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CRITICAL REVIEW

Implicit Memory: History and Current Status

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Memory for a recent event can be expressed *explicitly,* as conscious recollection, or *implicitly,* as a facilitation of test performance without conscious recollection. A growing number of recent studies have been concerned with implicit memory and its relation to explicit memory. This article presents an historical survey of observations concerning implicit memory, reviews the findings of contemporary experimental research, and delineates the strengths and weaknesses of alternative theoretical accounts of implicit memory. It is argued that dissociations between implicit and explicit memory have been documented across numerous tasks and subject populations, represent an important challenge for research and theory, and should be viewed in the context of other dissociations between implicit and explicit expressions of knowledge that have been documented in recent cognitive and neuropsychological research.

Psychological studies of memory have traditionally relied on tests such as free recall, cued recall, and recognition. A prominent feature of these tests is that they make explicit reference to, and require conscious recollection of, a specific learning episode. During the past several years, however, increasing attention has been paid to experimental situations in which information that was encoded during a particular episode is subsequently expressed without conscious or deliberate recollection. Instead of being asked to try to remember recently presented information, subjects are simply required to perform a task, such as completing a graphemic fragment of a word, indicating a preference for one of several stimuli, or reading mirror-inverted script; memory is revealed by a facilitation or change in task performance that is attributable to information acquired during a previous study episode. Graf and Schacter (1985, 1987; Schacter & Graf, 1986a, 1986b) have labeled this type of memory *implicit memory,* and have used the term *explicit memory* to refer to conscious recollection of recently presented information, as expressed on traditional tests of free recall, cued recall, and recognition.

Recent cognitive and neuropsychological research has demonstrated a variety of striking dissociations between implicit and explicit memory and has shown that under certain conditions, implicit and explicit memory can be entirely independent of one another. These observations have raised fundamental questions concerning the nature and composition of memory, questions that will have to be addressed by any satisfactory theory of memory. The purposes of this article are to present an historical survey of observations concerning implicit memory, to review modern experimental studies and theoretical analyses, with particular emphasis on recent work in cognitive psychology and neuropsychology, and to suggest directions for future research.

Before the historical survey is initiated, two points regarding the terms implicit and explicit memory should be clarified. First, I use these terms in the manner suggested by Graf and Schacter (1985). Implicit memory is revealed when previous experiences facilitate performance on a task that does not require conscious or intentional recollection of those experiences; explicit memory is revealed when performance on a task requires conscious recollection of previous experiences. Note that these are *descriptive* concepts that are primarily concerned with a person's psychological experience at the time of retrieval. Accordingly, the concepts of implicit and explicit memory neither refer to, nor imply the existence of, two independent or separate memory systems. The question of whether implicit and explicit memory depend on a single underlying system or on multiple underlying systems is not yet resolved, as will be discussed later in this article. Second, the term *implicit memory* resembles two more familiar terms from the psychological literature: unconscious memory (e.g., Freud & Breuer, 1966; Prince, 1914) and unaware memory or memory without awareness (e.g., Eriksen, 1960; Jacoby & Witherspoon, 1982). These two terms have been used to describe phenomena that will be referred to here with the term *implicit memory.* The main reason for adopting *implicit memory* in favor of either *unconscious memory* or *unaware memory* has to do with the conceptual ambiguity of the

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latter two terms. The terms *unconscious* and *unaware* have a large number of psychological meanings and implications (e.g., Bowers, 1984; Ellenberger, 1970; Eriksen, 1960), many of which do not apply to the phenomena of interest here. Although the term *implicit* is not entirely free of conceptual ambiguity, it is less saturated with multiple and possibly misleading meanings than are *unconscious* or *unaware*.

Implicit Memory: An Historical Survey

This section considers ideas and observations concerning implicit memory contributed by philosophers, psychologists, neurologists, psychiatrists, and others from the 17th century until the middle of the 20th century. Unless otherwise stated, these investigators did not actually use the term *implicit memory* in their writings. They did, however, describe and discuss situations in which memory for recent experiences was expressed in the absence of conscious recollection. I sometimes use the phrase *implicit memory phenomena* in reference to these observations. This is done purely for purposes of expositional clarity and should not be seen as an attempt to put present concepts in the minds of past observers.

Philosophical Analyses: Descartes, Leibnitz, and Maine de Biran

It is widely recognized that both Plato and Aristotle commented extensively about the nature of memory, but both appear to have been concerned exclusively with explicit memory. During the Middle Ages, St. Augustine and St. Thomas Aquinas had a great deal to say about explicit retrieval and search processes, but I have not found any discussion of implicit memory in their writings.

The first clear reference to an implicit memory phenomenon appears to have been made by Descartes in his 1649 *The Passions of the Soul* (cited by Perry & Laurence, 1984), in which he observed that a frightening or aversive childhood experience may "remain imprinted on his [the child's] brain to the end of his life" without "any memory remaining of it afterwards" (Haldane & Ross, 1967, p. 391). Descartes did not, however, elaborate on the philosophical consequences of this phenomenon. In 1704, Gottfried Wilhelm Leibniz developed a systematic doctrine that both allowed for and made reference to implicit memory (Leibniz, 1916). He emphasized the importance of "insensible" or "unconscious" perceptions: ideas of which we are not consciously aware, but which do influence behavior. Leibniz explicitly claimed that people may have "remaining effects of former impressions without remembering them," and that ". . . often we have an extraordinary facility for conceiving certain things, because we formerly conceived them, without remembering them" (1916, p. 106). Although Leibniz's ideas concerning unconscious perceptions were later championed by several students and followers, they constituted a minority view during the 18th century, owing largely to the predominance of the British associationists. Locke, Hume, Mill, Brown, Hartley and others discussed memory at considerable length, but their analysis was restricted entirely to the domain of explicit memory; they had virtually nothing to say about implicit memory. Darwin (1794, p. 12) distinguished between *involuntary* and *voluntary* recollection, but both of these concepts were used in reference to explicit memory phenomena.

The first philosopher after Leibniz to systematically discuss phenomena of implicit memory was a French philosopher known by the surname Maine de Biran. Though virtually unknown today, he published an important treatise in 1804 entitled *The Influence of Habit on the Faculty of Thinking* (Maine de Biran, 1929). Like others before him, Maine de Biran believed that the analysis of habit was central to an understanding of human thought and behavior. Unlike others, however, Maine de Biran elucidated a feature of habit that had not been discussed previously in philosophical or scientific analyses: After sufficient repetition, a habit can eventually be executed *automatically* and *unconsciously* without awareness of the act itself or of the previous episodes in which the habit was learned. Thus, he observed that repeated actions are eventually executed with "such promptitude and facility that we no longer perceive the voluntary action which directs them and we are absolutely unaware of the source that they have" (p. 73). The most striking feature of Maine de Biran's system, however, was his delineation and detailed discussion of three different types of memory: mechanical, sensitive, and representative. The first two types are driven by habit and are involved in the largely unconscious or implicit expression of repeated movements (mechanical) and feelings (sensitive); the third type (representative) is involved in conscious recollection of ideas and events (pp. 156–157). Thus, according to Maine de Biran,

> If signs [in Maine de Biran's system, a *sign* is a motor response code] are absolutely empty of ideas or separated from every representative effect, from whatever cause this isolation may arise, recall is only a simple repetition of movements. I shall call this faculty for it *mechanical* memory. When the . . . recall of the sign is accompanied or immediately followed by the clear appearance of a well circumscribed idea, I shall attribute to it *representative memory*. If the sign expresses an affective modification, a feeling or even a fantastic image whatsoever, a vague, uncertain concept, which cannot be brought back to sense impressions . . . the recall of the sign . . . will belong to *sensitive memory*. (p. 156)

Maine de Biran's scheme represents the first clear articulation of what we might now call a *multiple memory system* interpretation of differences between implicit and explicit memory. Although it is alleged that Maine de Biran influenced the thinking of both Pierre Janet and Henri Bergson (Ellenberger, 1970), his ideas went almost entirely unrecognized outside of France. Most subsequent 19th-century philosophers did not systematically discuss the implicit expressions of memory that were so central to Maine de Biran's view. One exception was Johann Friedrich Herbart, who in 1816 introduced the notion that "suppressed ideas," which are unable to exceed the threshold of conscious awareness, can nevertheless influence conscious thinking (Herbart, 1896). The next systematic contributions were made by 19th-century scientists who approached the issue from the standpoint of biology and physiology.

