Consciousness, not context, is the critical element of explicit remembering.

Other systems theorists, like Tulving (1985), on the other hand, hold that different kinds of consciousness are inherent properties of specific memory systems. Autonoetic (knowing with the self in it) consciousness is "correlated with episodic memory. It is necessary for the remembering of personally experienced events.... It is autonoetic consciousness that confers the phenomenal flavour to the remembering of past events, the flavour that distinguishes remembering from other kinds of awareness such as those characterizing perceiving, thinking, imagining or dreaming" (p. 3). According to Tulving, the system mediating performance on perceptual item-specific implicit tests is characterized by anoetic consciousness. Tulving's proposals are inconsistent with the idea that all systems or modules feed into a common consciousness system. Because Schacter believes they do, he is forced to say that the memories must be distinguished on the basis of content, of some properties other than consciousness, but we have seen that this is not always the case in principle or in fact. Tulving's proposal, though appealing on some grounds, lacks any principled rationale for assigning different types of consciousness to different systems. Tulving answers the question with which this section began by definition. Anoetic consciousness is an attribute of repetition priming as much as "autonoetic consciousness is a *necessary correlate* of episodic memory.... There is no such thing as 'remembering without awareness.' Organisms can [perceive] behave and learn without (autonoetic) awareness, but they cannot *remember* without awareness" (p. 5). But why? What is it about these systems that makes them that way?

Component Theory

According to component theory, the answer lies in combining aspects of Tulving's and Schacter's explanations. Rather than being dichotomous, their explanations can become complementary. As Schacter asserts, processes that are confined to perceptual modules do not give rise to conscious experience. Some interaction with other functional systems or components is necessary for phenomenal awareness to occur. Yet whether that interaction gives rise to a sense of familiarity, a recollection of the past, or a thought or percept without a sense of familiarity is not simply a function of contacting or failing to contact the CAS but of the properties of the perceptual modules themselves. By virtue of their being modular, perceptual representation systems cannot by their nature give rise to a sense of familiarity. That perceptual repetition priming effects are not accompanied by memory with awareness follows from the fact that they are mediated by input modules.

Being shallow, the output of perceptual input modules, is presemantic and ahistorical in the sense that it conveys no information on how the output was derived. All that can be made conscious on the basis of this output is information at the level at which the module processes it and commensurate with the domain-specific representation that the module forms. Typically, it is information about the structural features of the processed stimulus. What perceptual input modules make available to consciousness is a percept stripped of meaning and history, though the percept may be contextually bound at the perceptual level (Goshen-Gottstein and Moscovitch 1992) and may be delivered more quickly and fluently with repetition. But it is still a percept and not a memory, not even an impoverished one. Even if we supposed that the modules retained but did not deliver some historical information about the perceptual record's antecedents, the criterion of informational encapsulation indicates that we cannot penetrate the module to gain conscious access to that information. Finally, because the pickup of domain-specific information is obligatory, conscious awareness need not accompany this process or the formation of perceptual records.

Jacoby (1983) has argued that perceptual fluency associated with more rapid identification of repeated, as opposed to new, stimuli can give rise to a feeling that the target stimulus had been encountered previously (Johnson, Dark, and Jacoby 1985). As Jacoby and his colleagues have indicated, this sense of familiarity is an attribution based on perceptual judgments; it is not an attribute of the information that the shallow output conveys. What the subject experiences is that perception proceeded fluently and from that he or she infers that the stimulus so perceived may have been familiar (but see Brooks and Watkins 1989; Watkins and Gibson 1988, who even dispute that perceptual fluency can be the basis for recognition based on familiarity).

25.6 WHY CONSCIOUS AWARENESS ACCOMPANIES PERFORMANCE ON EXPLICIT TESTS OF MEMORY: A THEORY OF CONSCIOUS RECOLLECTION AND HIPPOCAMPAL FUNCTION

We can now address the converse question: Why does some of the information we retain carry with it a subjective awareness of pastness when it is recovered? What confers a conscience sense of familiarity to our memories that is immediate and not inferential?

One suggestion is that the formation and retrieval of semantically rich, contextual associations leads to conscious remembering when they contact the CAS (Mayes 1992; Schacter 1989). As we noted earlier, not all conscious recollection is accompanied by memory for context (Schacter, Harbluk, and MaLachlan 1984), and there is suggestive evidence that contextual information can improve performance on implicit tests without an accompanying sense of familiarity (Graf, chap. 27, this volume). The "contextual" hypothesis deals with the content of that which we are consciously aware of as a memory rather than with the conscious awareness itself.

We side with Tulving's (1985) proposal that conscious awareness, autonoetic consciousness, is a property of explicit remembering. To understand what this means and how it comes about, we offer a theory based on a component process model of hippocampal function (for more details, see Moscovitch 1992a, 1992b, 1994).

The central idea is that the hippocampal component, which consists of the hippocampus and related structures in the medial temporal lobe and diencephalon, acts as an associative, episodic memory module that mandatorily picks up information that is consciously apprehended. To the extent that an event does not receive full conscious awareness, it is not picked up by the hippocampal component. Using reciprocal pathways that connect parts of the hippocampal complex to the cortex, the hippocampal component binds or integrates into a memory trace the neural elements that mediate the information that constituted the conscious experience. That includes the collection of records or engrams of the modules and central systems whose output formed the content of the conscious experience as well as whatever component processes made the experience conscious. In this way, "consciousness" is bound by the hippocampal component to other aspects of the event and becomes an intrinsic property of the memory trace. The process-involved in the formation of episodic memory traces is known as consolidation. The memory trace is then encoded as a file entry or index within the hippocampal component.[1]

At a neurophysiological level, one can think of collections of neurons or cell assemblies whose firing pattern determines the different properties of the event we experience—its color, form, texture, spatial relations, and so on. Insofar as conscious awareness is a quality of our experience, there also must be neural correlates of it that interact with these cell assemblies or are part of them. It is this network of cell assemblies, which includes the neural correlates for consciousness, that are bound together.

To recollect an event consciously, the memory trace must be reactivated. This occurs when an external or internally generated cue automatically interacts with the memory trace, a process called ecphory (Semon 1921; cited in Schacter, Eich, and Tulving 1978). If the event was experienced recently, the hippocampus may still be needed to keep the elements of the trace bound together and so it participates, indirectly, in the ecphoric process. For remote events, the hippocampus is not involved.

