Implicit Memory

Retention Without Remembering

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ABSTRACT: Explicit measures of human memory, such as recall or recognition, reflect conscious recollection of the past. Implicit tests of retention measure transfer (or priming) from past experience on tasks that do not require conscious recollection of recent experiences for their performance. The article reviews research on the relation between explicit and implicit memory. The evidence points to substantial differences between standard explicit and implicit tests, because many variables create dissociations between these tests. For example, although pictures are remembered better than words on explicit tests, words produce more priming than do pictures on several implicit tests. These dissociations may implicate different memory systems that subserve distinct memorial functions, but the present argument is that many dissociations can be understood by appealing to general principles that apply to both explicit and implicit tests. Phenomena studied under the rubric of implicit memory may have important implications in many other fields, including social cognition, problem solving, and cognitive development.

Remembering is "recalling to the mind" or "thinking of again," according to the American Heritage Dictionary. The definition implies that the rememberer is conscious (or aware) of both the current contents of mind and the fact that these represent recollections of the past. We generally think of remembering as potentially reflecting whatever we have learned, but a moment's reflection leads us to realize that this cannot be so. Humans learn many skills in which conscious remembering is unlikely to play much of a role, such as the sequences of finger movements involved in typewriting or tying one's shoes, the virtuoso performances of gymnasts or ice skaters, and many more mundane activities such as driving or shaving. People are unlikely to recall how to perform these skills; rather, when placed in the appropriate situation the person performs with little conscious awareness of how the behavior runs off (Kolers & Roediger, 1984). Indeed, as has often been remarked, when a person pauses to reflect on how a complicated skill is carried off, performance deteriorates. In some sense, these performances reflect prior learning but seem to resist conscious remembering. They are "unconscious," in the sense that their basis is difficult to describe in words.

The study of unconscious learning has excited and plagued experimental psychology virtually throughout its history. To mention but a few prominent examples, the controversies surrounding perceptual defense (McGinnies, 1949), conditioning without awareness (Greenspoon, 1955), implicit learning of artificial grammars (Reber, 1967), and subliminal priming (Marcel, 1983) have occupied successive generations of researchers. In each case, the basic experimental phenomena have been called into question because of procedural problems, confounded factors, and the like. When these potential problems have been overcome and the phenomenon is more firmly established (e.g., Erdelyi, 1974), then usually its unconscious status is called into question (e.g., Dulany, Carlson, & Dewey, 1984; Holender, 1986). Despite these problems, the issue of unconscious or implicit learning has repeatedly been reintroduced into experimental psychology. The purpose of this article is to survey the most recent incarnation of this line of work, which is creating excitement in many circles.

This article is organized into several sections. The first is an historical interlude about one origin of implicit memory research. The second section relates how the contemporary interest in implicit retention arose from neuropsychological studies of amnesic patients, and the third recounts how analogous implicit memory phenomena are studied in normal adult subjects. The fourth section outlines the two primary theoretical approaches to explaining implicit memory phenomena, and the fifth discusses research directed at testing between the theories. A sixth section discusses difficulties for the theories and challenges for the future. The last main section briefly discusses extensions of implicit memory work into other fields. The coverage in this article is necessarily somewhat selective. More thorough reviews of the implicit memory literature can be found in Richardson-Klavehn and Bjork (1988), Schacter (1987), and Shimamura (1986).

A Bit of History

Hermann Ebbinghaus is justly celebrated as the founding father of the experimental study of human learning and memory. Nearly every introductory psychology textbook recounts the tale of how he painstakingly memorized lists of nonsense syllables and then relearned them at later

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times. The logarithmic forgetting curve he discovered is a depressing reminder of the evanescence of knowledge. But Ebbinghaus is rarely acknowledged for many other impressive achievements appearing in his famous monograph, *Memory: A Contribution to Experimental Psychology* (1885/1964; see Roediger, 1985; Slamecka, 1985).

In the first few pages of his book, Ebbinghaus distinguished among various types of memory, which form the topic of this article. In cases of *voluntary recollection*, "we can call back into consciousness, by an exertion of the will directed to this purpose, this seemingly lost state" of previous sense experience (Ebbinghaus, 1885/1964, p. 1). In a second case, that of *involuntary recollection*, "mental states once present in consciousness return to it with apparent spontaneity and without any act of the will . . . in the majority of cases we at once recognize the returned mental state as one that has already been experienced; that is, we remember it" (p. 2). Finally, and most interesting for present purposes, Ebbinghaus reckoned that a "third and large group" of cases exist in which prior experience is reflected in current thought or behavior, but this transfer brings with it no trace of conscious recollection. "Most of these experiences remain concealed from consciousness and yet produce an effect which is significant and which authenticates their previous experience" (p. 2). This last sentence could serve reasonably well as a modern definition of implicit retention, a term introduced to describe this field by Graf and Schacter (1985).[1]

Ebbinghaus noted that the "introspective methods" of recall and recognition, the tasks so popular in current experimental psychology, can accurately measure only the first group of cases, those of voluntary recollection. The second group, cases of involuntary recollection, can sometimes be discovered by standard methods. However, the third group of cases, representing unconscious knowledge, inevitably escape detection by introspective methods.

Because of this unsatisfactory state, Ebbinghaus developed his famous savings method for measuring retention. The idea is simple and ingenious. A subject first learns some material, usually nonsense syllables in Ebbinghaus's case, and the number of trials or the amount of time to effect one perfect recitation is recorded. At some later time the process is repeated by having the subject relearn the same material, and the savings can be measured in terms of the fewer number of trials or the less time taken to reach the criterion. Note that savings in relearning can be measured whatever the mental status of the original experience at the time of relearning (i.e., whether or not it can be consciously recalled). Even if the subject has absolutely no conscious recollection of the original experience because of great delay, massive interference, or other factors, relearning and savings measures can still be obtained. Thus, the savings measure permits a quantitative estimate of unconscious knowledge. It is interesting to note that 10 years before Freud began publishing his famous works on the unconscious (Freud & Breuer, 1895/1960), which have led psychologists ever since to wonder how unconscious forces could be measured, Ebbinghaus had already produced one solution to the problem: Unconscious knowledge can be measured by the relearning and savings techniques.

The savings methodology introduced by Ebbinghaus is not as prevalent now as it was at the turn of the century, although it is still put to good use (e.g., MacLeod, 1988; T. O. Nelson, 1978). However, modern methods of studying implicit retention share basic features of Ebbinghaus's original methodology. In these studies, subjects are typically given experiences in the laboratory and their memory for these experiences is probed indirectly by having them perform another task. The transfer task is usually disguised to discourage explicit remembering (conscious recollection). The measure of interest is how well subjects perform after prior experience with relevant material, relative to appropriate control conditions in which the material was not experienced. This abstract description will become concrete as we consider research on implicit memory in the next section.

