52 Implicit Memory: A New Frontier for Cognitive Neuroscience

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ABSTRACT Implicit memory refers to nonconscious effects of previous experiences on performance of memory tests that do not require explicit recollection. A growing number of studies during the past decade have shown that implicit and explicit forms of memory can be dissociated experimentally. This chapter provides an overview of implicit memory research from several perspectives that are central to cognitive neuroscience: cognitive studies of normal subjects, neuropsychological investigations of memory-impaired populations, and electrophysiological and neuroimaging studies. Taken together, evidence from these different perspectives supports the hypothesis that implicit and explicit forms of memory depend on different memory systems that are associated with distinct regions of the brain.

The topic of this chapter—implicit memory—is a relative newcomer to the landscape of memory research. In fact, the term *implicit memory* was first introduced to the field less than a decade ago (Graf and Schacter, 1985; Schacter, 1987). As stated in Schacter (1987, 501), "Implicit memory is revealed when previous experiences facilitate performance on a task that does not require conscious or intentional recollection of those experiences." By contrast, explicit memory "is revealed when performance on a task requires conscious recollection of previous experiences." The relatively recent emergence of the terms *implicit memory* and *explicit memory* is largely attributable to the fact that implicit memory constitutes a novel, if not entirely unprecedented, focus for memory research. Most psychological studies of memory have used tasks that involve intentional recollection of previously studied materials, and theoretical accounts have typically focused on data concerning explicit remembering. However, beginning in the 1960s and 1970s, and especially in the early 1980s, evidence began to accumulate indicating that effects of prior experiences could be expressed without, and dissociated from, intentional or conscious recollection. The terms *implicit* and *explicit* memory were put forward in an attempt to capture and describe essential features of the observed dissociations. Related distinctions include declarative versus nondeclarative memory (Squire, 1992), direct versus indirect memory (Johnson and Hasher, 1987), and memory with awareness versus memory without awareness (Jacoby and Witherspoon, 1982).

Despite the recent vintage of the concept, studies of implicit memory have had a profound impact on contemporary research and theorizing. As early as 1988, Richardson-Klavehn and Bjork were able to assert that research on implicit memory constitutes "a revolution in the way that we measure and interpret the influence of past events on current experience and behavior" (1988, 467–477). Since that time interest in the issue has continued and intensified, as studies concerning implicit memory have appeared with astonishing frequency in cognitive, neuropsychological, and even psychiatric journals.

The main purpose of this chapter is to provide an overview of implicit memory research with respect to the concerns of cognitive neuroscience. No attempt is made to provide exhaustive coverage of the area (for recent reviews, see Roediger and McDermott, 1993; Schacter, Chiu, and Ochsner, 1993). Rather, the goal is to acquaint the reader with the major methodological and theoretical issues in contemporary research, and to summarize experimental studies that have examined implicit memory at both the cognitive and neuropsychological levels of analysis. To accomplish this objective, the chapter is divided into four main sections. The first summarizes the historical back-

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ground of contemporary research, and the second considers some basic terminological and methodological issues. The third and major section reviews cognitive and neuropsychological evidence that illuminates the nature and characteristics of implicit memory. The fourth section summarizes contemporary theoretical approaches to relevant phenomena.

Historical background

Although sustained interest in implicit memory has arisen only recently, a variety of clinical, anecdotal, and experimental observations concerning pertinent phenomena have been made during the past several centuries. I have offered a relatively systematic treatment of historical developments elsewhere (Schacter, 1987), and will here only summarize briefly the immediate precursors to current research.

Contemporary concern with implicit and explicit memory can be traced to two unrelated lines of research that developed during the 1960s and 1970s. First, neuropsychological investigations revealed that densely amnesic patients could exhibit relatively intact learning abilities on certain kinds of memory tasks, such as motor skill learning (e.g., Milner, Corkin, and Teuber, 1968), and fragment-cued recall (e.g., Warrington and Weiskrantz, 1974). Second, cognitive psychologists interested in word recognition and lexical access initiated investigations of the phenomenon known as repetition or direct priming, that is, facilitation in the processing or identification of a stimulus as a consequence of prior exposure to it on tests that do not require explicit remembering. For example, several investigators found that performance on a lexical decision test, where subjects judge whether letter strings constitute real words or nonwords, is facilitated significantly by prior exposure to a target word (for historical review, see Schacter, 1987).