Middle 19th Century: Unconscious Cerebration and Organic Memory

It is now widely recognized that various 19th-century thinkers were concerned with the general problem of unconscious

mental processing (cf. Ellenberger, 1970; Perry & Laurence, 1984). One of the most prolific of them was the British physiologist William Carpenter, who invoked the term *unconscious cerebration* to refer to mental activity that occurs outside of awareness (Carpenter, 1874). To support this idea, Carpenter marshalled clinical and anecdotal observations which demonstrated that the effects of recent experiences could be expressed without conscious awareness of those experiences. For example, drawing on observations of automatic writing (writing that appears to occur involuntarily while a subject is in a hypnotic or similar state), he claimed that "It is a most remarkable confirmation of this view [unconscious cerebration], that ideas which have passed out of the *conscious* memory, sometimes express themselves in *involuntary muscular movements,* to the great surprise of the individuals executing them . . ." (1874, pp. 524–525). To Carpenter, the striking lack of autobiographical recognition or awareness that characterized implicit memory phenomena highlighted the critical role of such awareness in normal memory:

> Without this recognition, we should live in the present alone; for the reproduction of past states of consciousness would affect us only like the succession of fantasies presented to us in the play of the imagination . . . I am satisfied that I am the person to whom such and such experiences happened yesterday or a month, or a year, or twenty years ago; because I am not only conscious at the moment of the ideas which represent those experiences, but because I recognize them as the revived representations of my past experiences. (1874, p. 455)

Carpenter's concept of unconscious cerebration and consequent interest in implicit memory derived from a more general attempt to relate physiology and psychology. A similar integrative effort was made by the Viennese physiologist Ewald Hering, who in 1870 introduced the idea of *organic* or *unconscious* memory (Hering, 1920). Hering criticized earlier writers for restricting their analyses to conscious or explicit memory: "The word 'memory' is often understood as though it meant nothing more than our faculty of intentionally reproducing ideas or series of ideas" (1920, p. 68). Hering argued that it is necessary to consider unconscious memory, which is involved in involuntary recall, the development of automatic and unconscious habitual actions, and even in the processes of ontogenetic development and heredity. Although this latter aspect of Hering's analysis clearly lies outside the domain of the present concerns, his psychological analyses of involuntary recall and the development of automaticity shared much in common with the earlier ideas of Maine de Biran. Following Hering's lead, a large number of psychologists, biologists, and others developed ideas concerning organic memory and its relation to what they referred to as conscious memory (see Schacter, 1982, chap. 7).

Late 19th and Early 20th Century: Systematic Empirical and Theoretical Developments

Toward the end of the 19th century, systematic empirical and theoretical analyses of implicit memory emerged in five different areas: "psychical" research, neurology, psychiatry, philosophy, and experimental psychology.

Psychical research. Although modern practitioners might be reluctant to admit it, a good case can be made that 19th-century psychical researchers were the first to document implicit memory phenomena on the basis of controlled empirical observation. Two major "implicit memory tests" were used: crystal ball gazing and automatic writing. Both procedures were characterized by the main feature of an implicit memory test: When performing these tasks, subjects made no explicit reference to a specific past event; they either reported what they "saw" in the crystal or wrote whatever came to mind. Although the purpose of these procedures was to document phenomena such as telepathy and clairvoyance, several investigators reported that fragmentary representations of past experiences, devoid of any familiarity or autobiographical reference, frequently appeared during crystal gazing and automatic writing.

In an anonymously authored article in the *Journal of the Society for Psychical Research* (Miss X, 1889), it was reported that information that had been registered unconsciously (i.e., without attention) during the recent past often surfaced as an unfamiliar "vision" during crystal gazing. On the basis of this observation, the author questioned "spiritual" interpretations of crystal visions: "It is easy to see how visions of this kind, occurring in the age of superstition, almost irresistibly suggested the theory of spirit-visitation. The percipient, receiving information which he did not recognize as already in his own mind, would inevitably suppose it to be derived from some invisible and unknown source external to himself" (p. 513). In studies of automatic writing, several investigators described the emergence of knowledge acquired during past episodes which subjects were not aware that they possessed and that seemed foreign to their conscious personalities (Binet, 1890; Prince, 1914). On the basis of his own experiments with automatic writing, Barkworth (1891) concluded that "nothing is ever really forgotten, though the bygone memories evoked by pencil, or crystal, may appear so new and strange that we fail to recognize them as ever having been included in our experience" (p. 29).

Neurology. In 1845, the British physician Robert Dunn described the case of a woman who became amnesic after a near drowning and a long period of unconsciousness. During her amnesic state, the woman learned how to make dresses, even though she apparently did not explicitly remember that she had made any dresses: "She applied herself closely to her new occupation and abandoned altogether the old one. Still she had no recollection from day to day what she had done, and every morning began something new unless her unfinished work was placed before her" (1845, p. 588). Dunn did not discuss the theoretical implications of his observations.

Perhaps the first investigator to document implicit memory phenomena in neurological cases of amnesia and to delineate their theoretical implications was Sergei Korsakoff (1889). In one of his two classic papers describing the amnesic syndrome that now bears his name, Korsakoff observed that ". . . although the patient was not aware that he preserved traces of impressions that he received, those traces however probably existed and had an influence in one way or another on the course of ideas, at least in unconscious intellectual activity" (1889, p. 512). Korsakoff provided several insightful observations to support this notion. For example, he described a patient whom he had given an electrical shock. Though this patient did not explicitly remember being given any shocks, when Korsakoff showed him a case that contained the shock apparatus, "he told

me that I probably came to electrify him, and meanwhile I knew well that he had only learned to know that machine during his illness" (p. 512). Korsakoff went on to argue that amnesic patients retained "weak" memory traces that could affect behavior unconsciously, but were not "strong" enough to enter conscious memory. He emphasized that his observations had important implications for psychologists:

> We notice that a whole series of traces which could in no way be restored to consciousness, neither actively nor passively, continue to exist in unconscious life, continue to direct the course of ideas of the patients, suggesting to him some or other inferences and decisions. That seems to me to be one of the most interesting peculiarities of the disturbance about which we are speaking. (p. 518)

Over 20 years later, Claparède (1911/1951) reported observations that were similar to Korsakoff's, although they are somewhat better known today. Claparède described the now famous example of an amnesic woman who refused to shake hands with him after he pricked her with a pin, even though she did not explicitly remember that Claparède had done so. Claparède interpreted this implicit expression of memory in terms of a disconnection between the ego and the memory trace. At about the same time, Schneider (1912, cited in Parkin, 1982) reported experiments in which he demonstrated that amnesic patients required progressively less information across learning trials to identify fragmented pictures, even though patients did not explicitly remember having seen the pictures before.

Psychiatry. Seminal observations concerning implicit memory were reported in the late 1880s and early 1890s by Pierre Janet and by Sigmund Freud, partly in collaboration with Joseph Breuer. For both Janet and Freud, the critical phenomena were observed in patients suffering hysterical amnesia as a result of emotional trauma. Although these patients could not explicitly remember the traumatic events, their memories of them were expressed indirectly (implicitly) in various ways. Janet (1893), for example, described a case in which a woman became amnesic after being mistakenly informed by a man who appeared suddenly in her doorway that her husband had died. Even though she subsequently could not consciously remember this incident, she "froze with terror" whenever she passed the door that the man had entered. In a later article, Janet (1904) described a woman who had become amnesic following the death of her mother. Though she could not consciously remember any of the events surrounding her mother's death, she experienced "hallucinations" that preserved the contents of those events. After describing numerous other cases of implicit memory in hysteric patients, Janet concluded that hysterical amnesia consists of two key factors: "1. the inability of the subject to evoke memories consciously and voluntarily, and 2. the automatic, compelling, and untimely activation of these same memories" (1904, p. 24). He theorized that hysteria was attributable to a pathological process of dissociation that interfered with the ability to synthesize memories into the "personal consciousness."

Freud's observations on hysteria were similar to Janet's insofar as he emphasized that traumatic memories, inaccessible to consciousness, were expressed unconsciously by the patient as hysterical symptoms (see Freud & Breuer, 1966, for relevant cases). Although Freud later changed this view (Ellenberger, 1970), he never abandoned the idea that unconscious memories exert powerful influences on behavior.