Implicit Memory in Amnesics

The primary reason for renewed interest in implicit memory in the last decade is a set of remarkable findings reported by researchers interested in the neuropsychology of memory. It has long been known that certain forms of brain damage render individuals extremely forgetful, while leaving other functions such as perceptual abilities, language, and intelligence relatively intact. These qualities define an amnesic syndrome (Hirst, 1982). Typically, patients are classified as amnesic when some brain injury renders them seemingly incapable of retaining new experiences (anterograde amnesia), but leaves other cognitive functions relatively intact. For example, such patients often fail to learn the names of their doctors and nurses even after numerous meetings. Careful studies of such famous cases as H.M. (Milner, Corkin, & Teuber, 1968), whose amnesia was due to a temporal lobectomy, and others, led to the conclusion by about 1970 that amnesics were incapable of transferring verbal information from a relatively intact short-term store to a long-term store (e.g., Baddeley & Warrington, 1970). These patients usually showed normal performance on short-term memory tasks, but performed dismally on those tapping long-term verbal memory. Researchers were aware that

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[1] Alternate terms preferred by some (Johnson & Hasher, 1987; Richardson-Klavehn & Bjork, 1988) are direct and indirect tests, corresponding to explicit and implicit tests, respectively. The two sets of terms are used interchangeably here, but see Roediger (1990) for reasons to prefer the explicit/implicit contrast.

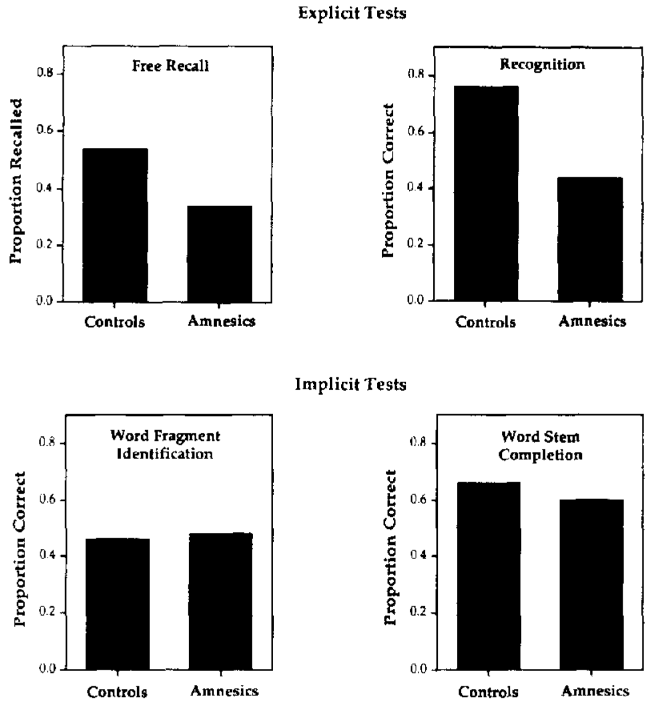
even profound amnesics such as H.M. were capable of learning and retaining motor skills at about the same levels as were normal subjects (e.g., Corkin, 1968), but retention of verbal information in amnesics was quite poor even after a brief delay. Thus, the inability to transfer (or consolidate) verbal information from a short-term to a long-term state seemed to play a critical role in amnesia.

This view of the amnesic syndrome began to change around 1970 because of startling new results revealing intact long-term verbal memory in amnesics on tests that today would be called *implicit* or *indirect*. Warrington and Weiskrantz (1968, 1970) performed much of this early work, and one of their studies (1970, Experiment 2) will serve as a convenient reference experiment. They presented 4 amnesic patients (3 with Korsakoff's syndrome[2] and 1 with a temporal lobectomy) words to remember and then assessed their retention on four tests. A total of 16 control patients without brain damage were similarly tested. Two of the four tests would today be classified as involving explicit retention (free recall and recognition) and the other two as assessing implicit retention (naming fragmented words in which each letter was degraded and completing words when given three-letter stems: e.g., *tab* for *table*).

In the free-recall test the subjects were simply given a blank sheet of paper and asked to recall as many of the recently presented words as possible, in any order. In recognition, the studied words were intermixed with new words and subjects were asked to indicate which ones had been studied. Both tests involve explicit remembering in the sense that subjects were attempting to recollect their recent experiences. The other two tasks (word-fragment identification and word-stem completion) seem to have been presented as word guessing games. In implicit tests, subjects are usually told simply to identify the mutilated word or to produce the first word to come to mind that completes the stem. These are indirect or implicit measures of retention in that the measure of interest is priming or transfer from the prior study of the words to the later tests. (For each test, words were selected that could not be identified by the subjects without prior study.)

Warrington and Weiskrantz's (1970, Experiment 2) results are presented in Figure 1. Performance on the explicit memory tests appears in the top part of the figure; control subjects outperformed amnesic patients on both free recall and recognition tests. This is no surprise because amnesic patients were selected for displaying poor retention on explicit tests. The bottom part of Figure 1 shows performance on the implicit memory tests, and it is apparent that the amount of repetition priming (the benefit in identification or completion from having studied the words) is comparable for control and amnesic patients. (The slight difference favoring control subjects in word-stem completion was not statistically significant.) To the extent that these tests provide an indirect or implicit measure of verbal long-term retention, amnesics seem to perform just as well as control subjects.

Figure 1
Results of Warrington and Weiskrantz (1970, Experiment 2)



Note. Amnesics performed more poorly than did control subjects on explicit tests (recall and recognition) but showed equal priming on implicit tests (word-fragment identification and word-stem completion). From "Amnesic Syndrome: Consolidation or Retrieval?" by E. K. Warrington and L. Weiskrantz, 1970, *Nature, 228*, p. 630. Copyright 1970 by the Macmillan Publishing Ltd. Reprinted by permission.

The results of Warrington and Weiskrantz (1970) were quite surprising in 1970, but have been replicated many times since then with other patient populations and tasks (e.g., Graf, Squire, & Mandler, 1984; Jacoby & Witherspoon, 1982). This intact retention in amnesics on implicit memory tests has also been found with tasks besides word-fragment and word-stem completion. Shimamura (1986) reviewed the literature and identified eight tasks showing generally comparable effects. One critical feature of tests showing preserved priming in amnesics is the instructions given to the subjects prior to testing. Subjects are not told that the test is measuring memory for recent experiences, but they are told just to perform the given task (such as guessing words from impoverished clues) as well as possible. Stated most boldly, dissociations such as those shown in Figure 1 indicate that implicit measures of retention reflect unconscious learning because amnesic patients are often unaware that they know the material when tested directly or explicitly, but perform at normal levels on the implicit or indirect tests. Thus, implicit or indirect tests seem to tap a different form of retention than do traditional explicit tests, such as recall or recognition.

[2] In Korsakoff's syndrome, patients' brain damage results from years of alcoholism that, combined with a vitamin deficiency, causes brain damage and renders patients amnesic.