In previous papers, it was stated that the product of the ecphoric process is delivered to consciousness (Moscovitch 1989, 1992a, 1992b). This language suggests that there is a system, such as Schacter's (1989) CAS, that confers consciousness on information that gains access to it. If "consciousness," however, is an intrinsic property of the memory trace, it may be more appropriate to say that the product of the ecphoric process becomes conscious, as if ecphory enabled that which was dormant to become active. In either case, the important point is that "consciousness" is recovered along with other elements of the memory trace: *consciousness in, consciousness out.*

It is the recovery of a trace imbued with consciousness that makes it feel familiar and immediately recognizable as something that had been previously experienced. This *recovered consciousness* is the signal that distinguishes a memory from thoughts and perceptions and is at the core of conscious recollection. With respect to remembering, and perhaps with respect to no other function, "consciousness" is an inherent property of the very thing we apprehend (see also Bentin, chap. 22, this volume).

We have tried to convey the central idea of a theory that accounts for the relationship between consciousness and memory. Elsewhere, we have discussed more fully other aspects of this theory and its implications, as well as considered the role of other components that contribute to successful remembering (Moscovitch 1992a, 1992b, 1994). Because our subject is implicit memory, we end with a brief review of other implicit tests of memory (for extended reviews, see Moscovitch, Vriezen, and Goshen-Gottstein 1993; Roediger and McDermott 1993).

25.7 CONCEPTUAL, ITEM-SPECIFIC TESTS OF MEMORY

Conceptual tests are distinguished from perceptual ones in that a semantic, rather than a perceptual, cue is provided to help elicit the target. For example, after studying a set of words that are drawn from different superordinate categories, subjects may then be given a category name and asked to supply the first exemplars that come to mind. Conceptual repetition priming effects are obtained if the exemplars generated are influenced by exposure to them at study.

Using techniques of this sort, it has been shown that conceptual repetition priming effects, unlike perceptual ones, are neither modality nor format specific but rather are influenced by levels of processing manipulations and by number of repetitions (Roediger and McDermott 1993). They are also quite susceptible to interference (Mayes, Pickering, and Fairbairn 1987; Winocur and Moscovitch 1994; Winocur and Weiskrantz 1976) whereas perceptual repetition priming effects are relatively resistant to interference (Graf and Schacter 1987).

The variables influencing performance on conceptual implicit tests are similar to those that affect explicit tests, suggesting a deep link between them that has yet to be explored empirically or theoretically. Nonetheless, performance on conceptual implicit tests is dissociable from performance on explicit tests in both normal people and amnesic patients (Roediger and McDermott 1993; Tulving, Hayman, and MacDonald 1991). Amnesic patients with medial temporal/hippocampal or diencephalic damage can perform well on various conceptual implicit tests while failing utterly on comparable explicit tests (for references, see Moscovitch, Vriezen, and Goshen-Gottstein 1993).

These results are consistent with the view that performance on conceptual implicit tests is mediated by central system, semantic structures that interpret the shallow output of perceptual modules and store a semantic record of their activity or representations (Moscovitch 1992a, 1992b; Tulving and Schacter 1990). As predicted by this interpretation, conceptual repetition priming effects are eliminated by damage to association cortex, particularly the temporal lobes, caused by degeneration, as in Alzheimer's disease (Martin 1992; Salmon et al. 1988), or by surgical excision (Blaxton 1992). Perceptual repetition priming effects, however, are preserved (Keane et al. 1991).

According to our theory, only those memory traces that have consciousness bound to them can support explicit remembering. Though central system structures that retain semantic records are open to conscious influences, there is no indication that the record itself contains more than semantic information. As a result, reactivating it cannot lead to conscious recollection. The same principle applies in considering performance on procedural, implicit tests.

25.8 PROCEDURAL TESTS

Procedural tests assess learning and retention of sensorimotor skills, procedures, and rules. Of the various types of tests, procedural ones are the most heterogeneous, consisting of a large variety of subtypes whose components are often difficult to specify. The tests range from mastering a sensorimotor skill (e.g., pursuit rotor or mirror drawing) to acquiring general perceptual skills (reading geometrically transformed texts) to learning and applying the rules or contingencies necessary to solve intellectual puzzles such as the Tower of Hanoi. Even classical or operant conditioning is considered by some to be a subtype of implicit procedural tests of memory (Squire 1992).

Some of the literature and many of the issues involving different types of procedural tests of memory are covered in the section on implicit learning in this volume. One of the primary questions addressed by the authors is whether learning is truly implicit, that is, whether subjects are aware of the knowledge they have acquired (Berry, chap. 30, this volume; Perruchet, chap. 32, this volume). A related question is whether conscious awareness is necessary at acquisition or retrieval. Taken together, the chapters in the section on learning (this volume, part VIII) offer a balanced review of a literature that is still grappling with these questions. There is an important distinction, however, that the authors did not consider in trying to determine whether procedural knowledge is implicit or explicit. The distinction concerns the relation of procedural knowledge to memory. The question of whether the knowledge subjects have of certain contingencies or rules is explicit or implicit is logically, but not necessarily empirically, orthogonal to the question of whether they can consciously recollect acquiring that knowledge. Thus, for example, it is possible that amnesic patients can acquire knowledge of serial sequences (Nissen, Willingham, and Hartman 1989) or the rules of artificial grammars (Knowlton, Ramus, and Squire 1992) and even know what those sequences or rules are explicitly, at least according to criteria that some authors wish to apply. Yet the same patients may lack explicit memory for how they came to acquire that knowledge, much as we lack explicit memory for our own semantic or procedural knowledge. In short, it is important to distinguish between implicit and explicit knowledge of procedures and implicit and explicit memory for them. What is striking in reviewing the neuropsychological literature is that there is double dissociation between them: a failure by some subjects, such as patients with basal ganglia damage, to acquire procedural knowledge with intact memory for the acquisition episodes (Butters, Heindel, and Salmen

1990) and the reverse effect in other types of subjects such as amnesic patients and patients with Alzheimer's disease.

In the brief review that follows, we will deal almost exclusively with the neuropsychological literature on two subtypes of procedural implicit tests: those that involve (1) sensorimotor learning and (2) learning rules and organized, response sequences. (For more detailed reviews, see Moscovitch, Vriezen, and Goshen-Gottstein 1993; Butters, Heindel, and Salmon 1990 and part VII, this volume).

Sensorimotor

Moscovitch (1992a, 1992b) has speculated that sensorimotor implicit tests are the procedural counterpart to perceptual item-specific tests. Improved performance on them, sometimes called habit formation (Mishkin and Appenzeler 1987), depends on the modification of neural structures associated with both sensory and motor functions that are involved in executing the task. Put another way, improved performance depends on the registration of sensorimotor records.

At the neuropsychological level, this hypothesis predicts that deficits on sensorimotor implicit tests should be associated only with damage to sensorimotor structures, such as the basal ganglia, that are involved in executing the tasks. To the extent that these structures are not involved in item-specific tests, there should be evidence of double dissociation between them and sensorimotor tests. Also, since sensorimotor tests are implicit tests of memory, performance on them should be independent of explicit tests and be preserved in amnesic patients.