By 1980, then, two independent lines of research indicated that effects of past experience could be demonstrated in the absence of, or without the requirement for, conscious recollection. But the possible links between them were not apparent, or at least were not discussed in scientific publications. The situation changed radically during the next few years. Cognitive studies of normal subjects revealed that priming effects on such tasks as word identification and word completion could be dissociated from recall and recognition (Jacoby and Dallas, 1981; Graf, Mandler, and Haden, 1982; Tulving, Schacter, and Stark, 1982; Graf and Mandler, 1984), and neuropsychological studies of amnesic patients with severe explicit memory deficits demonstrated entirely normal levels of skill learning (Cohen and Squire, 1980; Moscovitch, 1982) and priming (Jacoby and Witherspoon, 1982; Graf, Squire, and Mandler, 1984; Shimamura and Squire, 1984; Schacter, 1985). This convergence of cognitive and neuropsychological evidence provided a basis for the distinction between implicit and explicit memory (Graf and Schacter, 1985; Schacter, 1987).

These developments opened the floodgates for a virtual tidal wave of research. The range of phenomena subsumed under the general label of implicit memory has expanded, theoretical discussion is intense, and the rapid pace of investigation shows no signs of slowing down. Looking back to 1980 from the vantage point of the present, it is no exaggeration to say that we have witnessed the birth and development of a new subfield of memory research. While the vast scope of implicit memory research is in some sense exhilarating, it also means that one cannot hope to cover all of it in a relatively brief chapter. Accordingly, I will focus primarily on studies that have examined phenomena of direct priming, both because more is known about priming than any other implicit memory phenomenon, and because it has played a central role in theoretical discussion and debate. However, an exclusive focus on priming can lead to an overly narrow conception of implicit memory, so I will consider priming in relation to other forms of implicit memory where appropriate.

Methodological issues

The terms *implicit* and *explicit* memory were put forward in an attempt to capture salient features of the phenomena described in the preceding section, without implying commitment to a particular theoretical view of the mechanisms underlying the two forms of memory. Thus, Schacter (1987, 501) noted specifically that "the concepts of implicit and explicit memory neither refer to, nor imply the existence of, two independent or separate memory systems." Rather, these concepts "are primarily concerned with a person's psychological experience at the time of retrieval." The terms *implicit memory test* and *explicit memory test* have been used to characterize tasks on which memory performance can be characterized as either implicit (i.e., unintentional, nonconscious) or explicit (i.e., intentional, conscious).

One difficulty that arises when attempting to operationalize and experimentally examine implicit memory is that tasks that are characterized as implicit memory tests can be influenced by explicit memory. Thus, nominally implicit tests are not always functional measures of implicit memory. For example, when a severely amnesic patient exhibits a priming effect on a stem completion test, we can be relatively confident that the observed effect reflects the exclusive influence of implicit memory. However, when a college student or any other subject with intact explicit memory exhibits a priming effect, it is always possible that he or she has "caught on" to the fact that test stems can be completed with study list items, and has converted the nominally implicit test into a functionally explicit one (Bowers and Schacter, 1990).

This issue is fundamental to all research on implicit versus explicit memory, and procedures have been developed for confronting the problem. Consider, for example, the *retrieval intentionality criterion* suggested by Schacter, Bowers, and Booker (1989). The criterion consists of two key components: (1) The physical cues on implicit and explicit tests are held constant and only retrieval instructions (implicit or explicit) vary; and (2) an experimental manipulation is identified that affects performance on the two tests differently. The basic argument is that when these conditions are met, we can rule out the possibility that implicit test performance is contaminated by intentional retrieval strategies. The logic here is straightforward: If subjects are engaging in explicit retrieval on a nominally implicit test, then their performance on implicit and explicit tests that use identical cues should be affected similarly by a given experimental manipulation; thus, dissociations produced under these conditions indicate that the implicit test is not contaminated. And, indeed, a number of studies have produced dissociations that satisfy the retrieval intentionality criterion (e.g., Graf and Mandler, 1984; Hayman and Tulving, 1989; Roediger, Weldon, Stadler, and Riegler, 1992; Schacter and Church, 1992; for a different approach to the "contamination" problem, see Jacoby, 1991).