Both Janet and Freud emphasized the role of unconscious or implicit memory in psychopathology. The American psychiatrist Morton Prince clearly delineated the importance of implicit memory for normal cognitive function. In *The Unconscious* (1914), Prince drew together numerous observations of implicit memory from work with hysterical patients, hypnosis, dreams, and automatic writing, in which ". . . memories of the forgotten experiences [are expressed] without awareness therefore on the part of the personal consciousness" (p. 13). Noting that ". . . memories may be made to reveal themselves, without inducing recollection, at the very moment when the subject cannot voluntarily recall them" (p. 63), Prince concluded that ". . . a conscious experience that has passed out of mind may not only recur again as conscious memory, but may recur subconsciously below the threshold of awareness" (p. 8). These observations, Prince argued, demonstrate that experiences that are not available to conscious or voluntary recall nevertheless influence cognition and behavior in everyday life:

> In normal life ideas of buried experiences of which we have no recollection intrude themselves from time to time and shape our judgments and the current of our thoughts without our realizing what has determined our mental processes. We have forgotten the source of our judgments, but this forgetfulness does not affect the mechanism of the process. (p. 68)

Philosophy. The major philosophical contribution to the analysis of implicit memory was made by Henri Bergson. In *Matter and Memory* (1911), he argued that "*The past survives under two distinct forms: first, in motor mechanisms; secondly, in independent recollections*" (p. 87). The first form of memory involves gradual learning of habits and skills and does not entail explicit reference to any specific past events; a learned habit ". . . bears upon it no mark which betrays its origin and classes it in the past; it is part of my present . . ." (p. 91). Bergson's second form of memory, recollection, entails explicit remembering of "memory-images" that represent specific events from one's past. Although this view is clearly reminiscent of Maine de Biran, Bergson did not actually discuss or even reference Maine de Biran's views anywhere in *Matter and Memory.*

Experimental psychology. Experimental psychologists paid relatively little attention to implicit memory phenomena in the late 19th and early 20th centuries. Even though there was a large and thriving field in this post-Ebbinghausian era (cf. Schacter, 1982, chap. 8), most practitioners did not distinguish between explicit and implicit memory. Several exceptions, however, can be identified. Ebbinghaus (1885) himself acknowledged that not all effects of memory are expressed in conscious awareness (1885, p. 2). He also made a relevant empirical contribution, noting that savings was observed over a 24-hr retention interval for items that he did not consciously remember having studied before (pp. 58–59; see Slamecka, 1985a, 1985b; Tulving, 1985b). This intriguing observation was not systematically followed up by Ebbinghaus or others. Ebbinghaus' savings paradigm, in which memory is tested by relearning previously studied lists, can be viewed more generally as an implicit memory test: Explicit recollection of a prior episode or list is not called for during relearning (Slamecka, 1985b). Indeed, Ebbinghaus

noted that one advantage of the savings method was that it could provide evidence for the existence in memory of information that could not be recollected consciously (1885, p. 8). Of course, numerous subsequent investigators used the savings method to analyze learning and transfer of training. Although there is a sense in which "the entire literature on transfer of training may be perceived as the study of implicit memory" (Slamecka, 1985b, p. 499), researchers did not view it as such and did not elaborate any distinctions like the one between implicit and explicit memory.

After Ebbinghaus, three lines of experimental investigation were concerned with certain aspects of implicit memory. First, Thorndike conducted a large number of experiments that, he claimed, demonstrated that subjects could learn various rules without conscious awareness of them or explicit memory for them (Thorndike & Rock, 1934; see Irwin, Kauffman, Prior, & Weaver, 1934, for methodological criticisms). Second, Poetzl reported in 1917 that unreported features of subliminally exposed pictures appeared in subjects' subsequent imagery and dreams, even though they did not remember these features and were allegedly unaware of them at the time of stimulus exposure (see Poetzl, 1960). Poetzl's experiments, however, were characterized by serious methodological deficiencies (Dixon, 1981; Erdelyi, 1970). Third, studies of hypnotic phenomena by Clark Hull (1933) and his students provided numerous demonstrations of implicit memory for skills, conditioned responses, and facts acquired during hypnosis. Hull's description of the quality of recall by hypnotic subjects resembled Claparède's and Korsakoff's earlier observations of organic amnesia: "In such cases they stated that the name seemed to come from 'nowhere' and was not accompanied by any recollection that the character or syllable had ever been encountered before" (1933, p. 134).

One further contribution from experimental psychology ought to be noted. In *Outline of Psychology* (1924), William McDougall became the first investigator to use the terms *implicit* and *explicit* with reference to the different ways in which memory can be expressed. He distinguished between explicit recognition, which involves conscious recollection of a past event, and implicit recognition, which involves a change in behavior that is attributable to a recent event yet contains no conscious recollection of it or explicit reference to it (1924, pp. 308–309).

Summary of Historical Survey

Four general points can be made regarding the historical survey. First, observations of implicit memory were reported across a broad range of tasks, subjects, and conditions. Perhaps the richest sources of implicit memory phenomena were the clinical observations made by Claparède, Freud, Janet, Korsakoff, Prince, and others. With the exception of Prince, these clinicians did not set out with the specific aim of distinguishing between forms of memory. Nevertheless, they were insightful observers who recognized clearly that the phenomena they described had important implications for theories of normal and abnormal mental function. Indeed, there were relatively few investigators who explicitly raised the issue of whether different forms of memory could be distinguished and then went on to report original empirical observations; Ebbinghaus and Prince should be counted prominently among them. A second, related point is that most empirical observations either were anecdotal, were made under relatively uncontrolled clinical conditions, or were reported in experiments that lacked methodological rigor. Thus, even though the early observers reported phenomena that are broadly similar to those of interest today, methodological inadequacies limit the degree to which they bear directly on contemporary theoretical concerns. Third, there were only a few attempts to develop theoretical accounts of the dissociations that had been observed. The most popular idea was that implicit memory phenomena were produced by memory traces that are too "weak" to exceed the threshold of strength or activation needed for explicit memory (Herbart, 1896; Leibniz, 1916; Korsakoff, 1889; Prince, 1914). As will be shown later, recent experimental work has provided grounds for rejecting this view. However, several other ideas were advanced, including the multiple-memories view of Maine de Biran and Bergson, and the notion of a dissociation between memory traces and the "self" articulated by Claparède and Janet. Fourth, the various investigators who were concerned with implicit memory phenomena exhibited little or no knowledge of each other's work. This circumstance is perhaps not surprising, because observations of implicit memory were made in disparate fields of study.

Modern Research on Implicit Memory

Let us now consider research concerning implicit memory from the 1950s to the present. Data from five different though partly overlapping research areas will first be reviewed: savings during relearning, effects of subliminally encoded stimuli, learning and conditioning without awareness, repetition priming, and preserved learning in amnesic patients. This review is followed by a consideration of contemporary theoretical approaches to implicit memory.

Savings During Relearning

As noted earlier, it is possible to view the phenomenon of savings during relearning as an index of implicit memory, in the sense that relearning a previously studied list does not require explicit reference to a prior learning episode, although the influence of the prior episode is revealed by savings (cf. Slamecka, 1985b). However, little of the voluminous research on savings has addressed the question of whether subjects do indeed rely on explicit memory for prior learning episodes when relearning a list, so it is not entirely clear what savings studies tell us about implicit memory. The most directly pertinent evidence has been provided by Nelson (1978), who has shown savings for items that are neither recalled nor recognized, which thereby suggests that savings can occur in an entirely implicit manner.

Effects of Subliminally Encoded Stimuli

The controversy concerning subliminal perception is well known to experimental psychologists (Dixon, 1971). Although early experiments purporting to demonstrate subliminal perception were severely criticized (Eriksen, 1960), recent studies using a variety of new experimental techniques have supplied more convincing evidence that stimuli that are not represented in subjective awareness (Cheesman & Merikle, 1986) are never-

theless processed to high levels by the perceptual system (e.g., Cheesman & Merikle, 1986; Dixon, 1981; Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1983; see Holender, 1986, for a methodological critique). More relevant to the present concerns, several studies have purported to show that stimuli that are not consciously perceived, and hence cannot be explicitly remembered, influence subsequent behavior and performance on tasks that do not require conscious recollection of the subliminal stimulus, such as free association (Haber & Erdelyi, 1967; Shevrin & Fritzler, 1968) and imaginative story and fantasy productions (Giddan, 1967; Pine, 1960). However, questions regarding interpretation of these results have been raised (Dixon, 1981; Erdelyi, 1970).

The foregoing experiments did not systematically examine the relation between implicit and explicit memory for subliminally exposed stimuli. However, recent studies have demonstrated implicit memory for subliminal or briefly exposed stimuli under conditions in which subjects exhibit little or no explicit memory. Kunst-Wilson and Zajonc (1980) showed subjects geometric shapes at exposure durations that they contended were too brief (1 ms) to permit conscious perception. Explicit memory for the shapes, as indexed by forced-choice recognition performance, was at chance. However, subjects demonstrated implicit memory by showing a reliable preference for the previously exposed shapes on a test in which they rated which of two shapes—one old, one new—they liked better. Similar results have been reported by Seamon, Brody, and Kauff (1983) and Wilson (1979). Mandler, Nakamura, and Van Zandt (in press) showed that brief stimulus exposures that yield chance levels of recognition memory can influence nonaffective stimulus judgments (i.e., brightness). Bargh and Pietromonaco (1982) examined the effects of subliminal exposures to "hostile" words (e.g., unkind, thoughtless) on a subsequent impression formation task. Subjects who had been given subliminal exposures to hostile words later rated a target person more negatively than did those who had not received such prior exposure, even though explicit recognition of the hostile words was at the chance level. Bargh, Bond, Lombardi, and Tota (1986) observed similar implicit effects following subliminal exposure to various other types of words. Lewicki (1985) found that after subliminal exposure to adjective-noun pairs (e.g., *old–tree*) subjects tended to choose the previously exposed adjective in response to questions concerning how they "felt" about the noun (e.g., *Is a tree big or old?*).