By and large, the neuropsychological literature is consistent with these predictions. Deficits on sensorimotor tests such as pursuit-rotor, prism-adaptation, and sensory-adaptation level effects in a weight judgment task have been noted in patients with Parkinson's or Huntington's disease. These are neurodegenerative disorders that affect the basal ganglia, structures that are part of the extrapyramidal motor system (Benzig and Squire 1989; Heindel, Salmon, and Butters 1990; Canavan et al. 1990). Similar deficits are noted in these patients in acquiring general perceptual skills, such as are involved in reading geometrically transformed script and identifying degraded pictures (Bondi and Kaszniak 1991; Martone et al. 1984; but see Moscovitch, Vriezen, and Goshen-Gottstein 1993 for exceptions and for a discussion of the association between performance on procedural tests and degree of motor impairment and dementia). Importantly, performance on perceptual item-specific tests is spared in these patients as is memory on those explicit tests that do not have a strategic, retrieval component (Butters, Heindel, and Salmon 1990; Moscovitch 1989, 1992a, 1992b).

By contrast, and as predicted, sensorimotor learning on a wide variety of tests is spared in amnesic patients with damage to the medial temporal/hippocampal region and to diencephalic structures (Butters, Heindel, and

Salmon 1990; Corkin 1965; Milnes 1966; Moscovitch, Vriezen, and Goshen-Gottstein 1993; Squire 1992) and in patients with Alzheimer's disease whose pathology affects neocortical structure much more severely than the basal ganglia (Bondi and Kaszniak 1990; Butters, Heindel, and Salmon 1990; Moscovitch, Vriezen, and Goshen-Gottstein 1992).

Ordered/Rule Based

Improved performance on implicit tests that require mastering rules or organized sequences demands planning, hypothesis formation and testing, organization, and monitoring of response sequences in addition to mere repetition. Performance on tests in which such strategic, organizational factors play an important role is expected to be adversely affected by frontal lesions or frontal dysfunction that accompanies some neurological disorders. This seems also to be the case for rule-based implicit memory tests, but there is still too little evidence to assert this with confidence.

The most extensively studied test is the Tower of Hanoi, in its various versions. In this task, subjects must move a set of discs graded in size, one at a time, from the first of three posts to the third, such that a larger disc never comes to rest on a smaller one. Improved performance depends on acquiring a cursive rule. Patients with focal frontal lesions are impaired in learning even simple versions of this test (Shallice 1982; Owen et al. 1990), as are patients with frontal dysfunction associated with basal ganglia disorders (Saint-Cyr, Taylor, and Lang 1988). Amnesic patients can master at least simple versions of the task (Cohen et al. 1985; Saint-Cyr, Taylor, and Lang 1988), unless, like Korsakoff amnesics, they also have noticeable frontal impairment (Joyce and Robbins 1991; Butters et al. 1985).

Performance on other rule-based tests, such as learning mathematical rules (Kinsbourne and Wood 1975; Nichelli et al. 1988; Charness, Milberg, and Alexander 1988; Milberg et al. 1988), is preserved in amnesia and may even be normal in Korsakoff amnesics with frontal dysfunction if the rules did not have to be derived and their application provided little opportunity to diverge from the goal-directed path.

Similarly, amnesic patients, including Korsakoff amnesics, can learn artificial grammars (Knowlton, Ramus, and Squire 1992) and a repeating ten-trial sequence of lights in a serial reaction time test (Nissen, Willingham, and Hartman 1989; but see the critique in Perruchet, chap. 32, this volume). It has yet to be determined, however, whether patients with frontal lesions or more severe frontal dysfunction can learn these tasks.

What is critical in testing the "frontal-lobe hypothesis" is whether organizational factors are necessary in learning tasks that are ostensibly rule based and sequential but can be mastered by simpler means. For example, Cohen, Ivry, and Keele (1990) have noted that the sequence in Nissen, Willingham, and Hartman's (1989) serial reaction time test can be learned as a simple chain of responses (nonorganizational) or as a nested hierarchy of responses with subgroups at different levels (organizational). Patients with frontal deficits should be impaired only on the latter test. It is significant in this regard that old people, in whom frontal dysfunction is not uncommon (Moscovitch and Winocur 1992a,b), are only impaired at learning based on hierarchy formation (Jackson and Jackson 1992).

NOTES

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1. Alternatively, the hippocampus may be necessary initially and temporarily only for keeping elements of the trace bound together, but the trace itself may be accessed directly. After a while, the hippocampus is no longer necessary.

REFERENCES

Bartram, D. (1974). The role of visual and semantic codes in object naming. *Cognitive Psychology, 10,* 325–356.

Bassilli, J. N., Smith, M. C., and MacLeod, C. M. (1989). Auditory and visual word stem completion: Separating data-driven and conceptually-driven processes. *Quarterly Journal of Experimental Psychology, 41A,* 439–453.

Bauer, R. M. (1984). Automatic recognition of names and faces in prosopagnosia: A neuropsychological application of the guilty knowledge test. *Neuropsychologia, 22,* 457–469.

Bentin, S., and Moscovitch, M. (1988). The time course of repetition effects for words and unfamiliar faces. *Journal of Experimental Psychology: General, 117,* 148–160.

Benzig, W. C., and Squire, L. R. (1989). Preserved learning and memory in amnesia: Intact adaptation-level effects and learning of stereoscopic depth. *Behavioral Neuroscience, 103,* 538–547.

Biederman, I., and Cooper, E. E. (1991). Evidence for complete translational and reflectional invariance in visual object priming. *Perception, 20,* 585–593.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Support for a transfer appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15,* 657–668.

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

Bondi, M. W., and Kaszniak, A. W. (1991). Implicit and explicit memory in Alzheimer's disease and Parkinson's disease. *Journal of Clinical and Experimental Neuropsychology, 13,* 339–358.

Bonke, B., Fitch, W., and Millar, K. (Eds.) (1990). *Memory and awareness in anaesthesia.* Amsterdam: Swets and Zeitlinger.

Bowers, J. S., and Schacter, D. L. (1990). Implicit memory and awareness. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 404–416.

Bowers, J. S., and Schacter, D. L. (1992). Priming of novel information in amnesia: Issues and data. In P. Graf and M. E. J. Masson (Eds.), *Implicit memory: New directions in cognition, development, and neuropsychology*. New York: Academic Press.

Bransford, J. D., Franks, J. J., Morris, C. D., and Stein, B. S. (1979). Some general constraints on learning and memory research. In L. S. Cermak and F. I. M. Craik (Eds.), *Levels of processing in human memory*. Hillsdale, NJ: Erlbaum.