Characteristics of implicit memory: Cognitive and neuropsychological research

Cognitive Studies When contemplating the recent surge of research that constitutes the basis of this chapter, a question that naturally arises concerns the reasons for the intensive scrutiny: Why is implicit memory worth knowing about? One compelling answer to this question is that many situations exist in which implicit memory behaves quite differently from, and independently of, explicit memory. Scientists are naturally curious about surprising phenomena that violate their expectations, and implicit memory is surely one of them. Research with normal subjects has produced two main kinds of evidence for dissociation between implicit and explicit memory: *stochastic independence* and *functional independence.*

Stochastic independence Stochastic independence refers to a lack of correlation between two measures of memory at the level of the individual item. To illustrate the concept, consider an early study of priming by Tulving, Schacter, and Stark (1982). Subjects studied a long list of low frequency words (e.g., ASSASSIN), and were later given two successive memory tests: an explicit test of recognition memory in which they indicated via "yes" or "no" responses whether they recollected that a test item had appeared previously on the study list; and an implicit test of fragment completion in which they attempted to complete graphemic fragments of words (e.g., A--A--IN). Priming was observed on the fragment completion test: there was a significantly higher completion rate for fragments that represented previously studied words than for fragments that represented nonstudied words (e.g., -E-S--X for BEESWAX). More importantly, however, a contingency analysis of recognition and fragment completion performance revealed that the probability of producing a studied item on the fragment completion test was uncorrelated with—independent of—the probability of recognizing the same item. This finding of stochastic independence was striking and unexpected, because previous research had indicated that performance on explicit memory tests, such as cued recall, is correlated with, or dependent on, recognition memory (see Tulving, 1985).

Stochastic independence between priming and recognition memory has since been observed in a variety of experiments using different kinds of implicit memory tests (see, e.g., Jacoby and Witherspoon, 1982; Hayman and Tulving, 1989; Witherspoon and Moscovitch, 1989; Schacter, Cooper, and Delaney, 1990), and it has been suggested that such evidence is of great theoretical import (Tulving, 1985). But some have contended that findings of stochastic independence are artifacts of either the experimental procedures or the contingency analyses that are used to assess independence (cf. Shimamura, 1985; Hintzman and Hartry, 1990; Ostergaard, 1992). Many of these criticisms, however, have been answered convincingly (see, for example, Hayman and Tulving, 1989; Schacter, Cooper, and Delaney, 1990; Tulving and Flexser, 1992).

Functional independence Functional independence between implicit and explicit memory occurs when experimental manipulations affect performance on implicit and explicit tasks in different and even opposite ways. A key source of evidence for functional independence is provided by experiments that manipulate the conditions under which subjects study or encode target items. For instance, a seminal finding from the early 1980s involved experiments that varied the level or depth of encoding during a study task. Research in the levels of processing tradition (e.g., Craik and Tulving, 1975) had already established that explicit recall and recognition performance are much more accurate following "deep" encoding tasks that require semantic analysis of target words (e.g., judging the category to which a word belongs) than following "shallow" encoding tasks that only require analysis of an item's surface features (e.g., judging whether a word has more vowels or consonants). In striking contrast, several studies revealed that the magnitude of priming effects on the word identification task (Jacoby and Dallas, 1981) and stem completion task (Graf, Mandler, and Haden, 1982; Graf and Mandler, 1984) are not significantly influenced by levels of processing manipulations. More recent studies have confirmed and extended this general pattern of results in a variety of experimental paradigms (e.g., Bowers and Schacter, 1990; Graf and Ryan, 1990; Roediger et al., 1992).

While the foregoing studies used familiar words as target materials, and visual presentation and testing procedures, recent work indicates that the critical dissociation observed in these experiments can be produced with nonverbal figures (e.g., Schacter, Cooper, and Delaney, 1990) and in the auditory modality (Schacter and Church, 1992). Various other ways of manipulating encoding processes have also produced dissociative effects on implicit and explicit tests (e.g., Jacoby, 1983; Roediger and Challis, 1992).

Additional evidence is provided by studies that have altered the surface features of target items between study and test. For example, it is well established that priming on identification and completion tests is reduced and sometimes eliminated by study-to-test changes in modality of presentation (e.g., Jacoby and Dallas, 1981; Roediger and Blaxton, 1987), even though modality change typically has less impact on explicit memory. In a compelling demonstration, Weldon and Roediger (1987) showed that priming on the word fragment completion test could be eliminated by presenting a picture of a word's referent, rather than the word itself, at the time of study. By contrast, explicit memory was considerably higher following study of the picture than of the word.

