RETHINKING IMPLICIT MEMORY

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CHAPTER 1

RECONSIDERING IMPLICIT MEMORY

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In some sense, the idea underlying the concept of implicit memory is quite old. Schacter (1987) traced the history of the concept back to the beginnings of psychology (and even before), although the topic was considered under different names and studied mostly with anecdotal methods. However, the work of these early scholars did not impinge much on the conscious thoughts of experimental psychologists studying human memory throughout most of the 20th century. These researchers were preoccupied with other matters: serial learning, chaining, the serial position effect, paired-associate learning, interference, free recall, retrieval cues, organization, transfer, and on and on. To paraphrase Ebbinghaus's famous quote about psychology, the concept of implicit memory may have a long past but its real history of experimental study is short.

The use of modern methods that would today qualify as implicit (or indirect) tests of memory may be traced to the studies of Warrington and Weiskrantz (1968, 1970). They introduced techniques referred to by contemporary workers as word stem completion, word fragment completion (although their fragments were different from the type most researchers use today), and picture fragment naming. They showed that when memory performance of amnesic patients was probed by these techniques, there did not seem to be much if any impairment in performance relative to control subjects. This outcome shocked the field and debate about these early findings swirled through the 1970s, but mostly in neuropsychological circles. It was not really until the early 1980s, with famous papers by Jacoby and Dallas (1981) and Tulving *et al.* (1982) (and then later many others) that at least some experimental psychologists started to take note of this new type of inquiry and this new way of measuring a form of memory. The new area struggled for a name until Graf and Schacter coined the term *implicit memory* (1985), although even that name is not without controversy. (Some researchers prefer the term *indirect tests of memory* to implicit tests, for various reasons, e.g., Richardson-Klavehn and Bjork, 1988.) Still, whatever these studies are called, research in the past 20 years has produced a robust new area of inquiry that has caused psychologists to think hard about the concept of memory, to debate the existence of systems and processes that underlie performance on these new tests, and to open the field to questions that would have remained beyond the ken of experimental psychologists in 1975. The area captured by the term *implicit memory* changed the way cognitive psychologists conceive of their task and mission.

The study of implicit memory poses challenges to the whole concept of memory, challenges with which the field has struggled ever since. How are we to define *memory* and

implicit memory without at once being too broad or too narrow? What are the appropriate contrasting terms for implicit or indirect memory tests? (Explicit memory and direct memory test?) How does the study of implicit memory fit into (and change) the broader picture? In this chapter I continue reflections on these matters begun earlier (Roediger, 1990a, b; 1993; Roediger *et al.*, 1999). However, the conclusion I come to is that the term *implicit memory* may have outlived its usefulness and that we gain no conceptual advantage from using this term that could not be obtained simply by calling the phenomena of interest long-term priming effects.

Defining memory

Memory can be defined in many different ways. In the first chapter of *Elements of episodic memory*, Tulving considered the issue of defining memory and suggested that 'Memory has to do with the after-effects of stimulation at one time that manifest themselves subsequently at a later time...' (1983, p. 7). He went on to say that this suggestion may be too broad, but let us stick with it for the time being because it is helpful for considering implicit memory. Explicit memory occurs, by the standard definition, when people attempt to recollect events from their past. The process is intentional, volitional. On the other hand, 'Implicit memory refers to manifestations of memory that occur in the absence of intentions to recollect' (McDermott, 2000, p. 231). (Definitions by others are similar in character and would not change the argument advanced here.)

If we put together Tulving's broad definition of memory with McDermott's definition of implicit memory, we might say that 'implicit memory refers to all after-effects of stimulation that do not involve explicit or conscious recollection'. When I have tried this broad definition of implicit memory on researchers who study this topic, many have nodded in approval and told me that they liked it. I am not surprised; they should like it. If we define implicit memory in these terms, then much of empirical psychology becomes a subfield (or a minor branch) of the study of implicit memory! Researchers from psychophysics to animal learning to social psychology are interested in 'after-effects of stimulation' as expressed on a tremendous variety of measures that do not require conscious recollection. If a surveyor asks about your opinion of gun control on a 1–7 scale, then surely you are expressing your past experience in an ongoing behavior—your current rating—and recent events or messages may prime your response one way or the other.

The case is similar for many (but certainly not all) standard dependent measures in the major fields of psychology. After all, the most common experimental technique in psychology is to manipulate some independent variable and to measure how it affects some dependent variable. Unless the dependent variable is recall, recognition, or another measure that reflects conscious recollection, then the dependent measure probably may qualify as an implicit memory measure by the definitions discussed above (and most other common definitions of implicit memory).

The foregoing consideration points to an obvious problem: If the concept of implicit memory (or indirect tests of memory) points to nearly everything, then there is a sense in which it points to nothing. The category is too broad and needs to be better specified. This point, which seems incontestable to me, has not been debated in the literature, although an

exception exists in a chapter by Tulving (2000, pp. 38–40) in which he considers such fundamental problems. I consider why researchers have rarely worried about the breadth and scope of the concept of implicit memory in the next section.

