Priming and Memory Systems

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Recent research suggests that the operations of human memory are carried out by a number of different but closely interacting functional systems and subsystems, subserved by corresponding brain structures and mechanisms. A good deal of current research effort is directed at identification of these memory systems, description of their properties, and the analysis of the relations among them. Dichotomies of classification that had been proposed earlier, short-term versus long-term memory, episodic versus semantic memory, procedural versus declarative memory, are being replaced with more comprehensive classificatory schemes.

One such scheme for which there is some empirical support is summarized in Table 1. It includes five major learning and memory systems. The five are procedural memory, perceptual priming, short-term memory, semantic memory, and episodic memory. Each of the five systems is large and complex, comprising a number of subsystems for which evidence at the present stage of our knowledge is of variable quality.

The ordering of the major systems in the overall classification scheme corresponds roughly to their presumed developmental sequence, with the procedural system the earliest and the episodic the latest. The ordering of the systems also reflects the conjectured relations among the systems: the operations of the higher ones depend on and are supported by the operations of the lower ones, whereas lower systems can operate essentially independently of the higher.

The scheme in Table 1 does not include primitive forms of learning, such as sensitization and habituation, because little is known about their relation to other forms of learning and memory in humans. But, some widely used classificatory terms are shown. Thus, since semantic and episodic memory share a number of features, they are frequently referred to collectively as declarative (or propositional or factual) memory. Another frequently used distinction is that between implicit and explicit memory. Implicit memory designates the *expression* of stored information without awareness of its acquisition coordinates in space and time, that is, expression of what the individual knows without necessarily remembering how, when, or where the knowledge was acquired. Explicit memory, on the other hand, refers to the expression of what the person consciously *remembers* as a personal experience.

Table 1. Classification of Human Memory Systems

Major systems		Other terms
Procedural memory		Implicit memory
Perceptual priming (PRS)		Implicit memory
Short-term memory	Declarative	Explicit memory
Semantic memory	Declarative	Implicit memory
Episodic memory	Declarative	Explicit memory

The procedural system is an action system: its operations are expressed in behavior, independently of any cognition. Skillful performance of perceptual-motor tasks and conditioning of simple stimulus-response connections are examples of tasks that depend heavily on the procedural memory system.

The other four are cognitive systems. They mediate changes in cognition, or conscious experience. In the course of normal, everyday activity, the computational outputs of the cognitive memory systems typically guide overt behavior, but such conversion of cognition into behavior is not necessary. Indeed, in the laboratory, the products of cognitive memory systems are analyzed in the form of "pure" experience or thought, with behavioral expression serving merely as an indicator of properties of cognitive processes.

Short-term memory (also referred to as primary memory) registers and retains incoming information for a period of time measured in seconds. It makes possible a lingering impression of the individual's present environment beyond the duration of the physical presence of the stimulus information emanating from the environment.

The function of semantic memory is to model the external world. Semantic memory represents many aspects of the world; it renders possible acquisition and retention of factual knowledge in the broadest sense. Semantic memory, for instance, mediates knowledge of location of objects in the space beyond the reach of perception. Another example of the capability of semantic memory is classification of objects, events, or situations (or symbolic descriptions of them) into higher order conceptual categories.

Episodic memory depends on, but transcends, the range of the capabilities of semantic memory. The function of episodic memory is to enable the individual to remember experienced events as embedded in a matrix of other personal happenings in subjective time. One's recollections of something that happened 10 minutes ago, or the day before, or in the more distant past depend critically on short-term memory, semantic memory, and especially episodic memory.

Perceptual priming (henceforth just "priming") is the latest addition to the developing list of major categories of memory. It has been studied by neuropsychologists and cognitive psychologists only for the past 10 years or so. The idea that it expresses the operations of a memory system other than procedural, semantic, and episodic memory is of even more recent origin.

Priming does not involve explicit recollection of recent events or episodes. It refers to a facilitative effect of exposure to a word or object on subsequent identification of that word or object from reduced perceptual cues. Priming is a type of nonconscious or implicit memory, in the sense that exposure to an item during a study episode can produce priming on a subsequent test even when people do not explicity remember the item or the study episode in which it was previously encountered.

Priming has several interesting properties. One is that its operations are unconscious: people are not aware that their facility of identification of an object has benefited in any way from earlier exposures to the same or similar objects. A second property of priming is that it is unrelated to explicit memory: experiments show that priming effects are as large for the stimulus items that people consciously remember having encountered earlier as they are for the stimulus items that they do not remember. Third, priming, as measured in some tests, lasts over long intervals: a single presentation of a familiar word for a few seconds in a list of 100 other words may result in priming effects that can be readily detected more than 1 year later.