Other experiments have investigated the extent to which priming is sensitive to within-modality changes of perceptual information between study and test. For example, a number of studies have assessed whether visual word priming is affected by study-to-test changes in letter case (i.e., upper or lower), typeface, or other perceptual features. The studies have yielded a mixed and complex picture, with some experiments providing evidence of perceptually specific priming (e.g., Jacoby and Hayman, 1987; Roediger and Blaxton, 1987; Hayman and Tulving, 1989) and others revealing no such effects (e.g., Clarke and Morton, 1983; Carr, Brown, and Charalambolous, 1989). Some attempts to resolve the discrepancies have been made (cf. Graf and Ryan, 1990; Marsolek, Kosslyn, and Squire, 1992), but simple answers are not yet available. Rather more consistent evidence of within-modality perceptual specificity has been reported in studies of auditory word priming, where study-to-test changes in speaker's voice can affect priming significantly (Schacter and Church, 1992; Church and Schacter, in press). Finally, several studies of visual object priming have revealed significant effects of changing an object's picture plane orientation between study and test (e.g., Biederman and Cooper, 1991; Cooper, Schacter, and Moore, 1991), although study-to-test changes in object size appear to have no effect on priming (Biederman and Cooper, 1992; Cooper, Schacter, Ballesteros, and Moore, 1992).

The view of priming that emerges from cognitive research, then, depicts a form of memory that is little affected by semantic or conceptual factors, strongly dependent on modality-level information, and sometimes dependent on highly specific, within-modality perceptual information. Note, however, that this characterization applies to priming effects that have been observed on so-called *data-driven* implicit tests, in which subjects' attention is focused primarily on the physical properties of test cues (e.g., Jacoby, 1983; Roediger and Blaxton, 1987). Priming has also been examined on *conceptually driven* implicit tests, which focus subjects' attention on semantic properties of test cues (cf. Blaxton, 1989; Hamman, 1990). Still other implicit tests appear to involve a mixture of data-driven and conceptually driven processes, such as the cued stem completion task developed by Graf and Schacter (1985) to study priming of newly acquired associations. Here, priming depends on some semantic study elaboration (Schacter and Graf, 1986b) but also exhibits modality specificity (Schacter and Graf, 1989).

NEUROPSYCHOLOGICAL STUDIES While cognitive research provides insights into the psychological and behavioral properties of implicit memory, it does not illuminate the neural bases of the critical phenomena. We now consider several kinds of evidence that provide pertinent information. The bulk of this section is devoted to considering studies of patients with memory disorders. However, we will also touch briefly on evidence from electrophysiological, neuroimaging, and pharmacological studies.

Memory-impaired patients The amnesic syndrome has played an important role in the development of implicit memory research, as noted in the introduction. Because it has been reasonably well established that human amnesia is produced by lesions to limbic and diencephalic structures (cf. Weiskrantz, 1985; Squire, 1992), findings of spared skill learning and priming are frequently taken as evidence that these structures are not necessary for, or involved in, these expressions of implicit memory.

The claim that priming can be fully intact in amnesia was not established firmly until the 1980s. In the earlier studies of Warrington and Weiskrantz (1974) that used word fragments as test cues, there was some ambiguity concerning whether subjects were given implicit or explicit test instructions. Moreover, in these studies amnesic patients sometimes exhibited normal performance and sometimes exhibited impaired performance. These issues were clarified by data indicating that amnesic patients show normal performance on fragmented word tests and similar tasks when given implicit memory instructions, and show impaired performance when given explicit memory instructions (cf. Graf, Squire, and Mandler, 1984; Shimamura and Squire, 1984; Cermak et al., 1985; Schacter, 1985).

During the past decade, research has focused on exploring the boundary conditions of preserved priming in amnesic patients. One issue that has assumed center stage during the past decade concerns whether amnesic patients, like normal subjects, exhibit normal priming for novel or unfamiliar materials that do not have preexisting representations in memory. Early evidence indicated that priming of nonwords (e.g., *numby*) is either absent or impaired in amnesic patients (Diamond and Rozin, 1984; Cermak et al., 1985), but methodological and conceptual considerations limit the force of these conclusions (for discussion, see Bowers and Schacter, 1993). Recent experiments have delineated conditions under which amnesic patients can exhibit intact priming for nonwords (e.g., Haist, Musen, and Squire, 1991; but see also Cermak et al., 1991).