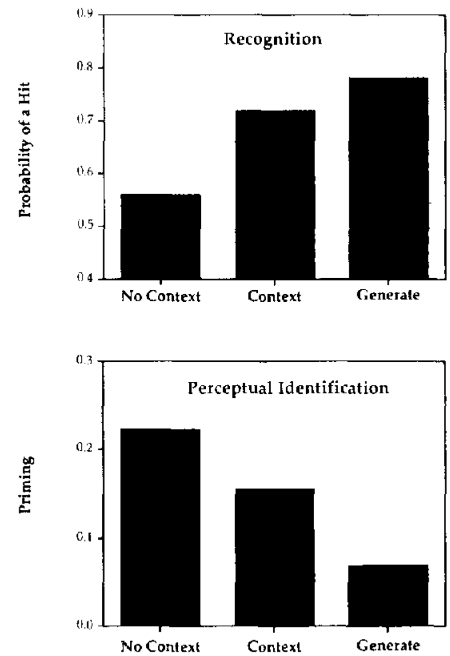
Implicit Retention in Normal Subjects

If explicit and implicit measures of retention produced differences only in amnesic patients, then these phenomena might be of limited interest. However, this is not the case; analogous phenomena have been repeatedly demonstrated in normal subjects who suffer from no observable brain damage. The assumption typically made is that performance on implicit tests in normal subjects reflects unconscious or unaware expressions of retention, just as in amnesic patients. Of course, this assumption can be called into question because normal subjects may realize that the ostensibly implicit test can be solved by explicitly retrieving prior experiences from an earlier phase in the experiment. The evidence to date indicates that this rarely happens, and procedures have been suggested for assessing the extent of contamination of implicit tests by explicit retrieval strategies (see Schacter, Bowers, & Booker, 1989). For the remainder of this article I assume that measures of implicit memory tap an unaware (or at least different) form of retention than do traditional explicit measures such as free recall, without defending this assumption further (see Schacter et al., 1989). Dissociations between explicit and implicit measures of retention in normal subjects provide one justification for this assumption; several examples are provided here.

Larry Jacoby has provided numerous clever demonstrations of implicit retention in normal subjects (e.g., Jacoby, 1983, 1988; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982). In most of Jacoby's experiments, undergraduate subjects were presented with a list of English words during the study phase and later were given one of two types of test. The explicit memory test involved recognition; subjects were given a long list of words, some of which had been studied and some of which were new, and the task was to select previously studied words. The implicit memory test involved perceptual identification; subjects were shown exactly the same words as on the recognition test but at very fast rates (around 30 ms); the subject's job was simply to read each word aloud, if possible. No mention was made of "remembering," and the subjects were presented with the task as one of identifying rapidly presented words. The measure of interest was priming or the greater facility in naming words during the test if they had been studied earlier in the experiment than if they were new.

In one series of experiments, Jacoby (1983) manipulated the conditions in which subjects studied words prior to receiving one of the two tests, exploring a finding known as the *generation effect* (Jacoby, 1978; Slamecka & Graf, 1978). The study manipulation involved whether or not subjects read aloud a single word (e.g., COLD) out of context (xxx–COLD), read it in a meaningful context (hot–COLD), or generated it from the context (hot–???). Target words were always antonyms of the context words, and subjects could generate them almost perfectly. Following study of many words in these three conditions, subjects took either a recognition test or a perceptual identification test. The results shown in the top panel of Figure 2 reveal that generated words were recognized better than those read in context, which in turn were recognized better than those read out of context. The finding that generated words are remembered better than read words has been revealed in many studies of explicit memory and is the source of much empirical and theoretical interest (e.g., McDaniel, Waddill, & Einstein, 1988). Interestingly, exactly the opposite ordering of conditions occurred on the perceptual identification test (bottom panel). The greatest priming occurred for words read out of context and the least for words that were generated.

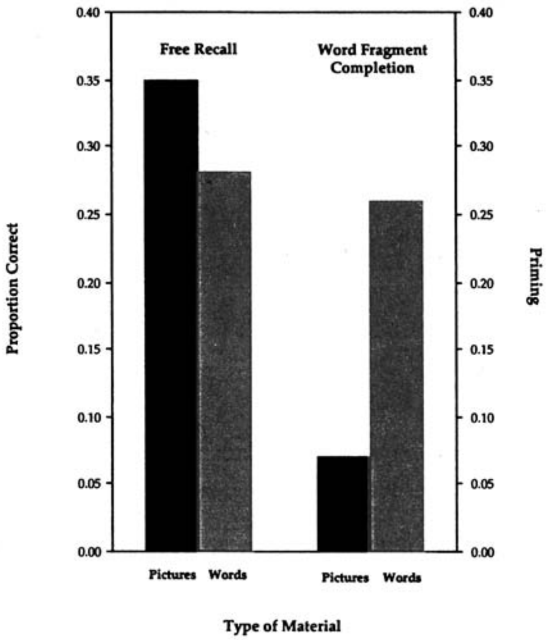
Figure 2
Results of Jacoby (1983, Experiment 2)



Note. The study manipulation produced opposite results on recognition memory (an explicit test) and on primed perceptual identification (an implicit test). From "Remembering the Data: Analyzing Interactive Processes in Reading" by L. L. Jacoby, 1983, *Journal of Verbal Learning and Verbal Behavior, 22,* p. 493. Copyright 1983 by Academic Press. Adapted by permission.

Similar cross-over dissociations between implicit and explicit tests have been reported from other manipulations (e.g., Blaxton, 1989; Srinivas & Roediger, 1990; Weldon & Roediger, 1987). For example, Weldon and Roediger (Experiment 1) had students study a list composed of pictures and words. The pictures were line drawings that represented easily named objects and, similarly, the presented words referred to concrete objects. Following study, one group of subjects was given a free-recall test (attempting to recollect, in any order, the names of the presented drawings and words) and another group was given a word-fragment completion test (trying to produce words from fragments such as s_r_w b__r_). Some fragments corresponded to presented words, some to the names of pictures, and others to nonstudied items. Subjects were told to guess the word from its fragment.

Figure 3
Results of Weldon and Roediger (1987, Experiment 1)



Note. The names of pictures were better recalled than were words on the explicit free-recall test, but words produced more priming than did pictures on the implicit word-fragment completion test. From "Altering Retrieval Demands Reverses the Picture Superiority Effect" by M. S. Weldon and H. L. Roediger, 1987, *Memory & Cognition, 15,* p. 272. Copyright 1987 by the Psychonomic Society. Reprinted by permission.

Results are shown in Figure 3. On the explicit free-recall test, pictures were remembered better than words. This finding replicates the typical picture-superiority effect shown on many explicit tests (e.g., Madigan, 1983). However, on the word-fragment completion test, prior study of words produced greater priming than did study of pictures. The overall pattern of results reveals another cross-over dissociation between performance on explicit and implicit tests.

The third example of a dissociation between explicit and implicit tests of retention in normal subjects also illustrates the applicability of these measures to other domains. E. R. Smith and Branscombe (1988), working on problems in social cognition, investigated the phenomenon of priming in person perception (e.g., Srull & Wyer, 1979). In a typical paradigm, subjects are exposed to some information during an initial phase in which (for example) many of the words have a hostile connotation. Later, during an apparently unrelated phase of the experiment, subjects are asked to rate hypothetical people in terms of their personality traits when various ambiguous behaviors are attributed to the people. The measure of interest is how much prior exposure to the hostile concepts affects use of this category in describing people, relative to ratings of subjects who have not been primed with hostile words. Srull and Wyer reported large priming effects on category accessibility that persisted for a week.