A recent study by Eich (1984) that used a different method to attenuate conscious perception of target materials yielded data consistent with the foregoing results. Eich used an auditory divided attention task in which homophones were presented on the unattended channel together with words intended to bias the low frequency interpretation of the homophone (e.g., *taxi–*FARE). Subjects subsequently showed no explicit memory for the homophones on a *yes/no* recognition test. However, when required to spell the target words, subjects provided the low frequency spelling of the homophones more often than in baseline conditions, thereby demonstrating implicit memory for the unattended information.

Learning and Conditioning Without Awareness

In learning-without-awareness studies, subjects allegedly learn rules or contingencies without awareness of learning them and, hence, without explicit memory for them (cf. Greenspoon, 1955; Thorndike & Rock, 1934). The phenomenon was studied extensively during the 1950s in multitrial learning experiments in which subjects were reinforced for making specific responses or types of responses. Several investigators reported that subjects who were unaware of the reinforcement-response contingency provided the reinforced response with increasing frequency across trials, but others pointed to the lack of appropriate methods for determining subjects' awareness of the reinforcement-response contingency (for review, see Eriksen, 1960). Studies that used more rigorous methods for assessing awareness reported some positive evidence of learning without awareness (Giddan & Eriksen, 1959; Krieckhaus & Eriksen, 1960), as did research in which the reinforcement-response contingency was thoroughly disguised (Rosenfeld & Baer, 1969; see also Nisbett & Wilson, 1977). However, many negative observations were also reported (Brewer, 1974).

In related research, several investigators presented evidence that subjects could acquire various types of classically conditioned responses without awareness of conditioning contingencies (cf. Adams, 1957; Lacey & Smith, 1954), but assessment of awareness was often insufficient (Brewer, 1974). Along these same lines, research concerning the phenomenon of subception (Lazarus & McCleary, 1951) indicated that an experimentally acquired conditioned response, revealed by the galvanic skin response to nonsense syllables that had been accompanied by shock, could be subsequently elicited by brief exposures to the nonsense syllables, even though subjects did not detect the presence of the syllables. Although some questions and criticisms were raised about interpretations of the subception phenomenon, the finding that a conditioned response could sometimes be elicited by an unreported stimulus was not challenged (Eriksen, 1960, pp. 287–288).

Recent evidence concerning rule or contingency learning without awareness has been reported in a series of experiments by Reber and his colleagues concerning a phenomenon that they call *implicit learning* (e.g., Reber, 1976; Reber, Allen, & Regan, 1985; see also Brooks, 1978; Gordon & Holyoak, 1983; McAndrews & Moscovitch, 1985). In these studies, subjects were presented with letter strings that were organized according to various rules of a synthetic grammar. Reber and his associates reported that subjects learned to identify grammatically correct strings even when they were not consciously or explicitly aware of the appropriate rules (for critique and discussion, see Dulany, Carlson, & Dewey, 1984, 1985; Reber et al., 1985). Using a somewhat different procedure, Lewicki (1986) showed that contingencies between different features of stimulus information influenced latencies to respond to questions regarding the contingent features, even though none of the subjects could explicitly state the nature of the contingency.

Repetition Priming Effects

Most of the recent work in cognitive psychology that can be characterized as implicit memory research has been concerned with the phenomenon of direct or repetition priming (cf. Cofer, 1967): facilitation in the processing of a stimulus as a function of a recent encounter with the same stimulus. Repetition priming has been observed on a variety of tests that do not make

explicit reference to a prior study episode. The tests most commonly used in priming research are *lexical decision, word identification,* and *word stem* or *fragment completion.* On the lexical decision test (e.g., Forbach, Stanners, & Hochhaus, 1974; Scarborough, Gerard, & Cortese, 1979), subjects are required to state whether or not a particular letter string constitutes a legal word; priming is reflected by a decreased latency in the making of a lexical decision on the second presentation of a letter string relative to the first. On the word identification test (also referred to as *tachistoscopic identification* or *perceptual identification;* e.g., Feustel, Shiffrin, & Salasoo, 1983; Jacoby & Dallas, 1981; Neisser, 1954), subjects are given a brief exposure (e.g., 30 ms) to a stimulus and then attempt to identify it. Priming on this task is indicated by an increase in the accuracy of identifying recently exposed items relative to new items or by a decrease in the amount of exposure time necessary to identify recently exposed items. On word completion tests (e.g., Graf, Mandler, & Haden, 1982; Tulving, Schacter, & Stark, 1982; Warrington & Weiskrantz, 1974), subjects are either given a word *stem* (e.g., tab____ for table) or *fragment* (e.g., __ss__ss__ __ for assassin) and are instructed to complete it with the first appropriate word that comes to mind. Here, priming is reflected by an enhanced tendency to complete test stems or fragments with words exposed on a prior study list. Other priming tests include reading of transformed script (Kolers, 1975, 1976; Masson, 1984), face identification (Bruce & Valentine, 1985; Young, McWeeny, Hay, & Ellis, 1986), and free association (Storms, 1958; Williamsen, Johnson, & Eriksen, 1965).

The current interest in repetition priming derives from two distinct and at times independent areas of investigation. The first area grew out of research on word recognition and lexical organization. The general purpose of these studies was to use the pattern of priming effects observed on tasks such as word identification and lexical decision as a basis for making inferences about the nature of lexical access and representation (cf. Morton, 1979; Murrell & Morton, 1974; Scarborough et al., 1979). This line of research has yielded a number of useful findings about performance on implicit memory tests. Several investigators who attempted to distinguish between modality-specific and modality-nonspecific components of lexical organization by examining the effect of auditory–visual modality shifts on the magnitude of repetition priming reported little or no priming of tachistosopic identification (e.g., Kirsner & Smith, 1974; Kirsner, Milech, & Standen, 1983) and lexical decision performance (e.g., Kirsner et al., 1983; Scarborough et al., 1979) following an auditory study presentation. A number of studies have compared repetition priming of real words and nonwords, and have generally found that nonwords show either no priming or smaller amounts of priming than real words (Forbach et al., 1974; Forster & Davis, 1984; Kirsner & Smith, 1974; Scarborough, Cortese, & Scarborough, 1977), although robust priming of nonwords has been observed under some experimental conditions (Feustel et al., 1983; Salasoo, Shiffrin, & Feustel, 1985).

Several studies have demonstrated that priming of word identification performance occurs for morphologically similar words (e.g., exposure to *seen* facilitates identification of *sees;* Murrell & Morton, 1974), but not for visually similar words (*seen* does not facilitate *seed;* Murrell & Morton, 1974; see also Osgood & Hoosain, 1974) or phonologically similar words (*frays* does not facilitate *phrase;* Neisser, 1954). In an important study, Winnick and Daniel (1970) examined word identification performance following three types of study conditions: reading a familiar word from a visual presentation of it, generation of the word from a picture of it, or generation of the word from its definition. They observed significant priming on the word identification task following visual presentation but observed no priming in either of the generation conditions. By contrast, they found that free recall of words in both generation conditions was considerably higher than in the read condition. Although Winnick and Daniel did not set out to compare implicit and explicit memory, their results revealed a sharp dissociation between these two forms of memory (for similar results, see Jacoby, 1983b).

The second line of investigation concerned with priming effects was initiated in the context of research on episodic memory. It was stimulated largely by Warrington and Weiskrantz's (1968, 1974) work on amnesia, which will be reviewed in the next section. Their experiments demonstrated that amnesic patients showed excellent retention when required to complete three-letter stems of recently presented words, despite their inability to remember the prior occurrence of the words on a *yes/no* recognition test. Several investigators examined whether similar dissociations could be produced in normal subjects by manipulation of appropriate experimental variables (e.g., Graf et al., 1982; Jacoby & Dallas, 1981; Tulving et al., 1982), and thereby initiated systematic comparison of performance on implicit and explicit memory tests. Data generated by this line of investigation indicate that repetition priming effects on implicit memory tests can be experimentally dissociated from explicit recall and recognition in a number of ways.