A number of investigators have examined whether amnesic patients show priming for newly acquired associations between unrelated words, using variants of the paradigm introduced by Graf and Schacter (1985). The general outcome of these studies has pointed to impaired or absent priming of novel associates (Schacter and Graf, 1986b; Cermak, Bleich, and Blackford, 1988; Shimamura and Squire, 1989), although positive results have been reported in patients with mild memory impairments (e.g., Schacter and Graf, 1986b). In contrast to the inconsistent pattern of results observed with nonwords and unrelated paired associates, more convincing evidence for priming of novel information has been reported in studies using nonverbal materials, including novel objects (Schacter et al., 1991; Schacter, Cooper, and Treadwell, 1993) and dot patterns (Gabrieli et al., 1990; Musen and Squire, 1992). These data indicate that amnesic patients can form some sort of novel representation for unfamiliar objects and patterns.

A related issue concerns whether amnesic patients exhibit implicit memory for specific perceptual features of target materials, as has been observed in some studies of normal subjects that were noted earlier. Kinoshita and Wayland (1993) reported that on a visual fragment completion test, Korsakoff amnesics failed to show more priming when surface features of target words (handwritten vs. typed) were the same at study and test than when they differed. In an as-yet-unpublished study of auditory priming on a low-pass filter identification test, Barbara Church and I found that normal control subjects, but not amnesic patients, showed more priming in a same-voice condition than in a different-voice condition; amnesic patients do, however, show normal auditory priming when voice change effects are not involved (Schacter, Church, and Treadwell, 1994). Although these observations are preliminary, they have potentially important theoretical implications because they suggest that not all aspects of priming are fully observed in amnesic patients (for discussion, see Schacter, in press).

It was noted earlier that an exclusive focus on priming could lead to an overly narrow conception of implicit memory, and this is certainly true when considering amnesic patients. For example, while the evidence for priming of newly acquired associations in amnesic patients is weak, recent work indicates that amnesic patients can show robust implicit learning of new associations under conditions in which learning develops gradually across multiple trials (Musen and Squire, 1993). Similarly, research concerning the learning of skills and procedures, where implicit knowledge is acquired gradually across multiple trials, provides evidence that amnesics can show robust and even normal learning of novel spatiotemporal associations (Nissen and Bullemer, 1987), grammatical rules (Knowlton, Ramus, and Squire, 1992), and procedures for performing computer-related tasks (e.g., Glisky and Schacter, 1989). These kinds of observations suggest that priming of novel associations from a single study exposure depends on different mechanisms than does gradual learning of skills and contingencies.

Although the neuropsychological investigation of implicit memory has been dominated by experiments with amnesic patients, during the past several years the scope of investigation has broadened, and studies of various other patient populations have begun to make important empirical and theoretical contributions. Research with patients suffering from different kinds of dementia has proven particularly revealing. For example, studies of patients with Alzheimer's disease, who are typically characterized by extensive damage to cortical association areas as well as limbic structures, have consistently revealed impairment of priming on the word stem completion task together with spared procedural learning on motor skill tasks (e.g., Butters, Heindel, and Salmon, 1990). By contrast, patients with Huntington's disease, who are typically characterized by damage to basal ganglia, exhibit normal stem completion priming together with impaired acquisition of motor skills (Butters, Heindel, and Salmon, 1990). The double dissociation between priming and skill learning indicates clearly that different mechanisms underlie the two forms of implicit memory. Another example is provided by recent evidence indicating normal auditory priming in a patient with cortical (left hemisphere) damage and a severe auditory comprehension deficit (Schacter et al., 1993). This finding supports the idea discussed earlier that perceptual priming is a presemantic phenomenon that does not depend on the integrity or involvement of conceptual processes.

Electrophysiological, neuroimaging, and pharmacological studies Whereas studies of patient populations are potentially valuable sources of information about the brain processes and systems that subserve implicit and explicit memory, it also would be desirable to obtain relevant evidence from research with intact brains. Although relatively little work has been carried out along these lines, a few beginning steps have been taken.

A number of studies have examined priming effects by recording event-related potentials (ERPs), or electrophysiological changes in the brain that are linked to specific stimulus events, measured at the scalp, and quantified through signal averaging techniques. To take just one example, Paller (1990) measured ERPs to target words during an encoding task in which subjects were instructed to try to remember some words and to forget others (i.e., directed forgetting). The directed forgetting manipulation influenced explicit recall but not stem completion priming. More importantly, Paller found that ERP responses during encoding differed reliably for words that subsequently were or were not recalled, whereas these same ERP responses were unrelated to whether or not an item exhibited priming on the stem completion test. These findings thus provide converging electrophysiological evidence for the dissociative effect of different encoding processes on priming and explicit memory (see also Rugg and Doyle, in press).