Implicit memory research

Although the general definition of implicit memory may be quite broad—after-effects of stimulation that occur in the absence of attempts at conscious recollection—the study of implicit memory employs a rather limited range of actual measures. Borrowing a tip from Jacoby (1983), Roediger and Blaxton (1987) suggested that most verbal implicit memory tasks could be classified as data-driven (or perceptual) tests or conceptually-driven (or conceptual) tests. The idea is that some tests strongly involve the perceptual system in identifying or resolving ambiguous perceptual clues, whereas for other tasks seem to draw on meaning or concepts. Roediger *et al.* (1989) proposed converging measurement operations that would identify tests as perceptual and conceptual. Some tests might be difficult to classify, of course, either because the measuring operations could not be applied to the test or because the results of the tests would turn out ambiguously, with some markers pointing to the test as conceptual and others as perceptual. The distinction between perceptual and conceptual tasks works to a first approximation, given these limitations in measurement, but problems have arisen (see McDermott and Roediger, 1996; Roediger and McDermott, 1993 for examples and discussion).

I would estimate that 80% of all implicit memory research conducted from 1980–2001 used perceptual or data-driven implicit memory tests. A common example is shown in Figure 1.1. The ambiguous picture there can be named quite quickly by practically every cognitive psychologist, although if the same figure were shown to an equally intelligent group of chemists, their responses would be very variable and (like introductory psychology students) many of the chemists would take minutes rather than seconds to resolve the figure (and then only with verbal clues). Cognitive psychologists have seen the figure dozens of times and so are primed to name it quickly, even if it is presented in a new context (Roediger and Srinivas, 1993). I suspect that even if I were not to see R. C. James' fragmented figure for another 20 years, I would have no trouble in quickly naming it. In short, psychologists' ability to name the figure quickly and easily is a manifestation of long-term perceptual priming. The fragmented elements of the scene coalesce rather easily into a figure due to prior practice that transfers well to this task when it is presented again, even in an unexpected context.

The most common perceptual implicit memory tasks are verbal in nature (although pictorial tasks like that of Figure 1.1 have been used, too). In all cases subjects are told to name or to complete the fragmented form or brief glimpse of some stimulus, typically a word. The tasks include word stem completion (ele_____), word fragment completion (e_e_h_n_), word identification (naming the word from a very brief glimpse), anagram solution (rearranging the letters in *phelante* to form a word), and other variants of these tasks. Prior study of a word such as *elephant* will produce priming on these tasks relative to a non-studied baseline. However, studying a picture of an elephant produces little or no priming on these same verbal tasks despite activating the same concept in semantic

Figure 1.1 The fragmented form of a picture taken by R. C. James. Novices (those who have never seen the picture before) often take several minutes to identify the figure—a Dalmatian with his nose to the ground. However, cognitive psychologists who have practiced seeing the figure many times show almost instant recognition of the figure even when it is shown unexpectedly and after long periods of time. This kind of perceptual priming is the most commonly studied form of implicit memory.

memory (Rajaram and Roediger, 1993; Srinivas, 1993; Weldon and Roediger, 1987). These tasks are deemed perceptual (in part) because prior presentation of the word-form is necessary to produce priming on these lexical implicit memory tests. As already pointed out, perceptual implicit memory tasks can also be non-verbal, such as picture fragment naming (somewhat like the task in Figure 1.1), or naming pictures from brief displays, or naming pictures as they are gradually clarified from very small amounts of information. (In this last task, the measure is how much of the fragment is required to name the picture.) Once again, if subjects have recently seen words naming these concepts, then little or no priming occurs on these pictorial tasks (Srinivas, 1993; McDermott and Roediger, 1994). (References that provide examples of all these tasks can be found in Roediger and McDermott's 1993 review chapter.)

Although most of the implicit memory literature is based on perceptual implicit memory tests, perhaps 10% of the tasks used are conceptual implicit tests. If a subject had studied the word elephant or seen a picture of an elephant in a study phase, the conceptual tests could be of at least three types. One is the answering of general knowledge questions, such as 'What animal helped Hannibal in his attack on Rome?' (Blaxton, 1989). Another is a free association task, such as providing the first five words that come to mind in response to a cue such as *tusk*. A third task is naming category instances, so that subjects would be given a*nimals* and asked to list as many as possible in 30 seconds. These three tasks are just a subset of many possible conceptual tests, but they are the most common ones. All have been used in at least a handful of experiments. These tasks behave differently as a function

of independent variables than do perceptual implicit tests. For example, prior study of pictures and words produces equivalent priming on conceptual implicit memory tests (McDermott and Roediger, 1996; Weldon and Coyote, 1996) rather than showing the sharp specificity found on perceptual tests.