E. R. Smith and Branscombe (1988), in a procedure similar to that used in Jacoby's (1983) experiment, described earlier, had subjects either read priming words in the first phase of their experiment or generate them from conceptual clues. For example, subjects either read a trait word such as *religious* out of context, or generated it from three relevant phrases (e.g., "attended church three times a week") and the word's initial letter. After reading or generating many words, subjects were given one of three types of test. One group of subjects was given the category accessibility test, in which they were given a description of ambiguous behaviors exhibited by a person and were asked to provide a one-word trait adjective to describe this person. A second group of subjects was given the same materials during the study phase, but then was given a word-fragment completion test for the primed concepts. Finally, a third group received an explicit, free-recall test after the study phase. (One set of trait words was not presented during the study phase to permit assessment of facilitation on the two priming tests.)

E. R. Smith and Branscombe's (1988) results are presented in Table 1. The top two rows show a dissociation between an explicit and implicit test of retention: Generating items at study led to better free recall than did reading them, whereas reading words produced greater priming on the word-fragment completion test than did generating them. (This pattern provides a conceptual replication of Jacoby's, 1983, results shown in Figure 2.) The results of the other implicit test—if category accessibility is so considered—are shown in the third row. The pattern here resembles that of the explicit test, rather than the other implicit test. Among the lessons to be learned from E. R. Smith and Branscombe's experiment are that (a) the notion of implicit retention—unaware expressions of knowledge—can be extended beyond traditional tasks tapping learning, (b) implicit memory tests can be dissociated from each other, and consequently, (c) performance on implicit tests can resemble that on explicit tests. I will return to these three themes.

In summary, dissociations between explicit and implicit memory tests can be shown in normal subjects, just as in amnesics. These demonstrations are often impressive

Table 1
Proportion of Words Correctly Recalled, Completed, or Accessed in the Three Test Conditions as a Function of Study Conditions

	Study condition		
Test condition	Read	Generate	Nonstudied
Free recall	.45	.61	—
Word-fragment completion	.62 (.21)	.43 (.02)	.41
Category accessibility	.43 (.09)	.52 (.18)	.34

Note. Numbers in parentheses indicate priming (studied–nonstudied performance) in the implicit memory conditions. From "Category Accessibility as Implicit Memory" by E. R. Smith and N. Branscombe, 1988, *Journal of Experimental Social Psychology, 24,* p. 498. Copyright 1988 by Academic Press. Reprinted by permission.

because an independent variable may exert opposite effects on the two types of test, rather than affecting performance on one test and having no impact on the other. Also, performance on implicit tests often reveals a pattern at variance with standard effects expected on explicit tests, such as when retention was better for words than for pictures on the primed word-fragment completion test (Weldon & Roediger, 1987). I turn next to theoretical accounts of dissociations between explicit and implicit tests.

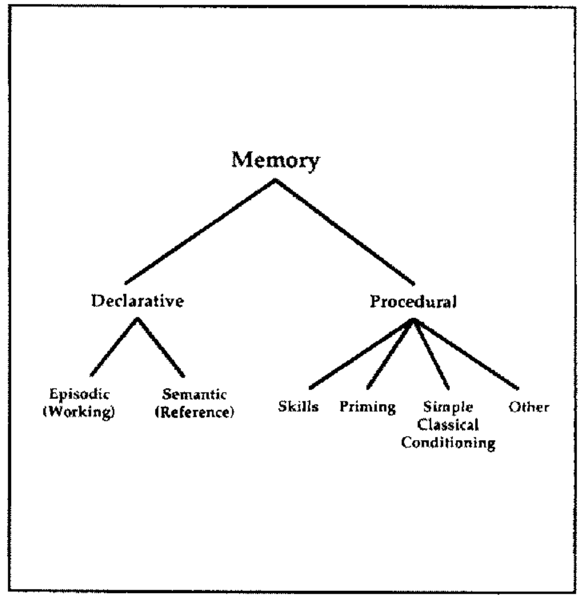
Theoretical Alternatives

Cognitive psychologists interested in learning and memory have traditionally employed recall and recognition tests (explicit tests). Theories of memory have been based on data from these tasks almost exclusively, at least until recently. The sharp dissociations between explicit and implicit forms of memory reviewed in the previous two sections present a challenge to traditional memory theories.

Two general approaches have been used to explain these new findings. Researchers working in the neuropsychological tradition (and a few others) have favored the theoretical approach of postulating distinct memory systems in the brain for explaining the dissociations (e.g., Cohen & Squire, 1980; Johnson, 1983; Schacter, 1989; Squire, 1986, 1987; Tulving, 1983, 1985; Weiskrantz, 1987, 1989). Alternatively, other researchers, generally working in the framework of cognitive psychology, have proposed various processing approaches to explaining these dissociations (e.g., Craik, 1983; Graf & Mandler, 1984; Jacoby, 1983, 1988; Kolers & Roediger, 1984; Mandler, 1989; Masson, 1989; Moscovitch, 1984; Roediger & Blaxton, 1987a, 1987b; Roediger, Weldon, & Challis, 1989). Within each of these two broad frameworks, individual theories differ in their particulars, and a complete discussion would be beyond the scope of this article. Instead of a thorough review, I will present one exemplar of each approach for further discussion, which will serve to illustrate each type of theory.

Researchers postulating distinct memory systems derive support from studies of brain-damaged patients, particularly amnesics. The idea is that the brain damage selectively affects the memory system for conscious recollection, but leaves the system responsible for other forms of learning relatively intact. Squire's (1986, 1987; see also Cohen & Squire, 1980) theory is an influential representative of this approach and is shown in Figure 4. The basic distinction is between declarative and procedural memory systems, with the former referring to verbalizable knowledge and the latter to the running off of skilled behavior without the need for conscious recollection. According to Squire, different neural structures underlie performance on tests tapping the two kinds of memory; hence, dissociations between explicit and implicit measures of memory are explained by appealing to the different systems. In general, the declarative memory system (involving neural structures in the limbic system) is responsible for performance on explicit (or aware) tests of

Figure 4
Schematic Representation of Squire's (1987) Theory Postulating Distinct Memory Systems.



Note. From *Memory and Brain* (p. 170) by L. R. Squire, 1987, New York: Oxford University Press. Copyright 1987 by Oxford University Press. Reprinted by permission.

retention, whereas the procedural system underlies motor skills, priming, classical conditioning and other forms of learning. In amnesics, the system responsible for declarative, episodic memory is disrupted, leading to their poor performance on explicit tests. In normal subjects, variables may affect explicit remembering and have no effect (or opposite effects) on implicit retention, and conversely. Because the systems are largely independent, dissociations are to be expected. Much evidence can be interpreted within the framework of distinct memory systems (see Squire, 1987, and Tulving, 1985, 1989), although difficulties also exist (e.g., McKoon, Ratcliff, & Dell, 1986).