Brooks, J. O., and Watkins, M. J. (1989). Recognition memory and the mere exposure effect. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*, 968–976.

Butters, N., Heindel, W. C., and Salmon, D. P. (1990). Dissociation of implicit memory in dementia: Neurological implications. *Bulletin of the Psychonomic Society, 28*, 359–366.

Butters, N. Wolfe, J., Martone, M., Granholme, E., and Cermak, L. S. (1985). Memory disorders associated with Huntington's disease: Verbal recall, verbal recognition and procedural memory. *Neuropsychologia, 23*, 729–743.

Canavan, A. G. M., Passingham, R. E., Marsden, C. D., Quinn, N., Wyke, M., and Polkey, C. E. (1990). Prism adaptation and other tasks involving spatial abilities in patients with Parkinson's disease, patients with frontal lobe lesions and patients with unilateral temporal lobectomies. *Neuropsychologia, 28*, 969–984.

Carr, T. H., Brown, J. S., and Charalambous, A. (1989). Repetition and reading: Perceptual encoding mechanisms are very abstract but not very interactive. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 763–779.

Cave, C. B., and Squire, L. R. (1992). Intact and long-lasting repetition priming in amnesia. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18*, 509–520.

Cermak, L. S., Blackford, S. P., O'Connor, M., and Bleich, R. P. (1988). The implicit memory ability of a patient with amnesia due to encephalitis. *Brain and Cognition, 7*, 312–323.

Cermak, L.S., Bleich, R. P., and Blackford, M. (1988). Deficits in the implicit retention of new associations by alcoholic Korsakoff patients. *Brain and Cognition 7*, 145–156.

Cermak, L. S., Chandler, K., and Wolbarst, L. R. (1985). The perceptual priming phenomenon in amnesia. *Neuropsychologia, 23*, 615–622.

Cermak, L. S., Verfaellie, M., Milberg, W., Letourneau, L. and Blackford, S. (1991). A further analysis of perceptual identification priming in alcoholic Korsakoff patients. *Neuropsychologia, 29*, 725–736.

Challis, B. H., and Sidhu, R. (1993). Massed repetition has a dissociative effect on implicit and explicit measures of memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19*, 115–127.

Charness, N., Milberg, W., and Alexander, M. P. (1988). Teaching an amnesic a complex cognitive skill. *Brain and Cognition, 8*, 253–272.

Clarke, R., and Morton, J. (1983). Cross-modality facilitation in tachistoscopic word recognition. *Quarterly Journal of Experimental Psychology, 35A*, 79–96.

Cohen, A., Ivry, R. I., and Keele, S. W. (1990). Attention and structure in sequence learning. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16*, 17–30.

Cohen, N. J., Eichenbaum, H., Deacedo, B. S., and Corkin, S. (1985). Different memory systems underlying acquisition of procedural and declarative knowledge. *Annals of the New York Academy of Sciences, 444*, 54–71.

Cohen, N. J., and Squire, L. R. (1980). Preserved learning and retention of pattern analysing skill in amnesia: Dissociation of "knowing how" and "knowing that." *Science, 210*, 207–209.

Coltheart, M. (1980). Deep dyslexia: A right hemispheric hypothesis. In M. Coltheart, K. Patterson, and J. C. Marshall (Eds.), *Deep dyslexia*. London: Routledge and Kegan Paul.

Cooper, E. E., Biederman, I., and Hummel, J. E. (1992). Metric invariance in object recognition. A review and further evidence. *Canadian Journal of Psychology, 46,* 191–214.

Cooper, L. A., Schacter, D. L., Ballesteros, S., and Moore, C. (1992). Priming and recognition of transformed three dimensional objects: Effects of size and reflectance. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18,* 43–57.

Corkin, S. (1965). Acquisition of motor skill after bilateral medial temporal-lobe excision. *Neuropsychologia, 6,* 255–265.

Coslett, B., and Saffran, E. M. (1989). Evidence of preserved reading in pure alexia. *Brain, 112,* 327–359.

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

De Haan, E. H. F., Bauer, R. N., and Greve, K. W. (1992). Behavioral and physiological evidence for covert face recognition in a prosopragnosic patient. *Cortex, 28,* 77–96.

De Hann, E. H. F., Young, A., and Newcombe, F. (1987). Face recognition without awareness. *Cognitive Neuropsychology, 4,* 385–415.

Diamond, R., and Rozin, P. (1984). Activation of existing memories in anterograde amnesia. *Journal of Abnormal Psychology, 93,* 98–105.

Eich, E. (1984). Memory for unattended events: Remembering with and without awareness. *Memory and Cognition, 12,* 105–111.

Ellis, A. W., Young, A. W., Flude, B. M., and Hay, D. C. (1987). Repetition priming of face recognition. *Quarterly Journal of Experimental Psychology, 39A,* 193–210.

Fodor, J. (1983). *The modularity of mind.* Cambridge, MA: MIT Press.

Gabrieli, J. D. E., and Keane, M. M. (1988). Priming in the patient H.M.: New findings and a theory of intact and impaired priming in patients with memory disorders. *Society for Neuroscience Abstracts, 14,* 1290.

Gabrieli, J. D. E., Milberg, W., Keane, M. M., and Corkin, S. (1990). Intact priming of patients despite impaired memory. *Neuropsychologia, 28,* 417–428.

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

Glass, A. L., and Butters, N. (1985). The effects of associations and expectations on lexical decision making in normals, alcoholics, and alcoholic Korsakoff patients. *Brain and Cognition, 4,* 465–476.

Gordon, B. (1988). Preserved learning of novel information in amnesia: Evidence for multiple memory systems. *Brain and Cognition 7,* 257–282.

Goshen-Gottstein, Y., and Moscovitch, M. (1992). Repetition priming effects for pre-existing and novel associations between words. Paper presented at the Psychonomic Society, St. Louis, MO.

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

Graf, P., Mandler, G., and Haden, P. E. (1982). Simulating amnesic symptoms in normal subjects. *Science, 218,* 1243–1244.

Graf, P., and Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic patients. *Journal of Experimental Psychology: Learning, Memory and Cognition, 11,* 501–518.

Graf, P., and Schacter, D. L. (1987). Selective effects of interference on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory and Cognition, 13,* 45–53.

Graf, P., Shimamura, A. P., and Squire, L. R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved functioning in amnesia. *Journal of Experimental Psychology: Learning, Memory and Cognition, 11,* 385–395.

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

Greve, K. W., and Bauer, R. M. (1990). Implicit learning of new faces in prosopagnosia: An application of the mere-exposure paradigm. *Neuropsychologia, 28,* 1035–1042.