If it is true, as I estimated, that 80% of all implicit memory tests are perceptual in nature and 10% are conceptual, then what about the other 10%? I would place in this class a few tasks that have been dubbed procedural in the sense used by Squire (1987). These are tasks such as mirror tracing and pursuit rotor tracking that defy classification as perceptual or conceptual (the measuring operations cannot be applied to ask the question), but the tasks are classified as implicit because even deeply amnesic patients can learn them. However, some researchers might question whether tasks such as pursuit rotor tracking and mirror tracing are implicit tasks in the same way as are the perceptual and conceptual tasks. Rather, some theorists might classify them as belonging to a somewhat separate area of inquiry referred to as implicit learning (see Stadler and Frensch's 1998 handbook with many chapters summarizing work on this topic). Implicit learning tasks often are spread out over time and involve subjects learning a subtle rule that affects their performance, although the subjects often seem unaware of the nature of the rule or even the fact that there is one. (However, this claim of 'unawareness' has been responsible for much research in this area, weighing in on each side of the issue.) The relation between studies of implicit memory and those of implicit learning have been rarely considered (although see Stadler and Roediger, 1998 for an exception). This relation will not be considered here, either, but should be considered more fully in the future.

The point being made here is that despite the wide scope of the definition of implicit memory, the actual range of tasks studied in this field of inquiry (narrowly defined) is relatively small. Although the study of implicit memory has been rightly championed as opening up the concept of memory to new tasks and new insights, the surface has barely been scratched once one pauses to consider the totality of possible tasks and possible measures that qualify as 'implicit memory tasks' under most definitions. Some type of memory is involved in practically every measure psychologists take.

Priming

The hallmark of all the implicit memory tasks—perceptual and conceptual—is that they show priming. 'Priming refers to facilitative effects of an encounter with a stimulus on subsequent processing of the same stimulus (direct priming) or a related stimulus (indirect priming)' (Tulving *et al.*, 1982, p. 336).[1] All the tasks listed above reveal priming, and for practically all these tasks an important dissociation has been observed. Severely

[1] Some people have referred to indirect priming as 'false priming' (e.g., McKone and Murphy, 2000), but of course there is nothing false about it. Priming from indirectly related experiences is as valid as any other kind of priming. Veridicality of memory (is the recollection true or false?) is only an issue in declarative memory tests, if we use Squire's (1987) framework, that is, in episodic or semantic memory.

memory-impaired (amnesic) patients who show greatly reduced performance on tests of explicit (episodic) memory, such as free recall, cued recall, and recognition, often show perfectly intact priming (just like that of healthy college students) on both perceptual and conceptual implicit memory tests.

The dissociation of priming from other forms of memory (chiefly episodic memory) underlies the discovery of other memory systems besides episodic memory. One defining characteristic of a new system is to show a strong dissociation between performance on standard explicit memory tests and a measure reflecting some other putative system. Intact priming on some new measure in subjects who reveal greatly impaired performance on explicit tests reveals two things: first, the task reveals memory (priming shows that) and second, the form of memory is different from that displayed on explicit memory tests. We will use this logic here in an effort to uncover other memory processes and systems in the body that have not yet been much discussed in the literature (but see Roediger, 1993 for a start). In the famous hierarchical representation in Squire's (1987) theory, there was a place for 'other' memory systems. Tentative evidence for them is forwarded in this chapter.

Memory and the body

Proponents of memory systems have concentrated their attention on the central nervous system. There is good reason for that, of course. Conscious recollection (episodic recollection) is supported by structures and processes arising in the central nervous system, particularly areas in and around the hippocampus and certain regions of the frontal lobes. However, other bodily systems also display a form of memory, as is shown on some procedural memory tasks. Let us first consider a thought experiment: the amnesic weightlifter.

Suppose a young man, W. L., is involved in a tragic accident that causes a brief period of anoxia. The loss of oxygen to the brain causes damage to regions in and around the hippocampus that seem to be responsible for certain forms of episodic memory. W. L. recovers from his accident and has reasonably normal general intelligence, but displays classic signs of amnesia—poor recall of recent events after a brief delay. He is mostly confined to his home, cared for by his family. One day he discovers weight-lifting equipment in his basement, left there by a previous owner of the home. He sets it up, with some help, near the television. He spends considerable time each day watching television, so now he finds that whenever he is near the television, he begins lifting weights.

W. L.'s mother, a retired psychologist, begins measuring his performance. She measures repetitions per minute and plots changes. She discovers an orderly growth in the number of repetitions (of bicep curls) and other easily measured aspects of his performance. He shows procedural learning. When she asks him over dinner if he has ever lifted weights since his accident, he thinks for a while and says no. Nonetheless, he continues to practice as he watches television and he gets better and stronger.

In a sense there is nothing remarkable in this hypothetical example—just another case of motor/procedural learning in the absence of explicit or episodic recollection of the episodes that gave rise to the learning. But this case has another interesting feature: the man's body shows profound changes. His biceps are enlarged; his neck and chest become thicker; his legs increase in size. In a very real sense, these changes are 'memory traces' of the experiences the

man has had. He might not be able to read out these traces to know about the experiences, but others looking at him can. From observing the visible traces of W. L.'s past experience—his bulging muscles—others would know (if not remember) that he had been lifting weights, or at least engaging in strenuous physical activity. There is a sense that overt physical changes in an individual can signal their past experiences, as when adults who have had happy lives spent smiling have upturned mouths in their old age while perpetual naysayers have permanent frowns when they become old. These outward changes are 'traces of past experience manifested in current behavior' or, in this case, appearance. Therefore, they are memory traces, of a sort we usually don't consider.