The priming paradigm

To study memory systematically, experimental paradigms have been developed that allow relatively precise estimates to be made about the nature and characteristics of various memory processes. In most of the traditional explicit memory paradigms, memory is assessed with a three-stage procedure: a) a *study phase* in which people are exposed to a set of target materials, such as a list of words or pictures, b) a *retention interval*, which typically lasts for several minutes or hours, during which people perform tasks unrelated to the study phase, and c) a *test phase* in which people are asked to think back to the study phase and either produce the target materials (recall) or discriminate the targets from items that were not presented during the study phase (recognition). Experimental studies that have adhered to this basic procedure have provided a good deal of insight into the processes involved in conscious or explicit memory for recent events.

The typical priming experiment also comprises three stages. The first two are identical with explicit memory paradigms. It is during the test phase that the critical difference between priming and explicit memory experiments occurs. Instead of being asked to try to remember previously studied items, people are simply instructed to perform a task that typically involves identification of a stimulus on the basis of partial or reduced cues; no reference is made to the prior study episode. Some of the test cues represent new or nonstudied items that had not been presented during the study phase. Priming is said to occur when the probability of identifying previously studied items is increased, or the time required to identify them is decreased, relative to the accuracy or the latency of identification of nonstudied items.

For example, on stem completion tasks, people are asked to complete word stems or fragments (for example, TAB__) with the first word that comes to mind (e.g., TABLE); priming is inferred from an enhanced tendency to complete the stems with previously studied words relative to nonstudied words. On the perceptual identification task, people try to identify a word or object from a brief (e.g., 50 msec) perceptual exposure; priming is indicated by more accurate identification of recently studied items than of new, nonstudied items.

Dissociations between priming and other forms of cognitive memory

An early and important indication that priming is subserved by different processes from those underlying explicit memory for recent events was provided by studies of brain-damaged patients with organic amnesia. Amnesic patients are characterized by a severe impairment in explicit memory for recent events, despite relatively normal intelligence, perception, and language. This memory deficit is typically produced by lesions to either medial temporal or diencephalic brain regions. A number of studies have demonstrated, however, that amnesic patients show just as much priming as do normal subjects on stem completion and other implicit memory tasks, despite their inability to remember explicitly the target items or the study episode in which the items were encountered. Thus, the memory processes that subserve priming are apparently supported by a different brain system from the processes underlying explicit memory for a recent event, because normal priming can occur in the absence of explicit memory.

Although the dissociation between priming and explicit memory is highlighted most dramatically by studies of amnesic patients, similar dissociations have been produced in experiments with normal subjects who do not have any brain damage or memory deficits. One particularly important dissociation has been observed in experiments that have compared the effects of semantic and nonsemantic study tasks on priming and explicit memory. It has been well established that performance on explicit recall and recognition tests is higher after semantic that nonsemantic study of an item. For example, when subjects perform a semantic encoding task during the study phase of an experiment (e.g., rate the pleasantness of a word or provide a definition of a word), subsequent probability of explicitly remembering the word is much higher than if subjects perform a nonsemantic encoding task during the study phase (e.g., count the number of vowels and consonants in the word). In contrast, however, it has been shown that the magnitude of priming on a stem completion task or perceptual identification task is unaffected by type of study task: priming effects are equivalent after semantic and nonsemantic encoding.

The finding that priming is unaffected by semantic versus nonsemantic encoding manipulations that greatly influence explicit memory was reported initially in experiments that used familiar words as target materials. Recently, the same pattern of results has been observed in studies with visual objects. For example, in one experiment, subjects were shown line drawings of common objects during the study phase, and performed either a semantic encoding task (think of functions that the object can be used to perform) or a nonsemantic task (count the number of vertices in the object). Priming was later assessed with an object completion test in which subjects were shown perceptual fragments of studied and nonstudied objects, and provided the first object that came to mind in response to the perceptual fragment. The magnitude of priming on this test was identical after the semantic and nonsemantic encoding tasks, even though explicit memory for studied objects was considerably higher after the semantic study task than the nonsemantic study task.