An alternative proposal is that many dissociations between standard explicit and implicit memory tests may reflect the operation of different cognitive procedures required by the tests. Rather than assume that implicit and explicit tests tap separate memory systems, the guiding assumption of processing theories is that memory tests are composed of various component processes and dissociations between tests reflect the operation of different processes. Because it is well-known that many variables can create dissociations between different types of explicit memory tests (such as recall and recognition), the same explanatory principles used in understanding these dissociations can be brought to bear in explaining dissociations between explicit and implicit tests. My students and I have tried to spell out this point of view in several publications (e.g., Roediger & Blaxton, 1987b; Roediger & Weldon, 1987; Roediger, Weldon, & Challis, 1989), so here I just summarize its main assumptions. The framework is referred to as the *transfer-appropriate procedures approach,* for reasons that will be discussed.

A first assumption is that performance on memory tests benefits to the extent that the cognitive operations at test recapitulate (or overlap) those engaged during initial learning. There is considerable evidence for this general point (e.g., Kolers & Roediger, 1984), and its adoption is hardly controversial. This assumption is embedded in the encoding specificity hypothesis (Tulving & Thomson, 1973) and in the idea of transfer-appropriate processing (e.g., Morris, Bransford, & Franks, 1977). A second assumption is that explicit and implicit tests typically (but not always) require different retrieval operations (or access different forms of information) and consequently benefit from different types of processing during learning. If so, dissociations between explicit and implicit tests may be expected. This second assumption is spelled out in the next two assumptions: Third, most explicit tests draw on the encoded meaning of concepts, or on semantic processing, elaborative encoding, and the like. Much evidence shows that standard explicit tests are quite sensitive to conceptual elaboration and are insensitive to changes in surface features of information. Fourth, most implicit tests (and all those tests in which impoverished perceptual information is presented) rely heavily on the match between perceptual operations between study and test. These tests (which would include the perceptual identification, the word-fragment-completion, and the word-stem-completion tests described previously) seem to reflect a perceptual form of memory (Kirsner & Dunn, 1985). They are quite sensitive to manipulations that change the surface form of information (e.g., auditory vs. visual presentation), but relatively insensitive to manipulations that vary the elaboration of processing on a constant surface form (e.g., Jacoby & Dallas, 1981).

To put matters in slightly different terms (Jacoby, 1983), because standard explicit tests reflect meaning or conceptual elaboration, they can be referred to as *conceptually-driven* tests. On the other hand, many implicit tests reflect *data-driven* (perceptual) processing, because perceptual operations matter. To reiterate, this general approach to understanding dissociations between tests has been called transfer-appropriate processing (Morris et al., 1977; Roediger, Weldon, & Challis, 1989) because performance on a test is assumed to benefit as a direct function of similarity in operations between learning and testing activities.

These assumptions account well for the cross-over dissociations between explicit and implicit tests reviewed earlier (see Figures 2 and 3). In Jacoby's (1983) research, generating information was assumed to lead to greater conceptual elaboration than reading the word in context, which in turn provided greater elaboration than reading it out of context; a recognition test, believed to be largely conceptually driven, reflected this ordering (see Figure 2). On the other hand, reading a word out of context maximizes data-driven processing (the perceptual features of the word must be "driven through" the perceptual system); reading a word in context likely reduces data-driven processing; and when a word is generated from a conceptual clue (hot–???), no overt data in the form of its constituent letters guide production of the target word. The amount of priming on the data-driven perceptual identification test reflected this ordering. These assumptions also account for Weldon and Roediger's (1987) picture/word data in Figure 3. Pictures are assumed to access meaning more rapidly and fully than do words (M. C. Smith & Magee, 1980; D. L. Nelson, 1979), hence leading to greater free recall. But when given the challenge of completing fragmented words, the perceptual procedures brought into play share more operations with prior reading of words than with prior examination of pictures.

Although the dissociations in Figures 2 and 3 can be explained by the principle of transfer-appropriate processing, each also represents a dissociation between declarative (episodic) memory on the one hand, and the priming component of procedural memory on the other (see Figure 4). Thus, Squire's (1987) theory, or any other systems theory, could also account for the results at a general level.

Comparing Systems and Processing Theories

At one level, the theories postulating memory systems and those emphasizing different component processes in explicit and implicit memory tests seem quite different. Thus, they can be considered theoretical competitors and compared in their effectiveness at explaining dissociations between explicit and implicit tests. However, the issues are tricky. Defining exactly what constitutes a memory system or a mode of processing requires theoretical subtlety and is beyond the scope of this article; it has been discussed elsewhere (e.g., Neely, 1989; Roediger, Rajaram, & Srinivas, in press; Roediger, Weldon, & Challis, 1989; Sherry & Schacter, 1987; Tulving, 1985).

One difficulty in deciding whether systems views or processing views better account for explicit/implicit dissociations is portrayed in Figure 5, in which the two proposed modes of processing, perceptual (or data driven) and meaningful (or conceptually driven), are crossed with two postulated memory systems (declarative and procedural). In most prior research, a confounding has existed so that declarative (episodic) memory tests have required meaningful processing and procedural (priming) memory tests have required perceptual (data-driven) processing. Therefore, comparisons have been between tests falling into the lower left and upper right quadrants. Thus, either systems theories or processing theories can provide a general account for any dissociation found.

According to the transfer-appropriate processing theory previously outlined, there is no necessary correlation between the implicit or explicit nature of memory tests and the mode of processing they require. That is, it is perfectly possible to develop episodic (or explicit or declarative) memory tests that rely on perceptual information, and priming (or implicit or procedural) memory tests that tap semantic information and are, hence, conceptually driven. Thus, experiments can be conducted that conform to the 2 × 2 arrangement portrayed in Fig-

Figure 5
Alignment of Memory Systems and Modes of Processing Conceived as 2 × 2 Display

Mode of Processing	Memory System: Declarative (Episodic)	Memory System: Procedural (Priming)
Perceptual (Data-driven)		Perceptual Identification Word Fragment Completion
Meaning-based (Conceptually-driven)	Free Recall Recognition	

Note. This conception oversimplifies the issues by portraying the two approaches as dichotomies but serves to illustrate the point.

ure 5 to see if dissociations are caused by the different memory systems being tapped or the different modes of processing involved in the test.

The first such experiments were conducted by Blaxton (1985, 1989); part of one experiment will illustrate the argument. Blaxton (1989, Experiment 1) used methods similar to those of Jacoby (1983) by having subjects read words out of context (xxx–*treason*) or generate them from conceptual clues and their first letters (*espionage*–t______). Following study of a long list of words that instantiated these (and other) conditions, Blaxton had subjects take one of several types of test designed to represent the four cells in Figure 5.