First, several studies have demonstrated that variations in level or type of study processing have differential effects on priming and remembering, in conformity with the finding first reported by Winnick and Daniel (1970). For instance, Jacoby and Dallas (1981) showed subjects a list of familiar words and had them perform a study task that required elaborative processing (e.g., answering questions about the meaning of target words) or did not require elaborative processing (e.g., deciding whether or not a word contains a particular letter). Memory for the words was subsequently assessed with *yes/no* recognition and word identification tests. As expected on the basis of many previous experiments (cf. Craik & Tulving, 1975), explicit memory was influenced by type of study processing: Recognition performance was higher following elaborative study tasks than nonelaborative study tasks. Implicit memory, however, was unaffected by the study task manipulation; priming effects on word identification performance were about the same following the elaborative and nonelaborative processing tasks. Graf et al. (1982) reported a similar pattern of results by using free recall as an index of explicit memory and stem completion as an index of implicit memory. More recently, Graf and Mandler (1984) found dissociable effects of a study-task manipulation on implicit and explicit memory when test cues were identical (i.e., three-letter word stems) and only instructions were varied. When subjects were told to use the stems to try to remember study-list words (explicit memory instructions), more items were recalled following elaborative study processing than fol-

lowing nonelaborative study processing. However, when subjects were instructed to write down the first word that came to mind in response to a test stem (implicit memory instructions), type of study task did not affect the amount of priming observed. Schacter and McGlynn (1987) assessed implicit memory for common idioms (e.g., SOUR–GRAPES) with a free-association test (e.g., SOUR–?) in which subjects wrote down the first word that came to mind, and assessed explicit memory with a cued-recall test in which the same cue was provided and subjects were instructed to try to remember the appropriate study-list target. Implicit memory was invariant across several elaborative and nonelaborative study tasks that significantly influenced explicit memory.

A second type of dissociation between implicit and explicit memory involves the effect of study-test changes in modality of presentation and other types of surface information. As was noted earlier, priming effects on lexical decision and word identification tests are significantly reduced by study-test modality shifts (Clarke & Morton, 1983; Kirsner et al., 1983; Kirsner & Smith, 1974). Jacoby and Dallas (1981) compared the effects of modality shifts on implicit (word identification) and explicit (*yes/no* recognition) tasks. They found that changing modality of presentation from study (auditory) to test (visual) severely attenuated priming effects on word identification performance but had little or no effect on recognition performance. Graf, Shimamura, and Squire (1985) reported that priming effects on the stem-completion task were reduced by a study-test modality shift, whereas cued-recall performance was not significantly influenced by this manipulation, and Roediger and Blaxton (1987) found that priming of word-fragment completion performance was attenuated by modality shifts even though free-recall and recognition performance were largely unaffected. Along the same lines, several studies have shown that within the visual modality, priming effects on lexical decision, fragment completion, and reading tasks are highly sensitive to study-test changes of various types of surface information (Kolers, 1975, 1976; Roediger & Blaxton, 1987; Roediger & Weldon, 1987; Scarborough et al., 1979), whereas recall and recognition are either unaffected or slightly affected by such changes.

A third kind of evidence for implicit/explicit dissociations comes from studies that have manipulated retention interval. On both word-fragment completion (Komatsu & Ohta, 1984; Tulving et al., 1982) and word identification tests (Jacoby & Dallas, 1981), priming effects persist with little change across delays of days and weeks, whereas recognition memory declines across the same delays. In other situations, however, priming of word-stem completion (Graf & Mandler, 1984; Graf et al., 1984; Shimamura & Squire, 1984) and lexical decision (Forster & Davis, 1984) has proved to be a relatively transient phenomenon, decaying across delays of minutes and hours over which explicit remembering persists. Fourth, recent studies indicate that manipulations of retroactive and proactive interference that significantly impair explicit recall and recognition do not influence priming effects on either word-stem completion (Graf & Schacter, 1987) or word-fragment completion (Sloman, Hayman, Ohta, & Tulving, in press). A fifth and final type of evidence for dissociation between priming and remembering is the finding of statistical independence between performance on recognition tests and tests of word-fragment completion (Tulving et al., 1982), word-stem completion (Graf & Schacter, 1985), homophone spelling (Eich, 1984; Jacoby & Witherspoon, 1982), prototype identification (Metcalfe & Fisher, 1986), and reading of mirror inverted script (Kolers, 1976). In these experiments, successful performance on an implicit memory test was uncorrelated with success or failure on an explicit memory test.

Taken together, the foregoing studies provide impressive evidence that priming effects on implicit memory tests differ substantially from explicit recall and recognition. Other studies, however, have revealed several similarities between priming and remembering. First, under certain conditions manipulations of retention interval have parallel effects on priming effects and explicit memory (Jacoby, 1983a; Schacter & Graf, 1986a; Sloman et al., in press). Second, Jacoby (1983a) has shown that manipulating list context at the time of test, which is known to affect recognition memory, also affects performance on the word identification task: Identification performance was higher when 90% of tested words came from a previously studied list than when only 10% did. Third, both implicit and explicit memory are influenced by newly acquired associations between unrelated word pairs. On a variety of implicit memory tests, including word-stem completion (Graf & Schacter, 1985, 1987; Schacter & Graf, 1986a, 1986b), lexical decision (McKoon & Ratcliff, 1979, 1986), and reading of degraded word pairs (Moscovitch et al., 1986), more priming is observed when a target word is tested in the context of its study-list cue than when it is tested alone or in the presence of some other cue. Fourth, this phenomenon of *implicit memory for new associations* (cf. Graf & Schacter, 1985) resembles explicit remembering of new associations insofar as it depends on some degree of elaborative processing at the time of study. For example, Schacter and Graf observed associative effects on word completion performance after subjects had performed study tasks that required them to elaborate semantic links between two unrelated words, such as generating sentences or reading meaningful sentences (e.g., *The injured* OFFICER *smelled the* FLOWER). When subjects engaged in study tasks that prevented elaboration of semantic relations, such as comparing the number of vowels and consonants in the target words or reading anomalous sentences (e.g., *The dusky* COW *multiplied the* EMPLOYER), implicit memory for new associations was not observed. Schacter and McGlynn (1987), using free-association and cued-recall tests, also found that both implicit and explicit memory for newly acquired associations depends on elaborative study processing. A fifth type of evidence showing a relation between implicit and explicit memory was reported by Johnston, Dark, & Jacoby (1985). They demonstrated that processes subserving implicit memory can affect performance on an explicit memory task: Recently studied words that were identified quickly on a word identification test were more likely to be given a recognition judgment of "old" than were more slowly identified words. These similarities between implicit and explicit memory have a number of implications that will be discussed later when alternative theoretical accounts of implicit memory are compared.

Implicit Memory in Amnesia

The amnesic syndrome, which is produced by lesions to the medial temporal and diencephalic regions of the brain (e.g.,

Moscovitch, 1982; Rozin, 1976; Squire, 1986; Weiskrantz, 1985), is characterized by normal perceptual, linguistic, and intellectual functioning together with an inability to remember explicitly recent events and new information. Amnesic patients are seriously impaired on standard tests of explicit recall and recognition, and they perform disastrously in real-life situations that require explicit remembering, such as recollecting actions and events during a round of golf (Schacter, 1983). Beginning with the previously discussed clinical observations of Korsakoff (1889) and Claparède (1911/1951), instances of implicit memory by amnesic patients have been documented widely. Most modern studies of implicit memory in amnesia can be classified into two broad categories: skill learning or repetition priming.

Research on skill learning in amnesia was initiated by Milner and Corkin and their colleagues in the 1960s. They demonstrated that the profoundly amnesic patient H.M. could acquire motor skills such as pursuit rotor and mirror tracing, even though he did not remember explicitly that he had previously performed the task (Milner, 1962; Milner, Corkin, & Teuber, 1968). Robust learning of motor skills has been observed in various other amnesic patients (e.g., Butters, 1987; Eslinger & Damasio, 1986; Starr & Phillips, 1970). Amnesic patients have also exhibited normal or near-normal learning of perceptual and cognitive skills, including reading of mirror-inverted script (Cohen & Squire, 1980; Moscovitch, 1982), puzzle solving (Brooks & Baddeley, 1976), rule learning (Kinsbourne & Wood, 1975), and serial pattern learning (Nissen & Bullemer, 1987), despite their failure to remember explicitly that they had previously performed the skills. Similar dissociations have been observed in drug-induced amnesia (Nissen, Knopman, & Schacter, in press) and multiple-personality amnesia (Nissen, Ross, Willingham, Mackenzie, & Schacter, in press).

The second major area of research on implicit memory in amnesia, concerned with repetition priming effects, was initiated by the important series of experiments conducted by Warrington and Weiskrantz (1968, 1970, 1974, 1978). They found that amnesic patients could show normal retention of a list of familiar words when tested with word-stem or fragment cues, whereas these same patients were profoundly impaired on free-recall and recognition tests. Indeed, Warrington and Weiskrantz (1968) noted that patients often did not remember that they had been shown any study-list items and treated the fragment test as a kind of "guessing game." In subsequent research using the fragment cuing procedure, amnesic patients' performance was sometimes impaired with respect to that of control subjects (e.g., Squire, Wetzel, & Slater, 1978).