Haist, F., Musen, G., and Squire, L. R. (1991). Intact priming of words and nonwords in amnesia. *Psychobiology, 19,* 275–285.

Hayman, C. A. G., and Tulving, E. (1989). Contingent dissociation between recognition and fragment completion: The method of triangulation. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15,* 228–240.

Heindel, W. C., Salmon, D. P., and Butters, N. (1991). The biasing of weight judgments in Alzheimer's and Huntington's disease: A priming or programming phenomenon? *Journal of Clinical and Experimental Neuropsychology, 13,* 189–203.

Heindel, W. C., Salmon, D. P., Shults, C. W., Walicke, P. A., and Butters, N. (1989). Neuropsychological evidence for multiple implicit memory systems: A comparison of Alzheimer's, Huntington's, and Parkinson's disease patients. *Journal of Neuroscience, 9,* 582–587.

Hirshman, E., and Mulligan, N. (1991). Perceptual interference improves explicit memory but does not enhance data-driven processing. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17,* 507–513.

Hirshman, E., Snodgrass, J. G., Mindes, J., and Feenan, K. (1990). Conceptual priming in fragment completion. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 634–647.

Hirst, W. (1989). On consciousness, recall, recognition, and the architecture of memory. In S. Lewandowsky, J. C. Dunn, and K. Kirsner (Eds.), *Implicit memory: Theoretical issues.* Hillsdale, NJ: Erlbaum.

Howard, D. V., Fry, A. F., and Brune, C. M. (1991). Aging and memory for new associations: direct versus indirect measures. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17,* 779–792.

Jackson, G. M., and Jackson, S. (1992). *Sequence structure and sequential learning: The evidence from aging reconsidered.* University of Oregan Institute of Cognitive and Decision Sciences, Technical Report 92-9.

Jackson, A., and Morton, J. (1984). Facilitation of auditory word recognition. *Memory and Cognition, 12,* 568–574.

Jacoby, L. L. (1983). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory and Cognition, 9,* 21–38.

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

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

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

Johnson, H. I. L., Kim, J. K., and Risse, G. (1985). Do alcoholic Korsakoff's syndrome patients acquire affective reactions? *Journal of Experimental Psychology: Learning, Memory and Cognition, 11,* 22–36.

Johnson, W. A., Dark, W. J., and Jacoby, L. L. (1985). Perceptual fluency and recognition judgments. *Journal of Experimental Psychology: Learning, Memory and Cognition, 11,* 3–11.

Jolicoeur, P. (1985). The time to name disoriented natural objects. *Memory and Cognition, 13,* 289–303.

Jolicoeur, P., and Milliken, B. (1989). Identification of disorientated objects: Effects of context of prior presentation. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15,* 200–210.

Jones, D. (1993). Recognizing people by voice. Paper presented at the Eleventh European Workshop on Cognitive Neuropsychology, Bressanone, Italy.

Joyce, E. M., and Robbins, T. W. (1991). Frontal lobe function in Korsakoff and non-Korsakoff alcoholics: Planning and spatial working memory. *Neuropsychologia, 29,* 709–723.

Keane, M. M., Gabrieli, J. D. E., Fennema, A. C., Growdon, J. H., and Corkin, S. (1991). Evidence for a dissociation between perceptual and conceptual priming in Alzheimer's disease. *Behavioral Neuroscience, 105,* 326–342.

Kilstrohm, J. F., and Conture, L. J. (1992). Awareness and information processing in general anaesthesia. *Journal of Psychopharmacology, 6,* 410–417.

Kihlstrom, J. F., Schacter, D. L., Cork, R. C., Hurt, C. A., and Behr, S. E. (1990). Implicit memory following surgical anaesthesia. *Psychological Science, 1,* 303–306.

Kinoshita, S. and Wayland, S. V. (1993). Effect of surface features on word fragment completion in amnesic subjects. *American Journal of Psychology, 106,* 67–80.

Kinsbourne, M., and Wood, F. (1975). Short-term memory processes and the amnesic syndrome. In D. Deutsch and J. A. Deutsch (Eds.), *Short-term memory,* 258–291. New York: Academic Press.

Kirsner, K., and Dunn, D. (1985). The perceptual record: A common factor in repetition priming and attribute retention. In M. I. Posner and O. S. M. Marin (Eds.), *Attention and performance XI,* 547–566. Hillsdale, NJ: Erlbaum.

Kirsner, K., Dunn, J. C., and Standen, P. (1989). Domain-specific resources in word recognition. In S. Lewandowsky, J. C. Dunn, and K. Kirsner (Eds.), *Implicit memory: Theoretical issues,* 99–122. Hillsdale, NJ: Erlbaum.

Knowlton, B. J., Ramus, S. J., and Squire, L. R. (1992). Intact artificial grammar learning in amnesia: Dissociation of classification learning and explicit memory for specific instances. *Psychological Science, 3,* 172–179.

Kohn, S. E., and Friedman, R. B. (1986). Word-meaning deafness: A phonological-semantic dissociation. *Cognitive Neuropsychology, 3,* 291–308.

Kolers, P. (1973). Remembering operations. *Memory and Cognition, 1,* 347–355.

Kolers, P. (1976). Reading a year later. *Journal of Experimental Psychology: Human Learning and Memory, 2,* 554–556.

Kolers, P., Duchnicky, R. L., and Sundstroem, G. (1985). Size in the visual processing of faces and words. *Journal of Experimental Psychology: Human Perception and Performance, 11,* 726–751.

Kolers, P., and Roediger, H. L. (1984). Procedures of mind. *Journal of Verbal Learning and Verbal Behavior, 23,* 425–429.

Kunst-Wilson, W. R., and Zajonc, R. B. (1980). Affective discrimination of stimuli that cannot be recognized. *Science, 207,* 557–558.

Lewandowsky, S., Kirsner, K., and Bainbridge, V. (1989). Context effects in implicit memory: A sense-specific account. In S. Lewandowsky, J. C. Dunn, and K. Kirsner (Eds.), *Implicit memory: Theoretical issues*. Hillsdale, NJ: Erlbaum.

Light, L. L., and Lavoie, D. (1993). Direct and indirect measures of memory in old age. In M. E. J. Masson, and P. Graf (Eds.), *Implicit Memory: New directions in cognition, development and neuropsychology*. Hillsdale, NJ: Erlbaum.

Luria, A. R. (1966). *Higher cortical functions in man*. New York: Basic Books.

MacLeod, C. M. (1989). Word context during initial exposure influences degree of priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*, 398–406.

Madigan, S. (1983). Picture memory. In J. C. Yuille (Ed.), *Imagery, memory and cognition: Essays in honor of Allan Paivio*. Hillsdale, NJ: Erlbaum.