The foregoing example is hypothetical, but not farfetched; it gives a new meaning to the phrase 'body memories'. Our past experiences can change our bodies in many ways—not just changes in the c.n.s.—that then change our behavior. However, other bodily systems besides the muscular/procedural system display forms of memory that are not so easily encompassed under current theory.

The immune system

The clearest case of a bodily system that exhibits the primary property characteristic of implicit memory, viz., priming, is the immune system (see Roediger *et al.*, 1999). Indeed, immunologists have recognized this fact for years and have uncovered many of the mechanisms that endow the immune system with memory, although knowledge remains incomplete in some critical areas. A recent paper on the immune system in *Science* is entitled 'T cell death and memory' and it is not atypical (Sprent and Tough, 2001). (Because studies of behavioral psychology so rarely intrude on the pages of *Science*, I would hazard the guess that as many 'memory papers' appear in that journal on the immune system as on the central nervous system.)

The immune system responds to antigens that invade it. If a pathogen's effect is too great, death of the organism results. However, if a person's immune system can ward off the pathogen, the immune system is changed and is more likely to fight off future infections. Ahmed and Gray (1996) began another *Science* article on this topic with this sentence: 'The immune system can remember, sometimes for a lifetime, the identity of a pathogen' (p. 54). A contemporary psychologist might quibble with the word *remember* in that sentence, but nonetheless their paper and much other work documents the fact that the immune system changes as a function of experience and that these changes are retained for a long time. This change is recorded in the immune system in what are called 'memory cells'—the immune system's memory traces—and the effect of these memory cells are expressed later in behavior of the immune system when a new pathogen invades the system. The concept of immunological memory is well established and the quotes below are the accepted explanation from a standard biology textbook by Chiras (1993):

> The first time an antigen enters the body, it elicits an immune response, but the initial reaction—or *primary response*—is relatively slow and of small magnitude... During the primary response antibody levels in the blood do not begin to rise until approximately the second week *after* the intruder has been detected... If the same antigen enters the body at a later date, however, the

> immune system acts much more quickly and forcefully... This greatly fortified reaction constitutes the *secondary response*... [and] during a secondary response antibody levels increase rather quickly, only a few days after the antigen has entered the body. The amount of antibody produced also greatly exceeds quantities generated during the primary response. Consequently, the antigen is quickly destroyed, and a recurrence of the illness is prevented. (p. 360)

Researchers interested in implicit memory will immediately recognize the underlying concept described in the previous paragraph as priming. The introduction of the antigen into the body the first time leads to changes in the immune system that causes priming later, the second time the antigen is introduced. Note that the two measures reflecting priming in the immune system—magnitude of the response and speed of the response—are the same ones that cognitive psychologists measure in other systems. Although I do not know of research relevant to the issue, I would be willing to bet a large sum of money that amnesic patients such as H. M. or K. C. show intact priming in their immune systems. Priming in the immune system is, almost surely, independent of episodic/declarative memory (and, for that matter, other forms of implicit memory such as perceptual priming).

As noted above, the mechanism by which such priming is thought to occur is through creation of what are called memory cells, the memory traces of the immune system. To quote Chiras (1993) again:

> During the primary response, some lymphocytes divide to produce memory cells. Memory cells are immunologically competent B cells that do not transform into plasma cells. Instead, they remain in the body awaiting the antigen's reentry. These cells therefore create a relatively large reserve force of antigen-specific B cells. When the antigen reappears, memory cells proliferate rapidly, producing numerous plasma cells that quickly crank out antibodies to combat the foreign invaders... during the secondary response, the memory cells also generate additional memory cells that remain in the body in case the antigen should appear at some later date.
>
> Immune protection afforded by memory cells can last 20 years or longer and explains why once a person has had a childhood disease, such as mumps or chicken pox, it is unlikely that he or she will contract it again. Resistance to disease that is provided by the immune system is known as immunity. From an evolutionary standpoint, this adaptation serves us extremely well, greatly reducing the incidence of infectious disease. Without it, humans would probably not be able to survive.

Recent articles make it clear that the textbook description given above is somewhat simplistic and that many mysteries remain in immune system functioning (Fearon *et al.*, 2001; Lauvrau *et al.*, 2001; Sprent and Tough, 2001). Although the immune system clearly exhibits characteristics of memory and in some sense its operation depends on its being (or having) a memory system, the immune system never gets mentioned in discussion of nondeclarative memory systems in the psychological literature.