It is now clear that whether or not amnesic patients show normal retention when tested with word fragments and various other cues depends critically on the implicit/explicit nature of the test. For example, Graf et al., (1984) demonstrated that when subjects were given explicit memory instructions—that is, they were told to use word stems as cues for *remembering* previously studied words—amnesics were impaired with respect to controls. By contrast, when subjects were given implicit memory instructions—that is, they were told to complete the stems with the first word that comes to mind—amnesics and controls showed comparable amounts of priming (see also Graf et al., 1985). In an early and often overlooked study, Gardner, Boller, Moreines, and Butters (1973) presented Korsakoff's syndrome amnesics and controls with a categorized word list. When subjects were subsequently given category cues and asked to respond with the first category member that came to mind, both amnesics and controls showed equivalent amounts of priming. When asked to remember list items in response to category cues, amnesics were impaired with respect to controls (see also Graf et al., 1985; see Kihlstrom, 1980, for priming of category production performance in hypnotic amnesia). Schacter (1985) found that amnesic patients showed normal priming effects after studying a list of common idioms (e.g., SOUR–GRAPES) and then writing down the first word that came to mind on a free-association test (e.g., SOUR–?). Amnesics were impaired, however, when instructed to try to use the same cues to remember study-list targets. Shimamura and Squire (1984) obtained a similar pattern of results with highly related paired associates (e.g., TABLE–CHAIR). On the basis of these studies, it seems reasonable to conclude that normal retention of a list of familiar items by amnesic patients occurs only when implicit tests are used. Consistent with this observation, amnesic patients have shown normal priming effects on various other implicit memory tests, including lexical decision (Moscovitch, 1982), perceptual identification (Cermak, Talbot, Chandler, & Wolbarst, 1985), and homophone spelling (Jacoby & Witherspoon, 1982; for more extensive review, see Schacter & Graf, 1986b; Shimamura, 1986).

In most of the priming experiments discussed thus far, study materials consisted of items with integrated or unitized preexisting memory representations, such as common words, linguistic idioms, or highly related paired associates. Recently, several investigators have examined whether amnesic patients show normal priming or implicit memory for novel information that does not have any preexisting representation as a unit in memory, such as nonwords or unrelated paired associates. The results thus far have been mixed. Cermak et al. (1985) found that amnesic patients do not show priming of nonwords on a perceptual identification task, and Diamond and Rozin (1984) obtained similar results when implicit memory was tested with three-letter stems. Using a word completion test, Graf and Schacter (1985) and Schacter and Graf (1986b) found that some amnesic patients—those with relatively mild memory disorders—showed normal implicit memory for a newly acquired association between unrelated words, whereas severely amnesic patients did not show implicit memory for new associations. Moscovitch et al. (1986) assessed implicit memory with a task that involved reading degraded pairs of unrelated words, and observed normal implicit memory for new associations in patients with severe memory disorders. McAndrews, Glisky, and Schacter (in press) investigated implicit memory for new information by presenting subjects with novel, difficult-to-comprehend sentences (e.g., *The haystack was important because the cloth ripped.*), and requiring them to generate cues that rendered the sentences comprehensible (e.g., *parachute*). They found that severely amnesic patients' ability to generate the correct cues was facilitated substantially by a single prior exposure to the cue-sentence pair, despite their complete lack of explicit memory for the sentences and cues.

The foregoing studies indicate that amnesic patients can show priming effects for newly acquired information, but they

also suggest that such effects depend on the type of implicit memory test that is used and, in some instances, on the severity of amnesia. Another important issue concerning priming in amnesic patients concerns the duration of the phenomenon. Several investigators have reported that priming of word-completion performance in amnesic patients is a relatively transient phenomenon, lasting only a few hours (Diamond & Rozin, 1984; Graf et al., 1984; Rozin, 1976; Squire, Shimamura, & Graf, in press). By contrast, McAndrews et al. (in press) found that severely amnesic patients showed robust priming on their sentence puzzle task after a 1-week retention interval. These observations suggest that the duration of priming in amnesic patients may depend on the way that implicit memory is assessed and the nature of the target information.

In addition to skill learning and repetition priming phenomena, amnesic patients have also exhibited dissociations between implicit and explicit memory in various other situations. Schacter, Harbluk, and McLachlan (1984) demonstrated that amnesic patients could learn some fictitious information about people (e.g., *Bob Hope's father was a fireman*), but could not remember explicitly that they had just been told the information (see also Schacter & Tulving, 1982; Shimamura & Squire, 1987). Similarly, Luria (1976) observed that an amnesic patient produced bits and pieces of recently presented stories, even though he did not remember being told any stories. Glisky, Schacter, and Tulving (1986) showed that a densely amnesic patient could learn to program a microcomputer despite the patient's persistent failure to remember explicitly that he had ever worked on a microcomputer. Johnson, Kim, and Risse (1985) found that amnesics acquired preferences for previously exposed melodies, Crovitz, Harvey, and McClanahan (1979) demonstrated that amnesics could spot a hidden figure more quickly after a single exposure to it, and Weiskrantz and Warrington (1979) reported evidence of classical conditioning in amnesic patients—in all cases, with little or no explicit recollection of the experimental materials and of the learning episode itself.

Summary of Contemporary Studies

The research reviewed in the preceding five sections indicates that implicit memory has been documented across different tasks, materials, and subject populations. Although it is clear that a wide variety of phenomena can all be grouped together under the rather general heading of *implicit memory*, it is equally clear that there are differences among these diverse phenomena. One difference that may be significant theoretically concerns whether implicit memories are *accessible* or *inaccessible* explicitly—that is, whether or not information that is expressed implicitly can, under certain conditions, be remembered explicitly. Several studies have found substantial implicit memory when explicit recognition is at the chance level and explicit recall is at or close to the floor, thereby suggesting that the implicitly expressed information is inaccessible explicitly (e.g., Bargh & Pietromonaco, 1982; Eich, 1984; Graf et al., 1982, 1984; Kunst-Wilson & Zajonc, 1980; Lewicki, 1986; McAndrews et al., in press; Squire, Shimamura, & Graf, 1985). These findings come either from studies of amnesic patients or from experiments in which normal subjects are prevented from encoding target materials in a fully conscious or elaborative manner. By contrast, in studies of normal subjects that allow elaborative encoding of target materials, implicitly expressed information is generally accessible explicitly. For example, normal subjects who produce a previously studied word on a completion test following elaborative encoding are able to consciously remember having studied the word if an explicit recall test is given, whereas a densely amnesic patient who produces a recently studied word on a completion test cannot under any circumstances consciously or explicitly remember having studied the word.

The observation that many implicit memory phenomena in normal subjects fall into the category of "accessible explicitly" raises questions concerning the extent to which, and sense in which, such phenomena should be considered implicit. That is, if normal subjects *can* remember target information explicitly under appropriate test conditions, how can we be sure that they do not remember explicitly on a nominally implicit memory test? Some investigators have attempted to disguise the fact that previously presented items appear on a test by presenting an implicit memory task as one of several filler tasks during a retention interval, and by testing only a small proportion of previously studied items (e.g., Graf et al., 1984; Jacoby, 1983a; Schacter & Graf, 1986a). The point of these procedures is to prevent subjects from catching on concerning the nature of the test, or at least to discourage the use of explicit memory strategies. It seems quite likely, however, that subjects will "clue in" concerning the nature of the test once they have been exposed to, or have successfully produced, a number of list items. Nevertheless, the fact that several studies have shown differential effects of experimental variables on implicit and explicit memory tasks when identical test cues were provided, and only the implicit/explicit nature of test instructions were varied (e.g., Graf & Mandler, 1984; Schacter & Graf, 1986a), suggests that subjects do not deliberately use explicit memory strategies on implicit memory tasks. If subjects did use such strategies, we would expect to observe parallel effects of experimental variables when the same cues are provided on implicit and explicit tasks.

However, the foregoing considerations indicate only that it is possible to prevent intentional or *voluntary* explicit memory from influencing performance on implicit memory tests. It is possible that some instances of what appear to be implicit memory may be better described as *involuntary* explicit memory: cases in which a test cue leads to an unintentional but fully conscious and explicit "reminding" of the occurrence of a prior episode (cf. Ross, 1984). The possibility of confusing implicit memory with involuntary explicit memory would appear to be greatest in experiments with normal subjects that permit elaborative encoding of target materials. At present, we know little about the relation between implicit memory and involuntary explicit memory, but future research and theorizing should be directed toward this issue.