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

Marsolek, C. J., Kosslyn, S. M., and Squire, L. R. (1992). Form specific visual priming in the right cerebral hemisphere. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18*, 492–508.

Martin, A. (1992). Degraded knowledge representations in patients with Alzheimer's disease: Implications for models of semantic and repetition priming. In L. R. Squire and N. Butters (Eds.), *Neuropsychology of memory*. New York: Guilford Press.

Martone, M., Butters, N., Payne, M., Becker, J., and Sax, D. S. (1984). Dissociations between skill learning and verbal recognition in amnesia and dementia. *Archives of Neurology, 41*, 965–970.

Masson, M. E. J., and Freedman, L. (1990). Fluent identification of repeated words. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16*, 355–373.

Mayes, A. R. (1992). Automatic memory processes in amnesia: How are they mediated? In A. D. Milner and M. D. Rugg (Eds.), *The neuropsychology of consciousness*. New York: Academic Press.

Mayes, A. R., and Gooding, P. (1989). Enhancement of word completion priming in amnesics by cueing with previously novel associates. *Neuropsychologia 27*, 1057–1072.

Mayes, A. R., Meudell, P. R. and Neary, D. (1978). Must amnesia be caused by either encoding or retrieval disorders? In M. M. Gruneberg, P. E. Moris, and R. N. Sykes (Eds.), *Practical aspects of memory*. London: Academic Press.

Mayes, A. R., Meudell, P. R., and Pickering, A. D. (1985). Is organic amnesia caused by a selective deficit in remembering contextual information? *Cortex, 21*, 313–324.

Mayes, A. R., Pickering, A. D., and Fairbairn, A. (1987). Amnesic sensitivity to proactive interference: Its relationship to priming and the causes of amnesia. *Neuropsychologia, 25*, 211–220.

McAndrews, M. P., and Moscovitch, M. (1990). Transfer effects in implicit tests of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 772–788.

McCarthy, R., and Warrington, E. (1990). *Cognitive neuropsychology: A clinical introduction*. New York: Academic Press.

McKoon, G., and Ratcliff, R. (1979). Priming in episodic and semantic memory. *Journal of Verbal Learning and Verbal Behavior, 18*, 463–480.

McKoon, G., and Ratcliff, R. (1986). Automatic activation of episodic information in a semantic memory task. *Journal of Experimental Psychology: Learning, Memory and Cognition, 12*, 108–115.

Merikle, P. M., and Reingold, E. M. (1991). Comparing direct (explicit) and indirect (implicit) measures to study unconscious memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 224–232.

Milberg, W., Alexander, M. P., Charness, N., McGlinchey-Berroth, R., and Barrett, A. (1988). Learning of a complex arithmetic skill in amnesia: Evidence for a dissociation between compilation and production. *Brain and Cognition, 8,* 91–104.

Milner, B. (1966). Amnesia following operation on the temporal lobe. In C. W. M. Whitty and O. L. Zangwill (Eds.), *Amnesia.* London: Butterworth.

Milner, B., Corkin, S., and Teuber, H.-L. (1968). Further analysis of the hippocampal amnesic syndrome: 14-year follow-up study of H. M. *Neuropsychologia, 6,* 215–234.

Mishkin, M., and Appenzeler, T. (1987). The anatomy of memory. *Scientific American, 256,* 80–89.

Mitchell, D. B., and Brown, A. S. (1988). Persistent repetition priming in picture naming and its dissociation from recognition memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 14,* 213–222.

Morris, C. D., Bransford, J. P., and Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 16,* 519–533.

Mortensen, E. L. (1980). The effects of partial information in amnesic and normal subjects. *Scandinavian Journal of Psychology, 21,* 75–82.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76,* 165–178.

Moscovitch, M. (1976). On the representation of language in the right hemisphere of right-handed people. *Brain and Language 3,* 43–71.

Moscovitch, M. (1981). Right-hemisphere language. *Disorders of Language, 1,* 41–61.

Moscovitch, M. (1982a). Multiple dissociations of function in amnesia. In L. S. Cermak (Ed.), *Human memory and amnesia.* Hillsdale, NJ: Erlbaum.

Moscovitch, M. (1982b). A neuropsychological approach to perception and memory in normal and pathological aging. In F. I. M. Craik and S. Trehub (Eds.), *Aging and cognitive processes.* New York: Plenum Press.

Moscovitch, M. (1984). The sufficient conditions for demonstrating preserved memory in amnesia: A task analysis. In N. Butters and L. R. Squire (Eds.), *The neuropsychology of memory.* New York: Guilford Press.

Moscovitch, M. (1985). Memory from infancy to old age: Implications for theories of normal and pathological memory. *Annals of the New York Academy of Sciences, 444,* 78–96.

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

Moscovitch, M. (1992a). Memory and working-with-memory: A component process model based on modules and central systems. *Journal of Cognitive Neuroscience, 4,* 257–267.

Moscovitch, M. (1992b). A neuropsychological model of memory and consciousness. In L. R. Squire and N. Butters (Eds.), *The neuropsychology of memory,* 2d ed. New York: Guilford Press.

Moscovitch, M. (1994). Models of memory and consciousness. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences.* Cambridge, MA: MIT Press.

Moscovitch, M., and Bentin, S. (1993). The fate of repetition effects when recognition is at or near chance. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19,* 148–158.

Moscovitch, M., and Umiltà, C. (1990). Modularity and neuropsychology: Implications for the organization of attention and memory in normal and brain-damaged people. In M. E. Schwartz (Ed.), *Modular processes in dementia*. Cambridge, MA: MIT Press.

Moscovitch, M., and Umiltà, C. (1991). *Conscious and nonconscious aspects of memory: A neuropsychological framework of modules and central systems*. In R. G. Lister and H. J. Weingartner (Eds.), *Perspectives on cognitive neuroscience*. Oxford: Oxford University Press.

Moscovitch, M., Vriezen, E., and Goshen-Gottstein, Y. (1993). Implicit tests of memory in patients with focal lesions and degenerative brain disorders. In H. Spinnler and F. Boller (Eds.), *Handbook of neuropsychology*, vol. 8. Amsterdam: Elsevier.

Moscovitch, M., and Winocur, G. (1992a). The neuropsychology of memory and aging. In T. A. Salthouse and F. I. M. Craik (Eds.), *The handbook of aging and cognition*. Hillsdale, NJ.: Erlbaum.

Moscovitch, M., and Winocur, G. (1992b). Frontal lobes and memory. In L. R. Squire (Ed.), *Encyclopedia of learning and memory: Neuropsychology*. New York: Macmillan.

Moscovitch, M., Winocur, G., and McLachlan, D. (1986). Memory as assessed by recognition and reading time in normal and memory impaired people with Alzheimer's disease and other neurological disorders. *Journal of Experimental Psychology: General, 115*, 331–347.