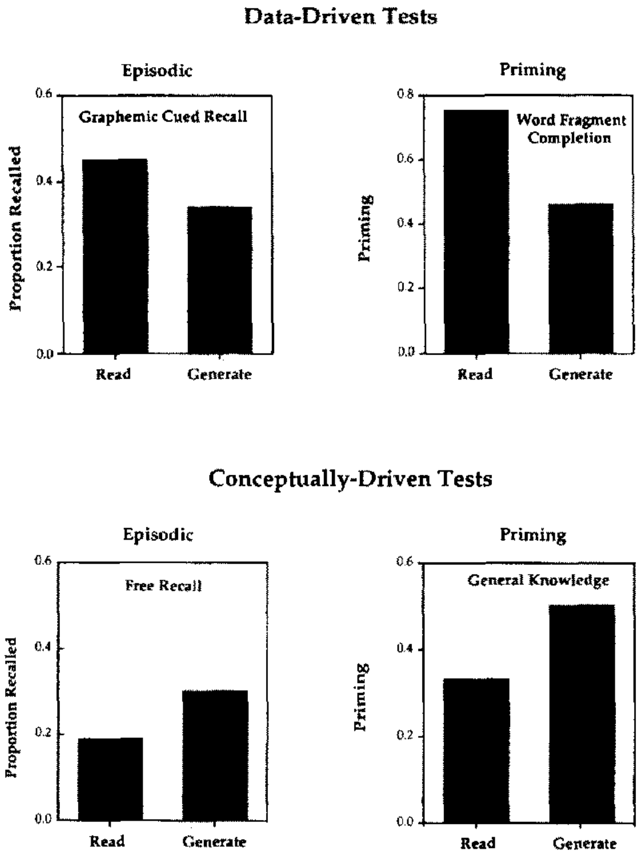
Free recall was intended to be a declarative (episodic, explicit) test that was conceptually driven; completing fragmented words was considered a procedural (priming, implicit) memory test by Squire's (1986) criteria, which was also perceptual in nature. Using free recall and word-fragment completion represents the standard contrast prevalent in research revealing dissociations between tests. Blaxton (1989) devised two new tests to fill the other cells in Figure 5. One was a graphemic cued-recall test in which subjects were given words that looked and sounded like the target words, but were not related to them in meaning (e.g., *treasure* as a cue for *treason*). Subjects were told that they should recall a word from the list that looked and sounded like the cue word; thus, the test was episodic but depended on the visual and phonemic similarity between the cue and target item, and thus seemed perceptual in nature. The fourth test involved answering general knowledge questions as in games such as Trivial Pursuit (e.g., "For what crime were the Rosenbergs executed?"). This priming test requires conceptual processing, so it filled the fourth (lower right) cell in Figure 5. The complete design permits one to examine whether dissociations are found between systems (the columns) or between modes of processing (the rows).

The answer is provided in Figure 6. First, compare the lower left and upper right cells to note that Blaxton (1989) replicated Jacoby's (1983) dissociation (seen in Figure 2) between episodic and priming memory tests: Generating produced greater free recall than did reading, whereas the reverse was the case for primed word-fragment completion. Examination of the whole pattern in Figure 6 shows, however, that the dissociations were as predicted by the type of processing invoked by the test rather than by the supposed memory system being tapped. Reading words during study produced better performance than did generating words on both graphemic cued-recall and word-fragment completion tests, despite the fact that one test was declarative and one procedural. Similarly, generating produced better performance both in free recall and in answering general knowledge questions than did reading. (Differences in each cell were statistically significant.) Thus, dissociations occurred between two episodic memory tests and between two priming tests, according to Squire's (1987) typology (Figure 4). The type of processing required by the test (and not the hypothetical memory system tapped) determined dissociations in Blaxton's (1989) Experiment 1, and in two subsequent experiments.

According to the logic of functional dissociation as applied by theorists postulating distinct memory systems, dissociations should occur when one test is implicit (involving the priming subsystem of procedural memory) and another is explicit (e.g., the episodic subsystem of declarative memory), but should generally not occur when both tests tap the same system. If dissociations are found as frequently when two priming tests are compared as when the comparison is between a priming test and an episodic test, then the idea that different systems underlie explicit and implicit tests is weakened. (Alternatively, additional memory systems may be implicated.) Blaxton's (1989) data showed just such dissociations between two explicit tests and between two implicit tests. But how general are such data? Can other examples be found?

The case is clear with regard to explicit tests, because dissociations between such tests have been found repeat-

Figure 6
Results From Selected Conditions of Blaxton (1989, Experiment 1)



Note. The pattern reflects operation of different modes of processing as critical in interpreting dissociations. From "Investigating Dissociations Among Memory Measures: Support for a Transfer Appropriate Processing Framework" by T. A. Blaxton, 1989, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* p. 660. Copyright 1989 by the American Psychological Association. Adapted by permission.

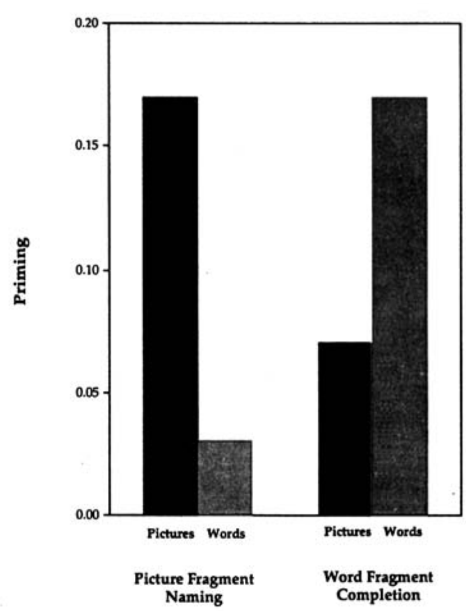
edly. To take a straightforward example, when high-frequency and low-frequency words are mixed within the same list and followed either by tests of free recall or by tests of recognition, a dissociation occurs. High-frequency words are better recalled than low-frequency words, but low-frequency words are better recognized (e.g., Balota & Neely, 1980). Numerous examples of dissociations between recall and recognition are available in the literature (see Tulving, 1976), and one can also find many dissociations between various kinds of recall tests (Tulving, 1983, chap. 12). Such findings were the basis for ideas of encoding specificity (Tulving & Thompson, 1973) and transfer-appropriate processing (see Morris et al., 1977; also McDaniel, Friedman, & Bourne, 1978).

The case for dissociations between implicit tests is more limited because only a handful of experiments like Blaxton's (1989) have been reported in which two or more implicit tests are compared as a function of the same independent variables. Roediger, Srinivas, and Weldon (1989) have reviewed the sparse literature on this issue and noted several dissociations. One such dissociation between two implicit (priming) tests has already been presented in the work of E. R. Smith and Branscombe (1988), who showed a dissociation between primed word fragment completion and primed personality categories (see Table 1).

Like Blaxton's (1989) experiments, the dissociations reported by E. R. Smith and Branscombe (1988) occurred between a perceptual priming test and a conceptual priming test. Srinivas and Roediger (1990) provided further dissociations of this ilk. However, dissociations between implicit memory tests can also be found when both tests are data driven. The strategy here is to create a match or mismatch between the procedures used during acquisition and those required by the test. Experiment 4 reported by Weldon and Roediger (1987) provides a relevant contrast. They had subjects study a mixed list of words and pictures and then take one of two implicit memory tests. One was the word-fragment completion test, and the other was a picture-naming test. In this latter test, subjects were shown degraded pictures and asked to name them. On both tests, some items had previously been studied as pictures, some as words, and some had not been studied.