Another difference among the various implicit memory phenomena concerns whether or not target information acquired during a study episode is represented directly in consciousness at the time of test. For example, in repetition priming studies, the target material (i.e., *assassin*) is represented in consciousness at the time of test, such as when the subject completes a

test fragment with a previously studied item. By contrast, in other situations target content is not represented in consciousness at the time of test, yet influences performance *indirectly*. For example, when subjects performing an impression-formation task rate a target person more negatively because of subliminal exposure to hostile words that cannot be recalled (e.g., Bargh & Pietromonaco, 1982), or when subjects make classification responses on the basis of rules that they cannot articulate (e.g., Lewicki, 1986; Reber, 1976), the influence of acquired information on implicit memory is indirect. Although we do not know whether direct and indirect expressions of implicit memory differ in theoretically significant ways, the issue has been previously overlooked and may be worth exploring in future studies.

The foregoing considerations also highlight the fact that we presently lack well-specified criteria for assessing whether subjects are explicitly aware of previous experiences at the time of test (Tulving, 1985c). Similar issues concerning criteria for determining awareness have been debated extensively in the literature on perception and learning without awareness (e.g., Cheesman & Merikle, 1986; Eriksen, 1960; Nisbett & Wilson, 1977), and memory researchers would do well to attempt to incorporate some of the lessons from these investigations into research on implicit memory.

Theoretical Accounts of Implicit Memory

In view of the diversity of phenomena that can be grouped under the rubric of implicit memory, it is perhaps not surprising that no single theory has addressed, much less accounted for, all or even most of the observations discussed in this article. Rather, different theoretical views have been advanced to accommodate different subsets of the data. However, one general idea that can be rejected on the basis of recent research is the threshold view discussed in the historical section. The finding that implicit memory is unaffected by experimental variables that have large effects on explicit memory, and that performance on implicit tests is often statistically independent of performance on explicit tests, is inconsistent with a threshold model in which implicit and explicit tests differ only in their sensitivity to the strength of memory traces. In this section, three more viable theoretical approaches to implicit memory phenomena are considered, which are referred to, respectively, as *activation, processing,* and *multiple memory system* accounts. Each of these views has been concerned primarily with repetition priming effects and with dissociations observed in amnesic patients.

Activation views hold that priming effects on implicit memory tests are attributable to the temporary activation of preexisting representations, knowledge structures, or logogens (e.g., Graf & Mandler, 1984; Mandler, 1980; Morton, 1979; Rozin, 1976). Activation is assumed to occur automatically, independently of the elaborative processing that is necessary to establish new episodic memory traces. An activated representation readily "pops into mind" on an implicit memory test, but it contains no contextual information about an item's occurrence as part of a recent episode and therefore does not contribute to explicit remembering of the episode.

Processing views seek to understand differences between implicit and explicit memory by explicating the nature of and relations between encoding and retrieval processes or procedures (e.g., Craik, 1983; Jacoby, 1983a, 1983b; Moscovitch et al., 1986; Roediger & Blaxton, 1987; Witherspoon & Moscovitch, 1986). Such views assume that both implicit and explicit memory rely on newly established episodic representations, and portray differences between them in terms of interactions between features of encoded representations and different demands posed by implicit and explicit tests. The best articulated version of this view relies on the distinction between *conceptually driven* processes and *data-driven* processes (Jacoby, 1983b; Roediger & Blaxton, 1987). Conceptually driven processes reflect subject-initiated activities such as elaborating, organizing, and reconstructing; data-driven processes are initiated and guided by the information or data that is presented in test materials. Although both explicit and implicit tests can have data-driven and conceptually driven components, it is argued that explicit memory tests typically draw primarily on conceptually driven processes, whereas implicit tests typically draw primarily on data-driven processes. Performance dissociations between implicit and explicit tests are thus attributed to differences between conceptually driven and data-driven processes.

Multiple memory system interpretations ascribe differences between implicit and explicit memory to the different properties of hypothesized underlying systems. For example, Squire and Cohen (1984) argued that conscious or explicit recollection is a property of, and supported by, a *declarative* memory system that is involved in the formation of new representations or data structures. By contrast, implicit memory phenomena such as learning of skills and repetition priming effects are attributed to a *procedural* system in which memory is expressed by online modification of procedures or processing operations. The distinction between episodic and semantic memory (Tulving, 1972, 1983) has also been invoked to account for dissociations on implicit and explicit tests (e.g., Cermak et al., 1985; Kinsbourne & Wood, 1975; Parkin, 1982; Schacter & Tulving, 1982; Tulving, 1983). The episodic memory system is viewed as the basis for explicit remembering of recent events, whereas semantic memory is seen as responsible for performance on tasks such as word completion, lexical decision, and word identification, which require subjects to make use of preexisting knowledge of words and concepts. A variety of other multiple memory system views have also been put forward (e.g., Johnson, 1983; O'Keefe & Nadel, 1978; Schacter & Moscovitch, 1984; Warrington & Weiskrantz, 1982).

Each of these three approaches is consistent with certain features of existing data and has difficulty accommodating others. Activation views account for the finding that priming of preexisting representations does not depend on elaborative processing (e.g., Graf et al., 1982; Jacoby & Dallas, 1981) and that under certain conditions, priming decays rapidly in both normals and amnesics (Cermak et al., 1985; Diamond & Rozin, 1984; Graf et al., 1984; Graf & Mandler, 1984; Shimamura & Squire, 1984; Squire et al., in press). Activation accounts are also consistent with the finding that some severely amnesic patients who show normal priming of items with preexisting memory representations (e.g., familiar words, idioms) do not show normal priming of nonwords or unrelated paired associates (Cermak et al., 1985; Diamond & Rozin, 1984; Schacter,

1985; Schacter & Graf, 1986b). However, an activation view does not readily accommodate those cases in which amnesic patients do show implicit memory for new information (Graf & Schacter, 1985; McAndrews et al., in press; Moscovitch et al., 1986), and has difficulty accounting for the effect of newly acquired associations on implicit memory tests in normal subjects (Graf & Schacter, 1985, 1987; McKoon & Ratcliff, 1979, 1986; Schacter & Graf, 1986a, 1986b; see Mandler, in press, for discussion). The activation notion is also inconsistent with the persistence of facilitation on certain implicit memory tests over days, weeks, and months in normal subjects (Jacoby, 1983a; Jacoby & Dallas, 1981; Komatsu & Ohta, 1984; Schacter & Graf, 1986a; Sloman et al., in press; Tulving et al., 1982) and amnesic patients (Crovitz et al., 1979; McAndrews et al., in press).

The strengths and weaknesses of the conceptual versus data-driven processing view are a virtual mirror image of those of the activation view. With its heavy emphasis on an episodic basis of implicit memory, this notion accounts well for observations of persistence, associative effects, contextual sensitivity, and study–test interactions (see Jacoby, 1983b; Roediger & Blaxton, 1987, for elaboration). However, it is less able to handle the findings on short-lived activation, dependence of some priming effects on preexisting representations in amnesic patients, and differences between priming of new and old representations in normals (cf. Feustel et al., 1983; Schacter & Graf, 1986a). This view also has difficulty accounting for the finding that implicit memory for newly acquired associations, as indexed by performance on the stem completion task, depends on some degree of elaborative study processing (e.g., Schacter & Graf, 1986a). Because it has been argued that elaborative study processing should not affect performance on data-driven implicit memory tasks such as stem completion (e.g., Roediger & Weldon, 1987), the finding that some aspects of performance on an implicit test are elaboration dependent is puzzling. It is also important to note that this view does not speak directly to the key feature of implicit memory phenomena: the absence of conscious recollection of a prior experience at the time of test. That is, it is not clear why data-driven processing should be associated with lack of explicit recollection of a prior experience, whereas conceptually driven processing is generally associated with conscious recollection of a prior experience (see Jacoby, 1984, for relevant discussion).

The strengths and weaknesses of multiple memory system views differ somewhat from the foregoing. The procedural/declarative view has been primarily applied to phenomena observed in amnesic patients. The strength of this view is that it provides a straightforward account of *normal* perceptual-motor skill learning in amnesics who lack conscious recollection of prior episodes: Skill learning is assumed to depend on a procedural memory system that is spared in amnesic patients, but does not provide a basis for explicit remembering. It has also been suggested that procedural memory is responsible for priming effects (Cohen, 1984; Squire, 1986). However, recent evidence indicates that priming and skill learning can be dissociated experimentally (Butters, 1987). This hypothesis also cannot readily account for amnesic patients' failure to show priming for nonwords: If priming reflects the modification of procedures used to encode target stimuli, it should occur for both old and new information. Moreover, amnesic patients show implicit memory in situations in which it is unlikely that performance is mediated by the procedural system. For example, amnesics can retrieve newly acquired facts and vocabulary even though they have no explicit recollection of having learned the information (Glisky et al., 1986; Schacter et al., 1984). It does not seem reasonable to attribute the implicit memory observed here to the procedural system, because learning of new facts is allegedly the responsibility of declarative memory (Squire & Cohen, 1984).