Musen, G., Shimamura, A. P., and Squire, L. R. (1990). Intact text-specific reading skill in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 1068–1076.

Musen, G., and Squire, L. R. (1991). Normal acquisition of novel verbal information in amnesia. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17*, 1095–1104.

Musen, G., and Squire, L. R. (1992). Nonverbal priming in amnesia. *Memory and Cognition, 20*, 441–448.

Musen, G., and Squire, L. R. (1993). On the implicit learning of novel associations by amnesic patients and normal subjects. *Neuropsychology, 7*, 119–135.

Musen, G., and Triesman, A. (1990). Implicit and explicit memory for visual patterns. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16*, 127–137.

Nichelli, P., Bahmanian-Behbahani, G., Gentilini, M., and Vecchi, A. (1988). Preserved memory abilities in thalamic amnesia. *Brain, 111*, 1337–1353.

Nissen, M. J., Willingham, D., and Hartman, M. (1989). Explicit and implicit remembering: When is learning preserved in amnesia? *Neuropsychologia, 27*, 341–352.

Oliphant, G. W. (1983). Repetition and recency effects in word recognition. *Australian Journal of Psychology, 35*, 393–403.

Owen, A. M., Downes, J. J., Sahakian, B. J., Polkey, C. E., and Robbins, T. W. (1990). Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia, 28*, 1021–1034.

Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.

Paller, K. A., Mayes, A. R., McDermott, M., Pickering, A. D., and Meudell, P. R. (1991). Indirect measures of memory in a memory duration judgment task are normal in amnesic patients. *Neuropsychologia, 29*, 1007–1018.

Paller, K. A., Mayes, A. R., Thompson, K. M., Young, A. W., Roberts, J., and Meudell, P. R. (1992). Priming of face matching in amnesia. *Brain and Cognition, 18*, 46–59.

Parkin, A. J., Reid, T., and Russo, R. (1990). On the differential nature of implicit and explicit memory. *Memory and Cognition, 18*, 307–314.

Patterson, K., Vargha-Khadem, F., and Polkey, C. E. (1989). Reading with one hemisphere. *Brain, 112*, 39–63.

Peterson, S. E., Fox, P. T., Posner, M. I., Mintun, M. A., and Raichle, M. E. (1989). Positron emission tomographic studies of the processing of single words. *Journal of Cognitive Neuroscience, 1*, 153–170.

Peterson, S. E., Fox, P. T., Synder, A. Z., and Raichle, M. E. (1990). Activation of extrastriate and frontal cortical areas by visual words and word-like stimuli. *Science, 249*, 1041–1044.

Rabinowicz, B., and Moscovitch, M. (1984). Right hemisphere literacy: A critique of some recent approaches. *Cognitive Neuropsychology, 1*, 343–350.

Rees-Nishio, M. (1984). Memory, emotion, and skin conductance responses in young and elderly normal and memory-impaired people. Unpublished Ph.D. dissertation. University of Toronto, Toronto, Ontario.

Richardson-Klavehn, A., and Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology, 39*, 475–543.

Roberts, J. (1988). A new method for testing implicit memory in normal and amnesic patients. Msc. thesis, University of Lancaster.

Roediger, H. L. (1990). Implicit memory: Retention without remembering. *American Psychologist, 45*, 1043–1056.

Roediger, H. L., and McDermott, K. B. (1993). Implicit memory in normal human subjects. In H. Spinnler and F. Boller (Eds.), *Handbook of neuropsychology*, vol. 8. Amsterdam: Elsevier.

Roediger, H. L., Weldon, M. S., and Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger and F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving*. Hillsdale, NJ: Erlbaum.

Roediger, H. L., Weldon, M. S., Stadler, M. A., and Riegler, G. H. (1992). Direct comparison of word stems and word fragments in implicit and explicit retention tests. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18*, 1251–1269.

Rozin, P. (1976). The psychobiological approach to human memory. In M. R. Rosenzweig and E. L. Bennet (Eds.), *Neural mechanisms of learning and memory*. Cambridge, MA: MIT Press.

Saffran, E. M., and Marin, O. S. M. (1977). Reading without phonology: Evidence from aphasia. *Quarterly Journal of Experimental Psychology, 29*, 515–525.

Saint-Cyr, J. A., Taylor, A. E., and Lang, A. E. (1988). Procedural learning and neostriatal dysfunction in man. *Brain, 111*, 941–959.

Salmon, D. P., Shimamura, A. P., Butters, N., and Smith, S. (1988). Lexical and semantic priming deficits in patients with Alzheimer's disease. *Journal of Clinical Experimental Neuropsychology, 10*, 477–494.

Scarborough, D. L., Cortese, C., and Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 1–17.

Scarborough, D. L., Gerard, L., and Cortese, C. (1979). Accessing lexical memory: The transfer of word repetition effects across task and modality. *Memory and Cognition, 7*, 3–12.

Schacter, D. L. (1987a). Implicit memory: History and current status. *Journal of Experimental Psychology; Learning, Memory, and Cognition, 13*, 501–518.

Schacter, D. L. (1987b). Memory, amnesia, and frontal lobe dysfunction. *Psychobiology, 15*, 21–36.

Schacter, D. L. (1989). On the relation between memory and consciousness: Dissociable interactions and conscious experience. In H. L. Roediger and F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving*. Hillsdale, NJ: Erlbaum.

Schacter, D. L. (1990a). Perceptual representation systems and implicit memory: Toward a resolution of the multiple memory systems debate. *Annals of the New York Academy of Sciences, 608*, 543–571.

Schacter, D. L. (1990b). Toward a cognitive neuropsychology of awareness: Implicit knowledge and anosagnosia. *Journal of Clinical and Experimental Neuropsychology, 12*, 155–178.

Schacter, D. L. (1992). Priming and multiple memory systems: Perceptual mechanisms of implicit memory. *Journal of Cognitive Neuroscience, 4*, 244–256.

Schacter, D. L., Bowers, J., and Booker, J. (1989). Intention, awareness and implicit memory: The retrieval intentionality criterion. In S. Lewandowsky, J. C. Bunn, and K. Kirsner (Eds.), *Implicit memory: Theoretical issues*. Hillsdale, NJ: Erlbaum.

Schacter, D. L., and Church, B. (1992). Auditory priming: Implicit and explicit memory for words and voices. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18*, 915–936.

Schacter, D. L., Cooper, L. A., and Delaney, S. M. (1990). Implicit memory for unfamiliar objects depends on access to structural descriptions. *Journal of Experimental Psychology: General, 119*, 5–24.