Of course, the fact that a system shows priming does not necessarily indicate that it is a memory system (Schacter and Tulving, 1994). However, both the visual and auditory perceptual systems show priming that is independent of conscious, episodic recollection. Indeed, it is this independence of perceptual priming from episodic recollection that is the primary evidence leading to postulation of various perceptual representation systems (PRS). These perceptual representation systems are deemed memory systems. However, in

principle, why shouldn't the immune system be said to have a memory system for the same reasons the auditory and visual systems do—both show priming independent of conscious recollection. Priming in perceptual systems probably evolved to help sharpen our recognition of frequently perceived sights and sounds. Priming in the immune system serves a critical evolutionary purpose, too, in helping us to ward off disease. These considerations lead to the hypothesis that perhaps many bodily systems have a kind of memory built into them that brings adaptive advantage. Many systems of the body profit in some way from past experience and help the organism to cope with the environment.

Other memory systems

Are there other bodily systems that display memory, like the immune system and the perceptual systems? My knowledge of biology is not great enough to answer this question with regard to respiratory, circulatory, and digestive systems, although clearly certain types of conditioning processes can affect these systems and classical conditioning (such as learning of taste aversions) is clearly a sign of a memory system.

There is at least one other system that shows a clear example of priming that is (probably) independent of conscious recollection and other implicit memory measures, too: the female reproductive system (Roediger, 1993). The birth process is extremely dangerous (as well as painful) for women. However, if women survive the birth of a first child, priming in the FRS (female reproductive system) helps facilitate the birth process for later children. Roediger (1993) summarized data reported by Friedman (1978) documenting priming in the FRS and these data are presented here in Table 1.1. Labor can be divided into a latent phase (dilation of the cervix) and an active phase (the rapid end to dilation and the descent of the fetus). Averaged over thousands of births, the mean times for these two phases were 6.1 and 3.4 hours, for a total of 9.5 for the birth of a first baby. However, for later-born children the numbers drop precipitously, to 4.5 and 2.1 hours for the two phases of labor, respectively, for a total of 6.6 hours. So, we see nearly three hours of priming for later-born than for first-born children. For psychologists used to measuring priming in a matter of milliseconds, the size of these priming effects in the FRS are staggering—a 10,440,000 ms effect (2.9 hours) of priming! These data for later-born children are collapsed over second-, third-, fourth-(etc.) born children. We can wonder if priming increases with the number of prior births, but I have been unable to find the relevant data.

Table 1.1 Selected data on duration of labor for first-born and later-born children during labors in which there were no medical complications (mean data are presented in hours, with standard deviations in parentheses)

	Phase of labor		
	Latent	Active	Total
First born	6.1 (4.0)	3.4 (1.5)	9.5
Later born	4.5 (4.2)	2.1 (2.0)	6.6
Savings	1.6	1.3	2.9

Adapted from Friedman (1978), data in Table 3 (p. 49).

Now, as with the immune system, I know of no evidence relevant to the issue of whether priming in the FRS is independent of episodic recollection. The relevant evidence would have to come from the case of a woman who became amnesic as a result of brain damage and who was impregnated more than once. I would predict that she would show intact priming in the FRS despite poor episodic recollection. Indeed, in the most dramatic case, she might show massive priming in the FRS but complete amnesia for the fact that she had had children. I also expect that priming in the FRS would be independent of priming in the PRS and the immune system.

It may well be that other bodily systems are already known to have forms of memory that have escaped my attention. As already noted, the muscular system and the skin system can show after-effects of prior experience that are visible to outsiders as well as to the person having had the experience, due to external memory traces. A person having spent a life working in the outdoors can easily be distinguished from one who has rarely seen the sun simply based on qualities of the skin on the face.

The notion that some type of memory is a general bodily function, characteristic of many systems, may seem new and odd given the recent preoccupation of researchers studying both implicit and explicit memory on a relatively narrow range of tasks (albeit a much wider range than in the 1960s or 1970s). However, this broader conception of memory really takes the field back to an earlier time because thinkers in the last part of the 19th century considered the concept of memory to apply more grandly to living matter.

On May 30, 1870 Ewald Hering (best remembered for a theory of color vision and for an illusion he discovered) addressed the Imperial Academy of Science in Vienna 'On memory as a function of organized matter'. Hering's conception of memory was much broader than even the examples given in this chapter. Edgell (1924) summarized Hering's approach this way:

> Memory is not merely a term used to denote a given collection of facts, but is used as an explanatory principle. Advance of the race, reproduction of one generation by another, material growth, increase in skill, recollection of the past, they are all explained by that function which is universal in organized matter: memory. If one tries to generalize these very diverse facts and regard them as a class one may term them each and all 'after-effects of stimulation' (Edgell, 1924, p. 7).

Behaviorists who studied various types of conditioning, verbal learners who examined serial and paired associate learning, and contemporary neurobiologists who study long-term potentiation have all considered (albeit for different reasons) the processes of learning and memory to be broadly generalizable throughout many systems and species. Therefore, in the historical sweep of ideas, it is only relatively recently that memory has become specialized again. Even modern theorists of memory systems typically consider only a few of the many systems that display memory-like qualities.