Proponents of the episodic–semantic distinction can account for some priming phenomena by postulating that performance on completion and identification tests depends upon activation of the semantic memory system, whereas explicit recall and recognition depend on episodic memory. This account would then be characterized by similar strengths and weaknesses as the activation view discussed earlier. Several other difficulties in applying the episodic–semantic distinction to implicit memory phenomena have been discussed elsewhere (McKoon, Ratcliff, & Dell, 1986; Roediger & Blaxton, 1987; Schacter & Tulving, 1982; Squire & Cohen, 1984; Tulving, 1983, 1986).

The foregoing considerations indicate that although each of the three main theoretical views accommodates certain aspects of the data, no single theoretical position accounts satisfactorily for all of the existing findings concerning implicit memory.

Implicit Memory: Future Directions

To conclude the article, I will first summarize key issues that need to be addressed in implicit memory research; I will then consider briefly a related domain of inquiry which may provide fruitful perspectives on implicit memory and suggest new directions for research.

Empirical and Theoretical Extensions of Implicit Memory Research

One of the most striking features of the historical survey and review of current research is the sheer diversity of implicit memory phenomena that have been observed. The fact that implicit memory has been observed across a wide variety of tasks and subject populations has both empirical and theoretical implications. On the empirical side, it seems clear that a critical task for future research is to delineate systematically the similarities and differences among the various implicit memory tests that have been used. Within the domain of repetition priming, for example, it would be desirable to further explore the relations among word-stem and fragment completion, word identification, lexical decision, free association, and other implicit memory tasks; each of these tests may be tapping different aspects of implicit memory (cf. Witherspoon & Moscovitch, 1986). Such research could help to clarify a number of unresolved issues. Consider, for example, the time course of repetition priming effects on implicit memory tests. It was noted earlier that activation views are consistent with findings of rapid decay of priming. However, the meaning of *rapid decay* varies widely, from seconds or minutes in some lexical decision paradigms (e.g., Forster & Davis, 1984) to several hours in stem-completion paradigms (e.g., Diamond & Rozin, 1984; Graf & Mandler, 1984). Moreover, as discussed previously, priming in

fragment completion, word identification, and other implicit memory paradigms can persist for days, weeks, and months (Jacoby, 1983a; McAndrews et al., in press; Schacter & Graf, 1986a; Sloman et al., in press; Tulving et al., 1982). To understand these differences in the time course of priming, researchers will need a better understanding of the nature of the information and processes tapped by different implicit memory tests.

It would also be desirable to attempt to relate the findings from priming studies to observations concerning implicit memory in other paradigms, such as implicit rule learning. One area that appears particularly promising concerns the role of implicit memory in affective and social phenomena such as mood states (Bowers, 1984), fears and phobias (Jacobs & Nadel, 1985), impression formation (Bargh & Pietromonaco, 1982), and self conceptions (Markus & Kunda, 1986). As revealed in the historical section, many striking implicit memory phenomena were reported by investigators concerned with the role of unconscious influences in affective states (e.g., Freud, Janet), and experimental studies of this issue could provide key insights into the functions of implicit memory. A second, related area that has not yet been fully exploited concerns the role of implicit memory in functional amnesias. A few investigators have examined implicit memory in hypnosis (Kihlstrom, 1980, 1984; Williamsen et al., 1965), multiple personality (Nissen, Ross, Willingham, Mackenzie, & Schacter, in press), and alcohol and drug intoxication (Hashtroudi, Parker, DeLisi, Wyatt, & Mutter, 1984; Nissen, Knopman, & Schacter, in press), but much work remains to be done. Third, research concerning the development of implicit memory in young and old populations is needed. Schacter and Moscovitch (1984) argued that infants and very young children may be capable of implicit memory only. However, there has been virtually no research that has explored the issue directly. Several studies have reported that older adults show intact repetition priming (Graf & Schacter, 1985; Light, Singh, & Capps, 1986) but little else is known about the relation between aging and implicit memory.

On the theoretical side, the diversity of implicit memory phenomena suggests that attempts to account for all relevant observations with a single construct or dichotomy will probably not be entirely successful. As was evident in the discussion of theoretical alternatives, no single position convincingly handles all relevant data. Accordingly, it is worth entertaining the idea that there are multiple sources of implicit memory phenomena. For example, Schacter and Graf (1986b) argued that automatic, relatively short-lived priming effects depend on activation of preexisting representations, whereas longer lasting, elaboration-dependent effects may be based on specific components of newly created episodic representations (see also Schacter & Graf, 1986a; Forster & Davis, 1984). Similarly, it is possible that some implicit memory phenomena, such as perceptual-motor skill learning in amnesic patients, reflect the operation of a memory system that is distinct from the system subserving explicit recall and recognition, whereas other implicit memory phenomena, such as associative effects on word-completion performance, depend on components of the same system that subserves recall and recognition. Unfortunately, firm criteria for distinguishing between multiple-system and single-system accounts do not exist, although some possibilities have been discussed (cf. Sherry & Schacter, in press; Tulving, 1985a). Nevertheless, in view of the diversity of implicit memory phenomena, the activation, processing, and multiple-memory system views need not be mutually exclusive. Each may account well for certain aspects of the data, and may be useful in generating different questions and problems for future research.

The Generality of Implicit/Explicit Dissociations: A Theoretical Challenge

Recent research has revealed that implicit/explicit dissociations are not restricted to situations involving memory for recent events. These studies have produced dissociations that are remarkably similar to some of those discussed here in one crucial respect: Subjects demonstrate that they possess a particular kind of knowledge by their performance on a task, yet they are not consciously aware that they possess the knowledge and cannot gain access to it explicitly. In cognitive psychology, evidence of this kind, although somewhat controversial, has been provided by previously mentioned studies on perception without awareness (e.g., Cheesman & Merikle, 1986; Marcel, 1983).

Neuropsychological research has demonstrated that patients with various lesions and deficits show implicit knowledge of stimuli that they cannot explicitly perceive, identify, or process semantically. First, patients with lesions to primary visual projection areas, who do not have conscious perceptual experiences within their hemianopic field, nevertheless perform at above-chance levels when given forced-choice discrimination tests concerning location, orientation, and other dimensions of a visual stimulus (e.g., Weiskrantz, 1986; see Campion, Latto, & Smith, 1983, for a critique). This phenomenon of "blindsight" occurs in patients who claim that they are guessing the location and identity of the visual stimulus but do not "see" anything at all. A second, similar dissociation has been reported in patients with lesions of the right parieto-occipital cortex who have deficits orienting and attending to stimuli which are presented in their left visual fields. Such patients can make accurate same–different judgments regarding stimuli that are presented simultaneously in the left and right visual fields, despite the fact that they cannot state the identity of the stimulus in the left visual field and often deny the presence of any left-field stimulus (Volpe, LeDoux, & Gazzaniga, 1979). Third, patients with facial recognition deficits (prosopagnosia) show stronger galvanic skin responses to familiar than to unfamiliar faces, even though patients do not explicitly recognize any faces as familiar (Bauer, 1984; Tranel & Damasio, 1985). Fourth, alexic patients, who have serious problems reading common words, perform at above chance levels when required to make lexical decisions and semantic categorizations regarding words that they cannot explicitly or consciously identify (Coslett, 1986; Shallice & Saffran, 1986), or to point to objects corresponding to words that they deny seeing (Landis, Regard, & Serrant, 1980). Fifth, aphasic patients with severe comprehension deficits show semantic priming effects for related word pairs without conscious understanding of the semantic relation that links the words (Blumstein, Milberg, & Shrier, 1982; Milberg & Blumstein, 1981).

The foregoing phenomena differ from one another, and from the implicit memory phenomena discussed earlier, insofar as

the performance of each type of patient reflects somewhat different residual or preserved capacities (for more detailed review, see Schacter, McAndrews, & Moscovitch, in press). The striking similarity, however, is that in all cases knowledge is expressed implicitly and does not give rise to a conscious experience of knowing, perceiving, or remembering. This observation suggests that conscious or explicit experiences of knowing, perceiving, or remembering are all in some way dependent upon the functioning of a common mechanism, a mechanism whose functioning is disrupted in various brain-damaged patients. Elsewhere, I have outlined a model that delineates some properties of this mechanism, describes how it is related to various memory structures, and suggests that it can be isolated or disconnected from specific memory and processing systems in different neuropsychological syndromes (Schacter, 1987). For the present purposes, the observation of implicit–explicit dissociations in multiple domains has several implications: It provides a possibly important clue for development of theories of implicit memory, it suggests that the study of implicit memory should be pursued in close conjunction with the study of related phenomena in normal and brain-damaged populations, and it highlights again the generality and pervasiveness of dissociations between implicit and explicit expressions of memory and knowledge.

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