Schacter, D. L., Cooper, L. A., Tharan, M., and Rubens, A. B. (1991). Preserved priming of novel objects in patients with memory disorders. *Journal of Cognitive Neuroscience, 3*, 118–131.

Schacter, D. L., Eich, J. E., and Tulving, E. (1978). Richard Semon's theory of memory. *Journal of Verbal Learning and Verbal Behavior, 17*, 721–743.

Schacter, D. L., and Graf, P. (1986). Preserved learning in amnesic patients: Perspectives on research from direct priming. *Journal of Clinical Experimental Neuropsychology, 8*, 727–743.

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

Schacter, D. L., McAndrews, M. P., and Moscovitch, M. (1988). Access to consciousness: Dissociations between implicit and explicit knowledge in neuropsychological syndromes. In L. Weiskrantz (Ed.), *Thought without language*. Oxford: Oxford University Press.

Schacter, D. L., Rapcsak, S. Z., Rubens, A. B., Tharan, M., and Laguna, J. M. (1990). Priming effects in a letter-by-letter reader depend on access to the word form system. *Neuropsychologia, 28*, 1079–1094.

Schwartz, B. L., and Hashtroudi, S. (1991). Priming is independent of skill learning. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17*, 1177–1188.

Seamon, J. G., Brody, N., and Kauff, D. M. (1983). Affective discrimination of stimuli that are not recognized: II. Effect of delay between study and test. *Bulletin of the Psychonomic Society, 21*, 187–189.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London, B298*, 199–209.

Sherry, D. F., and Schacter, D. L. (1987). The evolution of multiple memory systems. *Psychological Review, 94*, 439–454.

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

Shimamura, A. P., and Squire, L. R. (1989). Impaired priming of new associations in amnesia. *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*, 721–728.

Sloman, S. A., Hayman, C. A. G., Ohta, N., Law, J., and Tulving, E. (1988). Forgetting in primed fragment completion. *Journal of Experimental Psychology: Learning, Memory and Cognition, 14,* 223–239.

Smith, M. E., and Oscar-Berman, M. (1990). Repetition printing of words and pseudowords in divided attention and in amnesia. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 1033–1042.

Snodgrass, J. G. (1989). Sources of learning in the picture fragment completion task. In S. Lewandowsky, J. C. Dunn, and K. Kirsner (Eds.), *Implicit memory: Theoretical issues.* Hillsdale, NJ: Erlbaum.

Snodgrass, J. G., and Feenan, K. (1990). Priming effects in picture fragment completion: Support for the perceptual closure hypothesis. *Journal of Experimental Psychology: General, 119,* 276–296.

Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys and humans. *Psychological Review, 99,* 195–231.

Squire, L. R., Cohen, N. J., and Zouzounis, J. A. (1984). Preserved memory in retrograde amnesia: Sparing of a recently acquired skill. *Neuropsychologia, 22,* 145–152.

Squire, L. R., Ojemann, J., Miezin, F., Petersen, S., Videen, T., and Raichle, M. (1991). Activation of the hippocampus in normal humans: A functional anatomical study of memory. *Proceedings of the National Academy of Sciences, 89,* 1837–1841.

Squire, L. R., Shimamura, A. P., and Graf, P. (1987). Strength and duration of priming effects in normal subjects and amnesic patients. *Neuropsychologia, 25,* 195–210.

Squire, L. R., Wetzel, C. D., and Slater, P. C. (1978). Anterograde amnesia following ECT: An analysis of the beneficial effect of partial information. *Neuropsychologia, 16,* 339–347.

Srinivas, K. (1993). Perceptual specificity in nonverbal priming. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19,* 582–602.

Tranel, E., and Damasio, A. R. (1985). Knowledge without awareness: An automatic index of facial recognition by prosopagnosics. *Science, 228,* 1453–1454.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 25,* 1–12.

Tulving, E., Hayman, C. A. G., and MacDonald, C. (1991). Long-lasting perceptual priming and semantic learning in amnesia: A case experiment. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17,* 595–617.

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

Tulving, E., Schacter, D. L., and Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 336–342.

Verfaellie, M., Bauer, R. M., and Bowers, D. (1991). Autonomic and behavioral evidence of "implicit" memory in amnesia. *Brain and Cognition, 15,* 10–25.

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

Warrington, E. K., and Shallice, T. (1980). Word-form dyslexia. *Brain, 103,* 99–112.

Warrington, E. K., and Taylor, H. M. (1978). Two categorical stages of object recognition. *Perception, 7,* 695–705.

Warrington, E. K., and Weiskrantz, L. (1968). New method of testing long-term retention with special reference to amnesic patients. *Nature, 217,* 972–974.

Warrington, E. K., and Weiskrantz, L. (1970). The amnesic syndrome: Consolidation or retrieval? *Nature, 228,* 628–630.

Warrington, E. K., and Weiskrantz, L. (1974). The effect of prior learning on subsequent retention in amnesic patients. *Neuropsychologia, 12,* 419–428.

Warrington, E. K., and Weiskrantz, L. (1978). Further analysis of the prior learning effect in amnesic patients. *Neuropsychologia, 10,* 169–177.

Watkins, M. J., and Gibson, J. M. (1988). On the relation between perceptual priming and recognition memory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 14,* 477–483.

Weldon, M. S. (1991). Mechanisms underlying priming on perceptual tasks. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17,* 526–541.

Weldon, M. S., and Roediger, H. L. (1987). Altering retrieval demands reverses the picture superiority effect. *Memory and Cognition, 15,* 269–280.

Wetzel, C. D., and Squire, L. R. (1982). Cued recall in anterograde amnesia. *Brain and Language, 15,* 70–81.

Winocur, G., and Moscovitch, M. (1994). Negative transfer (A–B, A–C learning) in patients with unilateral temporal-lobe as frontal-lobe lesions: A case of heightened interference on conceptual, implicit tests of memory? *Brain and Cognition.* In press.

Winocur, G., and Weiskrantz, L. (1976). An investigation of paired-associate learning in amnesic patients. *Neuropsychologia, 14,* 97–110.

Witherspoon, D., and Allen, L. G. (1985). The effects of prior presentation on temporal judgments in a perceptual identification task. *Memory and Cognition, 13,* 101–111.

Witherspoon, D., and Moscovitch, M. (1989). Independence of the repetition effects between word fragment completion and perceptual identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 22–30.

Zaidel, E. (1985). Language in the right hemisphere. In D. F. Benson and E. Zaidel (Eds.), *The dual brain: Hemispheric specialization in humans,* 205–231. New York: Guilford Press.

Zaidel, E., and Peters, A. M. (1981). Phonologic encoding and ideographic reading by the disconnected right hemisphere: Two case studies. *Brain and Language, 14,* 205–234.