Implications

The definitions typically given for implicit memory (or for indirect tests for memory) are quite broad, even though as instantiated in 'implicit memory research' they have been considered rather narrowly. Implicit memory research today focuses on maybe a dozen

tasks, only a few of which have been carefully investigated. The conceptual definition of implicit memory is much broader, so broad that it is in danger of encompassing much of the experimental study of behavior. As noted above, almost all researchers in psychology are interested in how the after-effects of experience affect current behavior. Only studies directed at explicit (conscious) recollection and a few others would be eliminated by the standard definition. However, if implicit memory encompasses so much, it may be too general to be a useful scientific term. Tulving (1983) remarked that having a general theory of memory would be like having a general theory of locomotion—difficult to achieve except at the most vague and vacuous level. Like locomotion, there are simply too many ways to instantiate the term *memory* to provide a meaningful general theory or framework.

Implicit memory is a term that has the same drawback. Priming occurs in many biological systems—perceptual, conceptual, motor, immune, female reproductive, and probably others. The fact that priming occurs in all these systems probably serves a useful biological function. The first time a system has to process an event, whether perceiving an object, reacting to an antigen, or having a baby, certain processes are brought into play to accomplish the goal. The after-effects of this first experience create changes in the system which in turn prime the system to perform the same task more quickly and efficiently the next time the need arises. This is probably the general adaptive reason for priming in its many forms, but of course the specific mechanism creating priming will differ dramatically across the bodily systems. Any commonalities would exist only at the level of a general principle, as stated a few sentences above, and not in specific mechanisms.

Psychologists interested in the study of implicit memory have considered a relatively narrow set of tasks, primarily perceptual implicit memory tests that involve identifying objects and words from degraded representations. Even within the perceptual systems, priming of words in the visual system occurs from different processes and mechanisms than priming of these same words in the auditory system, although the fact of cross-modal priming implies that some common mechanisms are involved, too (see Church and Schacter, 1994; Pilotti *et al.*, 2000). Priming of concepts from pictures provides little or no transfer to verbal tests of those same concepts and vice versa (e.g., Srinivas, 1993). Tulving and Schacter (1990) proposed that there were several perceptual representation memory systems, presumably one for audition, one for vision, one for pictures, and so on. However, even within the visual word-form system, Hayman and Tulving (1989) argued that priming was 'hyperspecific' because the amount of priming of a word depended on the exact fragment that was used to test the concept. Changing the type of fragment between two test occasions changed the amount of priming. (On the other hand, in examining a different kind of evidence, Bowers, 1996 proposed that the visual word-form system at least generalizes across graphemic characteristics.)

One solution to the problem of the broad general definition usually used for implicit memory would be to sharpen the concept so that it more accurately represents the tasks and measures that are studied. I will not propose such a solution here because that course may not be wisest. Is it possible to define implicit memory in a sensible way that will include the perceptual systems responsible for word and object priming and exclude other, presumably more far-flung, systems such as the immune system and the female reproductive system? Even if it were possible, would it be advisable? I think not. Priming in

the immune, reproductive, and perceptual systems occurs as a function of past experience to prepare the body for similar experiences in the future—transfer appropriate priming. If we narrow our definition in such a way to include perceiving but to exclude immune function, the division would probably be arbitrary. For example, we could define 'memory' as processes relying on the central nervous system. Such 'neural chauvinism' seems unwise to me. Nature, via evolution, has endowed numerous bodily systems with forms of memory. Why consider only those represented by one bodily system as 'memory', except that we are psychologists and that is what we mostly care about? Immunologists would surely disagree with our categorizations and their study of their implicit memory system through immune priming is no less valid than our study of perceptual priming.

If we were to question some forms of priming as representing implicit memory, we would quickly be led to the issue of whether we should even consider perceptual systems as memory systems. The basic function of the perceptual systems is to take in information about the environment in various modalities (tastes, touches, smells, sights, and sounds). Priming in the perception of particular objects or words exists to improve the identification process after an initial occasion. Just as we may not want to consider the female reproductive system 'a memory system' just because it displays priming, so we need not consider the perceptual systems 'memory systems' because they show priming, either. The system exists to perceive the world and priming is just one feature of the system, as with the FRS or the immune system.

An alternative way of thinking about these issues seems more appropriate to me and calls into question whether the perceptual systems and other systems should be deemed memory systems. I would suggest that we rightly conceive of priming in various biological systems as an interesting fact. However, we should not use this fact to call these systems 'memory systems'. This point might seem mere semantics, but as usual, words and their meanings serve an important point here. Perceptual, reproductive, and immune systems exist to perform important biological functions. They exhibit characteristics of memory (that is, some of their operations show priming from past experience), but this 'memory' function may frequently be incidental to operation of the system which subserves a different basic function.