Neuroimaging techniques such as positron emission tomography (PET) provide a promising new tool for investigating the neural bases of implicit memory. Little evidence is yet available, but one study by Squire and colleagues (1992) indicates that primed visual stem completion performance is associated with decreased activity in right extrastriate occipital cortex relative to unprimed completion performance. In addition, however, there were significant changes in right hippocampus. One difficulty in interpreting these results is that the priming data were likely contaminated by explicit memory: The study lists were short, a semantic encoding task was used, there were multiple study–test trials, and the completion rate for primed items was extremely high. In a more recent PET study that eliminated explicit contamination, we found that visual priming on the stem completion test was associated with decreased activity in right extrastriate occipital cortex, but failed to observe any evidence of hippocampal activation (Schacter, Albert, Alpert, Rafferty, and Rauch, unpublished data, 1994).

A few studies have revealed that various pharmacological agents differentially affect implicit and explicit memory (Nissen, Knopman, and Schacter, 1987; Danion et al., 1989), and some evidence from anesthetized patients indicates implicit memory for information presented during anesthesia (e.g., Kihlstrom et al., 1990). Although the basis of drug effects on implicit memory is not well understood, further psychopharmacological investigations could elucidate the neurochemical basis of implicit memory.

Theoretical issues: Lessons of implicit memory research

I noted earlier that when we look back to 1980 from the perspective of the present, the explosion of studies concerning implicit memory can be seen to constitute a new subfield of memory research. What lessons have been learned from this work? What do we know about memory now that we did not know then, and that is worth knowing?

At a rather general level, many researchers would agree that a principal lesson centers on the idea that memory is not a unitary or monolithic entity: The effects of past events on current experience and performance can be expressed not only via explicit remembering, but also by subtle changes in our ability to identify, act on, and make judgments about words, objects, and other kinds of stimuli—changes that are frequently independent of the ability to engage in conscious recollection of a prior experience. At a more specific level, a number of researchers have argued that dissociations between implicit and explicit forms of memory are mediated by, and reflect the existence of, distinct and dissociable underlying memory systems (e.g., Cohen and Squire, 1980; Tulving, 1985; Hayman and Tulving, 1989; Gabrieli et al., 1990; Tulving and Schacter, 1990; Schacter, 1990, 1992; Squire, 1992).

What kinds of systems are involved in implicit memory? Because implicit memory is a rather general descriptive term that covers a number of distinct phenomena, formulating an answer to this question requires that one first specify the particular kind of implicit memory that one wishes to explain. Consider, for example, the priming effects on completion, identification, and similar data-driven implicit memory tests that have been studied so extensively. We (Tulving and Schacter, 1990; Schacter, 1990, 1992, in press) have argued that such effects depend to a large extent on a perceptual representation system (PRS) that is in turn composed of several domain-specific subsystems (e.g., visual word form, auditory word form, structural description). The various PRS subsystems are based in posterior regions of cortex and operate at a modality-specific, presemantic level—that is, they represent information about the form and structure, but not the meaning and associative properties, of words and objects (for details and background, see Schacter, 1990, 1992; cf. Moscovitch, 1992). This basic idea accommodates many of the known facts about priming on data-driven tests—that it does not depend on semantic or conceptual processing, does depend on modality-specific perceptual information, and is typically preserved in amnesic patients. The PRS is not, however, involved in all forms of implicit memory. To take just one example, motor skill learning likely depends on a habit or procedural learning system that appears to depend critically on the integrity of corticostriatal circuits (see, e.g., Mishkin, Malamut, and Bachevalier, 1984; Butters, Heindel, and Salmon, 1990).

The hypothesis that dissociations between implicit and explicit memory reflect the operation of multiple memory systems is not universally accepted. Some students, for example, have preferred to retain the notion of a single memory system, and have attempted to account for implicit–explicit dissociations by appealing to different processes operating within the system, using theoretical ideas that have been invoked previously to account for dissociations among explicit memory tests (see, e.g., Jacoby, 1983; Roediger and Blaxton, 1987). However, recent discussions indicate that so-called processing accounts are often complementary to, rather than competitive with, multiple systems views (Hayman and Tulving, 1989; Roediger, 1990; Schacter, 1992). The critical task for future work will be to develop more specific and neurobiologically plausible accounts of the processes and systems that are responsible for implicit and explicit forms of memory.

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