The results appear in Figure 7 and reveal a striking dissociation between two implicit tests. Pictures produced greater priming than did words on the picture-fragment naming test, whereas the reverse pattern appeared on the word-fragment completion test. The dissociation is easily

Figure 7
Results From Weldon and Roediger (1987, Experiment 4)



Note. Pictures produced more priming than did words on the picture-fragment naming test, but the reverse pattern occurred on the word fragment-completion test. From "Altering Retrieval Demands Reverses the Picture Superiority Effect" by M. S. Weldon and H. L. Roediger, 1987, *Memory & Cognition, 15,* p. 277. Copyright 1987 by the Psychonomic Society. Adapted by permission.

accommodated by the transfer-appropriate processing theory because prior study of pictures and a test requiring resolution of degraded pictures surely share more common operations than does study of words and the later resolution of degraded pictures. (The analogous argument has been made previously for the word-fragment completion test.) The data thus far collected showing dissociations between priming tests in normal subjects are in good agreement with the transfer-appropriate processing approach to explaining dissociations. However, when other considerations are brought to bear, the overall picture does not appear as satisfactory. In the next section I discuss some objections and challenges that have been raised.

Theoretical Challenges

The transfer-appropriate procedures approach accounts reasonably well for dissociations between explicit and implicit tests obtained in normal subjects as a function of various independent variables (e.g., Blaxton, 1989; Roediger & Blaxton, 1987b; Roediger, Weldon, & Challis, 1989; Srinivas & Roediger, 1990). The approach also can account for dissociations between explicit tests (Morris et al., 1977; Tulving & Thompson, 1973) and between implicit tests (Roediger, Srinivas, & Weldon, 1989). This is not to say that every data point from all experiments falls into line (some exceptions are listed later), but nonetheless the ideas seem to capture the basic phenomena reasonably well. Some retention tests seem to rely predominantly on perceptual operations, whereas other tests draw on conceptual (meaning-based) operations.

There is one sphere, however, in which the transfer-appropriate processing ideas fare less well. The recent flurry of interest in implicit memory was originally sparked by the exciting discovery of preserved priming in amnesic patients, so any general theory of priming should provide a ready explanation of phenomena in this realm. The most natural interpretation in terms of the transfer-appropriate procedures ideas is that amnesics may be deficient in the conceptual operations used in episodic memory but that perceptual operations—the perceptual record, as Dunn and Kirsner (1989) called it—supporting perceptual priming should be intact. This prediction turns out to hold quite nicely, in part. Amnesics do show preserved priming on implicit memory tests that involve challenging the perceptual system with degraded objects (words or pictures) that must be identified. However, amnesics also show intact priming on implicit memory tests that seem to be conceptually driven, such as free associating to category names (see Shimamura, 1986, for a review; also, McAndrews, Glisky, & Schacter, 1987, for an interesting example). Amnesics show preserved priming on many implicit tests, not just those that are perceptual in nature. In addition, further evidence favoring multiple priming systems comes from the finding that implicit memory tests can be dissociated from one another in different patient populations (Heindel, Salmon, Shults, Walicke, & Butters, 1989). In short, the evidence from patient populations fits well within the framework postulating multiple memory systems (see Sherry & Schacter, 1987; Squire, 1987; Weiskrantz, 1987, 1989).

At the present pass, transfer-appropriate procedures ideas account better for data from normal subjects, but memory systems proposals are favored by the neuropsychological data and that from psychobiological work with animals, as well (e.g., Mishkin & Appenzeller, 1987). Schacter (in press) and Tulving and Schacter (1990) have proposed a way beyond this impasse. They have pointed out that there is no necessary incompatibility between systems theories and processing theories. After all, proponents of memory systems must allow for processes by which these systems operate. Thus, the basic assumptions of transfer-appropriate processing can be incorporated into memory systems accounts, a position advocated by Hayman and Tulving (1989). Schacter (in press) has further argued that the pattern of dissociations seen in normal subjects results from the operation of distinct priming systems. In particular, he argued that what has been called *perceptual* or *data-driven* priming in tasks such as word-fragment completion is the result of priming in a perceptual representation system that preserves word form (hence the *word-form system*). Similarly, priming of pictures and objects results from operation of a second perceptual representation system called the *structural-description system* (normally used in perceiving objects). The assumption of these two perceptual systems accounts well for dissociations found in normal subjects between perceptual and conceptual tests (as reviewed in Roediger, Srinivas, & Weldon, 1989) and for data showing specificity of priming between pictures and words (see Figure 7; Weldon & Roediger, 1987). The postulation of these two new perceptual representation systems is not solely to account for the dissociations obtained in priming experiments, but is consistent with other neuropsychological work requiring such systems to explain results from dyslexic patients (the word-form system) and from patients with visual agnosia (the structural-description system). Schacter (in press) reviewed this evidence.

The proposals by Schacter (in press) and Tulving and Schacter (1990) advocating perceptual representation systems to account for preserved priming in amnesics and for dissociations between tasks in normal subjects still leaves one problem, the one shared with the transfer-appropriate processing approach: Why do amnesics show preserved priming on conceptual priming tasks (e.g., Graf, Shimamura, & Squire, 1985), and why is priming on conceptual tasks dissociated from that on perceptual tasks in normal subjects (Blaxton, 1989; Srinivas & Roediger, 1990)? One line of explanation is that such priming represents the operation of yet another memory system (Schacter, in press; Tulving & Schacter, 1990). Tulving and Schacter (1990) have suggested that "conceptual priming involves modification of semantic memory" (p. 305).

The ideas of Schacter (in press; Schacter, Cooper, & Delaney, 1990) and Tulving (Hayman & Tulving, 1989; Tulving & Schacter, 1990) do resolve the debate between memory systems and processing approaches. However, they do so at the sacrifice of parsimony. Whereas priming was viewed as a reflection of a rather general system just a few years ago (e.g., Squire, 1987; Tulving, 1985), three separate memory systems (a word-form system, a structural-description system, and a conceptual-semantic system) are now required just to explain priming effects. Roediger (1990) estimated that some 20 to 25 different memory systems might be implicated just on the basis of dissociations discovered by cognitive neuropsychologists in studying brain-damaged patients. Of course, parsimony is no virtue if the facts require complex explanation, but at the moment so many data are being collected that the "facts" about dissociations are still unclear. The number of dissociations discovered between tests appears likely to increase inexorably.