In short, these systems exist for some purpose and they should not be deemed memory systems just because they show priming in carrying out that purpose. The fact of perceptual priming that is independent of conscious recollection no more means that the perceptual systems are memory systems than the fact of reproductive or immune priming indicates that the reproductive or immune systems are memory systems. The perceptual, immune, and reproductive systems serve basic biological functions. Priming sharpens those functions. The fact of priming shows that the systems display a form of memory to enhance their operation, but does not necessarily show that they are memory systems. We should reserve this last term for systems whose primary function is to remember or to know the past, not for those systems in which memory is one component of the system's operation and the system exists for some other purpose. These systems evolved to serve some other biological purpose and they have a dash of memory tossed in to help the system profit from experience. Hence, calling them memory systems stretches the term too far.

Conclusion

The argument here is that the term implicit memory may be too broad, encompassing not only the traditional study of what are thought of as 'implicit memory tasks' but also many other processes—all those due to the 'after-effects of experience as expressed in behavior'. Assuming others see this issue as a problem that deserves attention, we may consider several solutions.

One strategy discussed above is to narrow our definitions of implicit memory to more appropriately capture the phenomena we study. The postulation of perceptual and conceptual implicit memory tests (Roediger and Blaxton, 1987) went some distance in this direction, but obviously many more categories exist than those two and need to be elucidated. Also, some tasks, such as priming of anagram solutions, are difficult to classify by the suggested criteria (Srinivas and Roediger, 1990). Even assuming we could achieve more exact definitions that would work, a danger exists with this strategy of defining a few tasks precisely. As discussed above, we may eliminate too much from the concept that should be saved. If we define implicit memory very narrowly, to (say) encompass only perceptual identification tasks, then why have this new term? Why not just discuss findings in terms of perceptual priming? However, the concept *implicit memory* is appropriately intended to cover more territory than perceptual priming.

Another strategy for solving these conceptual problems, and the one I prefer, is to welcome the diversity and the generality forced upon us by the general definitions of memory and to revel in them. Yes, perceptual priming reflects a form or memory, and so do does immune priming, reproductive priming, conceptual priming, motor learning, classical conditioning, and so on. All these phenomena are examples of memory and then our task is to classify them appropriately and study them in various ways. As Hering (1870) advocated 130 years ago, memory can serve as a unifying construct, with many manifestations. The trick is to appropriately conceptualize the many varieties of memory and study them appropriately (see Roediger *et al.*, 2002, for one attempt). If we take this approach, I would suggest that we not refer to all priming phenomena within the rubric of implicit memory, as the term would be stretched too broadly. Rather, we need to consider other concepts in our classification schemes and apply them more rigorously.

The primary intent of this chapter is to propose that we need to rethink and reconceptualize how we define the term *implicit memory* if it is to be of scientific use. Implicit memory may serve as a useful term, but it will take a considerable amount of further thought and writing to clarify the murky situation outlined in this chapter. It will also take a change of attitude. As Tulving (2000) has noted, psychologists interested in learning and memory have typically not been concerned with careful examination of the terms they use. However, in order to avoid the dangers discussed here regarding the breadth of the concept of implicit memory, we will need to devote considerable effort to developing conceptual clarity. If we do not make the effort to gain this conceptual clarity through further inquiry, then we could probably simply eliminate the term *implicit memory* and refer to 'long-term priming effects' to cover the phenomena of interest. Nothing much would be lost at this point, although we can hope that the situation will be different in the future.

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References

Ahmed, R. and **Gray, D.** (1996). Immunological memory and protective immunity: understanding their relation, *Science*, **272**, 54–60.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Evidence for a transfer appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **15**, 657–68.

Bowers, J. S. (1996). Different perceptual codes support priming for words and pseudowords: Was Morton right all along? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **22**, 1336–53.

Chiras, D. D. (1993). *Biology: the web of life.* West Publishing, St. Paul.

Church, B. A. and **Schacter, D. L.** (1994). Perceptual specificity of auditory priming: Implicit memory for voice intonation and fundamental frequency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**, 521–33.

Edgell, B. (1924). *Theories of memory.* England: Oxford University Press.

Fearon, D. T., Manders, P., and **Wagner, S. D.** (2001). Arrested differentiation, the self-renewing memory lymphocyte, and vaccination. *Science*, **293**, 248–50.

Friedman, E. A. (1978). *Labor: Clinical evaluation and management.* New York: Appleton-Century-Crofts.

Graf, P. and **Schacter, D. L.** (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11**, 501–18.

Hayman, C. A. G. and **Tulving, E.** (1989). Is priming in fragment completion based on 'traceless' memory system? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **14**, 941–56.

Hering, E. (1870/1910). On memory. Address given in 1870. Reprinted in *Unconscious memory* (ed. S. Butler). London: A. C. Fifield, 1910.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior*, **22**, 485–508.

Jacoby, L. L. and **Dallas, M.** (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, **3**, 306–40.

Lauvrau, G., Vijh, S., Kong, P., Horng, T., Kerksiek, K., Serbina, N., *et al.* (2001). Priming of memory but not effector CD8 T cells by a killed bacterial vaccine. *Science*, **294**, 1735–9.