Another important difference between priming and explicit memory is that priming is frequently influenced more by the physical form of a stimulus than is explicit memory. For example, priming on such visual implicit tests such as perceptual identification, stem completion, and fragment completion can be reduced or eliminated by presenting target words auditorily, thereby indicating that the phenomenon is modality-specific. Explicit memory, by contrast, tends to be less affected by such study/test modality shifts. There is also some evidence that priming can be reduced by changing the precise surface features of an item between study and test (e.g., if a word is studied in handwritten form and tested in typewritten form, there may be less priming than if the word is studied and tested in the same surface form).

The foregoing does not constitute an exhaustive list of dissociations between priming and explicit memory. For example, evidence also exists that priming is not influenced by presentation of interfering material during a retention interval, even though explicit memory is highly sensitive to such inteference effects; and several studies have shown that forgetting over time can proceed differently for priming and explicit memory. Another difference is that priming is unaffected by drug treatments that influence the expression of other forms of cognitive memory. As would be expected, a number of similarities have also been observed between priming and explicit memory, but the differences are most revealing theoretically and have led to a variety of proposals concerning the nature of priming.

Theoretical accounts of priming

One theoretical position holds that priming is attributable to the temporary activation of preexisting units or nodes in memory: exposure to a word or subject automatically activates a memory representation of it, and this activation then subsides rather rapidly. Although able to accommodate some experimental results, this general idea has difficulty accounting for the finding that priming can be surprisingly long-lived —under certain conditions, lasting for days and weeks. It also fails to explain the fact that priming has been observed after exposure to unfamiliar materials, such as nonsense words or novel patterns and objects that do not have any preexisting representation in memory as a unit.

A rather different view holds that both priming and explicit memory are based on newly created memory representations in the episodic or declarative memory system, and that experimental dissociations can be attributed to the differing demands of the tests used to assess priming and explicit memory, respectively. Specifically, it is held that most standard explicit memory tests require a good deal of conceptually driven processing: semantically based, subject-initiated attempts to recollect the study episode. By contrast, performance on such implicit memory tests as word completion and perceptual identification is held to be largely dependent on data-driven processing; processing that is determined largely by the physical characteristics of test cues. It thus follows that explicit memory, but not priming, should benefit from semantic study processing (which is thought to support conceptually driven processing) more than nonsemantic study processing, whereas priming should be more dependent than explicit memory on matching of surface features between study and test. However, a major problem for this view is that it does not provide a satisfactory explanation of why priming is preserved in amnesic patients.

To accommodate the data on amnesic patients, a number of investigators have proposed that priming depends on a memory system that is neuroanatomically distinct from the limbic system structures (most importantly, the hippocampus) that are damaged in amnesia and that are necessary for explicit memory. We recently developed a version of this hypothesis that holds that priming depends on a perceptual representation system (PRS): a presemantic system comprising several interacting subsystems that handles information about the form and structure, but not the meaning, of words and objects.

Under some experimental conditions, access to PRS is hyperspecific in that small variations in cues may greatly influence accessibility of the representations in PRS. Another important feature is that PRS reaches its optimal functional development before other cognitive memory systems do. Independent evidence for the existence of PRS has been provided by neuropsychological studies of patients with certain types of reading and perceptual deficits. These studies have shown that for both words and objects, access to semantic and structural knowledge can be dissociated, thus suggesting that the two kinds of knowledge are represented separately. In addition, neuroimaging studies of lexical processing using the technique of positron emission tomography lead to the same conclusion. Both the neurophysiological and neuroimaging data suggest that the neural locus PRS involves posterior cortical regions, including extrastriate occipital cortex and regions of temporal cortex.

In view of the previously discussed evidence that priming is independent of semantic study processing and dependent on structural information, it makes sense to hypothesize that a presemantic system such as PRS is critically involved in priming. In addition, there is no reason to believe that PRS is impaired in amnesic patients, so the fact that amnesics generally show intact priming can be accommodated.

It must be noted and emphasized, however, that the notion that priming is a presemantic phenomenon applies only to priming effects that are observed on such data-driven tests as word completion and perceptual identification. Priming in both normal subjects and amensic patients has also been observed on implicit memory tests that are primarily conceptually driven, such as producing members of a category in response to a category name. According to the PRS hypothesis, priming on conceptually driven tests has a different basis than does data-driven priming, and likely depends on semantic memory.

A great deal remains to be learned about priming; in particular, there is little direct evidence concerning the neural basis of the phenomenon. Nevertheless, the discovery and exploration of priming phenomena have already opened up some new vistas for memory research, and it seems likely that further empirical study and theoretical analysis of priming will continue to pay handsome dividends in the future.

Further reading

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