A primary challenge for the future will be to consider alternative interpretations of the plethora of dissociations between tests obtained in both pathological and normal populations. For example, different patterns of effects have been found on implicit memory tests that seem quite similar in their general characteristics (e.g., Schwartz, 1989), but investigators should hesitate to ascribe these differences to different memory systems, or else there will soon be a memory system for each priming task. But when does a pattern of dissociations implicate a new memory system and when should other explanations be sought? Sherry and Schacter (1987) proposed general principles for postulating memory systems, but current proposals rarely meet their strict criteria (Roediger et al., in press). A different avenue of explanation, more in harmony with the processing approach, is to consider the cognitive tasks used to assess retention as composed of component processes. Associations and dissociations between tasks can then be predicted as to whether tasks share component processes in common and whether independent variables affect these components (see Dunn & Kirsner, 1989; Hintzman, 1984; Kolers & Roediger, 1984; Moscovitch, 1984; Witherspoon & Moscovitch, 1989, for representative viewpoints). Of course, determining the component processes in a task and determining whether two tasks share them is as daunting an undertaking as uncovering separate memory systems. The theoretical challenges for the future seem obvious; the solutions much less so.

One general point of agreement between some proponents of a processing approach (Roediger, Weldon, & Challis, 1989) and others proposing distinct systems (e.g., Schacter, in press; Tulving & Schacter, 1990) is that some forms of priming are perceptual in nature and others conceptual. However, some recent results seem to challenge even this limited conclusion (e.g., Hunt & Toth, 1990; Hirshman, Snodgrass, Mindes, & Feenan, 1990; Toth & Hunt, in press). For example, these researchers find that generating information rather than reading it sometimes has small beneficial effects on perceptual tasks such as fragment completion, contrary to the literature reviewed earlier and other evidence (e.g., Java & Gardiner, in press). In addition, Kolers (1978) has pointed to the general problem of separating different forms of knowledge and argued that even perceptual activities form part of an event's meaning. Despite these difficulties, as yet no other theoretical proposals can both account for the body of past research and the anomalies cropping up in this recent research. It seems likely that theories of dissociations between memory tests will incorporate some form of a perceptual-conceptual contrast, at least until a more compelling theoretical interpretation becomes available.

Extensions and Applications

The study of implicit retention not only holds promise for revolutionizing the study of human learning and memory, but also ramifies into numerous cognate fields in important ways. I have already discussed one application to person perception in social cognition (E. R. Smith & Branscombe, 1988), but interrelations with other issues in this area also bear considering. Nisbett and Wilson (1977) pointed to many examples of how people's behavior is sometimes uncorrelated with their reports of the reasons for their actions. Although this claim strikes many as controversial, implicit memory studies also provide numerous examples of cases in which measures of conscious retention are dissociated from other measures of knowledge, such as priming. Also, Jacoby, Kelley, and their colleagues (e.g., Jacoby & Kelley, 1987; Jacoby, Kelley, & Dywan, 1989) have provided an attributional analysis of remembering in which they study the conditions under which people attribute familiarity of current conscious experience to past events (memory) or to other sources, such as the salience of the current event. They have provided many clever demonstrations of misattributions in memory; people can misattribute the familiarity caused by previous experience to a current event's perceptual salience, but under different circumstances can also misattribute the salience of a current event to its past history. When these misattributions are about memory for people and their actions, the relevance to social cognition is readily apparent.

The study of implicit retention has also penetrated the study of cognitive development, and much more research in this domain is likely to be seen. There is plentiful evidence that children's memories on many explicit memory tasks increase markedly over the early years of life (e.g., Kail, 1990); similarly, many studies attest to a general decline of explicit remembering late in life, especially on tasks that are quite effortful, such as free recall (Craik, 1977). Although relatively few developmental studies have yet been conducted, the evidence thus far does not show similar age-related benefits in priming over the early years nor declines in priming in the later years (Graf, 1990). For example, Parkin and Streete (1988) showed pictures to three-, five-, and seven-year-olds and later tested their memories for the pictures by presenting fragmented forms and having children guess the names of the pictures (half had been studied, half had not). This implicit test was followed by an explicit recognition test. The children showed marked improvement with age on the recognition test, but showed no differential priming on the implicit test. This outcome represents a dissociation between explicit and implicit retention similar to that obtained in amnesic populations. Light and Singh (1987), Mitchell (1989), and Java and Gardiner (in press) have reported similar findings in the aged; although explicit retention is impaired in old relative to young adults, the amount of priming (e.g., on word-fragment and word-stem completion tests) is affected either very little or not at all. The use of implicit tests of retention will likely grow in exploring other areas in which explicit tests of retention show poor performance, such as in hypnotic amnesia (Kihlstrom, 1980) or drug-induced amnesia (Hashtroudi, Parker, DeLisi, Wyatt, & Mutter, 1984).

Numerous other areas of psychology, from the most basic processes in perception to applied processes in clinical settings, may eventually be informed by studies of implicit retention (see Roediger, 1990, for further speculations). I conclude this section by mentioning just one more case of how studies of implicit retention may contribute to research on higher cognitive processes and on education. The topic of transfer of training used to be a fundamental issue in the study of learning and memory, but has largely dropped from the scene as a subject in its own right. The study of implicit memory may change this situation, because all implicit measures draw on the transfer of training logic: Subjects are given some training experiences (although they are not called this) and then transferred to some new situation. The effect of the training experiences is determined by transfer to the new situation, relative to a condition in which the training experiences were not given. Looked at this way, studies of implicit memory bear resemblance to the study of many cognitive phenomena. For example, if people learn to solve one type of problem and then are given new problems in which a similar solution will work, will they show transfer? Much research on the topic of analogical transfer in problem solving shows that transfer is often surprisingly specific to the training examples (e.g., Gick & Holyoak, 1983). Unless the surface form of the problem is so close to the training problem as to cause explicit remembrance (or unless subjects are explicitly told that the new problem is like the old one), positive transfer is generally small (e.g., Ross, 1987). The specificity of transfer is similar to that often observed in implicit memory experiments.

A related issue of educational importance is how well abstract principles learned in the classroom can be carried over (transferred) to problems in other contexts. Some work here is more hopeful because researchers have reported that thorough instruction of abstract principles and rules coupled with numerous concrete examples can produce substantial rates of spontaneous transfer (e.g., Bassok & Holyoak, 1989; Fong, Krantz, & Nisbett, 1986). As the study of implicit retention proceeds, investigators may anticipate cross-fertilization of thought from many other areas within psychology (Roediger, 1990).

Conclusion

Systematic study of implicit memory phenomena has been carried forward for only a decade, but already the returns are rich and exciting. Many "standard" variables exert surprisingly different effects on many more measures of implicit memory than on traditional explicit measures. Unraveling the puzzles presented by the new implicit memory phenomena and relating them to other domains should occupy researchers for many years. We now know enough about implicit memory phenomena to make us interested, but probably the important discoveries lie in the future. Although Ebbinghaus (1913/1964) outlined distinctions among various forms of memory, it is probably fair to say that we are only now even beginning to study and to understand them. Lewis Thomas made the following observations about biomedical research nearly two decades ago, but they capture well the current situation in the study of implicit memory:

> The new mass of knowledge is still formless, incomplete, lacking the essential threads of connection, displaying misleading signals at every turn, riddled with blind alleys. There are fascinating ideas all over the place, irresistible experiments beyond numbering, all sorts of new ways into the maze of problems. But every next move is unpredictable, every outcome is uncertain. It is a puzzling time, but a very good time. (Thomas, 1974, p. 119)

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