McDermott, K. B. (2000). Implicit memory. *The encyclopedia of psychology* (ed. A. E. Kazdin), pp. 231–4. New York: American Psychological Association and Oxford University Press.

McDermott, K. B. and **Roediger, H. L.** (1994). Effects of imagery on perceptual implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**, 1379–90.

McDermott, K. B. and **Roediger, H. L.** (1996). Exact and conceptual repetition dissociate conceptual tests: Problems for transfer appropriate processing theory. *Canadian Journal of Experimental Psychology*, **50**, 57–71.

McKone, E. and Murphy, B. (2000). Implicit false memory: Effects of modality and multiple study presentations on long-lived semantic priming. *Journal of Memory and Language*, **43**, 89–109.

Pilotti, M., Gallo, D. A., and Roediger, H. L. (2000). Effects of hearing words, imaging hearing words, and reading on auditory implicit memory tests. *Memory and Cognition*, **28**, 1406–18.

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

Roediger, H. L. (1990a). Implicit memory: Retention without remembering. *American Psychologist*, **45**, 1043–56.

Roediger, H. L. (1990b). Implicit memory: A commentary. *Bulletin of the Psychonomic Society*, **28**, 373–80.

Roediger, H. L. (1993). Learning and memory: Progress and challenge. In *Attention and performance XIV: A Silver Jubilee* (ed. D. E. Meyer and S. Kornblum), pp. 509–28. Cambridge, MA: MIT Press.

Roediger, H. L. and **Blaxton, T. A.** (1987). Retrieval modes produce dissociations in memory for surface information. In *Memory and learning: The Ebbinghaus Centennial Conference* (ed. D. S. Gorfein and R. R. Hoffman), pp. 349–79. Hillsdale, NJ: Erlbaum.

Roediger, H. L. and **McDermott, K. B.** (1993). Implicit memory in normal human subjects. In *Handbook of neuropsychology* (ed. F. Boller and J. Grafman), Vol. 8, pp. 63–131. Amsterdam: Elsevier.

Roediger, H. L. and **Srinivas, K.** (1993). Specificity of operations in perceptual priming. In *Implicit memory: New directions in cognition, development and neuropsychology* (ed. P. Graf and M. E. J. Masson), pp. 17–48. Hillsdale, NJ: Erlbaum.

Roediger, H. L., Weldon, M. S., and **Challis, B. H.** (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (ed. H. L. Roediger and F. I. M. Craik), pp. 3–39. Hillsdale, NJ: Erlbaum.

Roediger, H. L., Buckner, R. L., and **McDermott, K. B.** (1999). Components of processing. In *Memory: Systems, process or function?* (ed. J. K. Foster and M. Jelicic), pp. 31–65. Oxford, UK: Oxford University Press.

Roediger, H. L., Marsh, E. J. and **Lee, S. C.** (2002). Varieties of memory. In *Stevens' handbook of experimental psychology, 3e* (ed. D. L. Medin and H. Pashler), pp. 1–41. New York: John Wiley and Sons.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **13**, 501–18.

Schacter, D. L. and **Tulving, E.** (1994). What are the memory systems of 1994? In *Memory systems 1994* (ed. D. L. Schacter and E. Tulving), pp. 1–38. Cambridge, MA: MIT Press.

Sprent, J. and **Tough, D. F.** (2001). T cell death and memory. *Science*, **293**, 245–8.

Squire, L. R. (1987). *Memory and brain.* New York: Oxford University Press.

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

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

Stadler, M. A. and **Frensch, P. A.** (ed.) (1998). *Handbook of implicit learning.* Thousand Oaks, CA: Sage Publications.

Stadler, M. A. and **Roediger, H. L.** (1998). The question of awareness in research on implicit learning. In *Handbook of implicit learning* (ed. M. A. Stadler and P. A. Frensch), pp. 105–32. Thousand Oaks, CA: Sage Publications.

Tulving, E. (1983). *Elements of episodic memory.* Oxford: Clarendon Press.

Tulving, E. (2000). Concepts of memory. In *The Oxford handbook of memory* (ed. E. Tulving and F. I. M. Craik), pp. 33–57. Oxford: Oxford University Press.

Tulving, E. and **Schacter, D. L.** (1990). Priming and human memory systems. *Science*, **247**, 301–6.

Tulving, E., Schacter, D. L., and **Stark, H. A.** (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **8**, 336–42.

Warrington, E. K. and **Weiskrantz, L.** (1968). New method of testing long-term retention with special reference to amnesic patients. *Nature*, **217**, 972–4.

Warrington, E. K. and **Weiskrantz, L.** (1970). Amnesic syndrome: consolidation or retrieval? *Nature*, **228**, 629–30.

Weldon, M. S. and **Coyote, K. C.** (1996). Failure to find the picture superiority effect in implicit conceptual memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **22**, 670–86.

Weldon, M. S. and **Roediger, H. L.** (1987). Altering retrieval demands reverses the picture superiority effect. *Memory and Cognition*, **15**, 269–80.