1

Concepts of Human Memory

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Scientific study of human memory has been proceeding apace for over a hundred years. Original experiments on normal memory by Ebbinghaus, early clinical observations of pathological memory by Korsakoff, and pioneering studies of conditioning and learning in animals by Pavlov and Thorndike laid the foundations of a science of memory that has been expanding ever since and that now has branched out in many directions. Today, learning and memory are explored at several levels of analysis in different organisms from a number of complementary perspectives.

The first century of research on human memory has had two major effects: (a) it has produced a wealth of empirical data, and (b) it has forcefully demonstrated the enormous complexity of learning and memory. In so doing, it has also promised more of the same in the future—an ever-increasing number of detailed facts, and an even greater complexity. An individual practitioner can take defensive action against this dual onslaught in either of two ways: concentrate on some narrow corner of the domain and seek order and harmony locally, or ignore the minutiae and contemplate the broad outlines of the total scene. Although one's choice depends on temperament and previously reinforced behavior, observation suggests that one's selection of the strategy for minimizing perplexity also correlates with age. Young investigators like confrontations with specific problems; older ones prefer to look down on things from the stratosphere.

In this chapter I discuss some general ideas in the broad field of human memory. Ideas are the lifeblood of science. In the final analysis, the fortunes of any scientific discipline depend at least as much on the quality of its ideas as on the raw facts about Nature. It is easy to agree with Ernst Mayr when he says that "those are not far wrong who insist that the progress of science consists principally in the progress of scientific concepts" (Mayr, 1982, p. 24). The reason that, say, a telephone directory fails to pass muster as a scientific publication is that one cannot have any interesting ideas about its contents, although it qualifies splendidly on several other relevant criteria: it provides a large number of very tightly organized empirical facts, a large proportion of the information in it can be regarded as quantitative, and the number of accurate predictions even a small directory allows greatly exceeds

3

the number of predictions possible on the basis of the best contemporary models and theories of memory.

I will refer to the ideas that I wish to discuss as "concepts" in order to convey the impression that they are not just fleeting thoughts anyone might have about the subject matter, but rather that they are products of careful thought, sometimes a great deal of hard thought. But it should be clear that, even under the cloak of the more respectable term, a concept is nothing more than an idea, a thought, or a hunch about something. As such, it can be powerful or impotent, brilliant or shallow, enduring or ephemeral. It can help or hinder, encourage or frustrate, inspire or stifle.

In other fields of scientific endeavor, concepts vary in the importance of the role they play. Some concepts are central, whereas others play secondary, tertiary, and further subsidiary roles. Central concepts of other sciences are universally known. They include things such as force and acceleration in classical mechanics, metabolism in understanding living matter, homeostasis in defining disease states, atmospheric pressure in the understanding of weather phenomena, and lithospheric plates in the science of plate tectonics. These concepts are central in that their absence would greatly hamper the exposition of theory in which they play a part, and in that the understanding of the target phenomena would be incomplete in their absence.

The concepts of human memory to be discussed in this chapter are not quite in the same class as the major concepts of more mature sciences, but they are broad and general, transcending individual phenomena and stretching across the boundaries of particular models and theories. In this sense they are central to the science of human memory. The concepts I discuss are well known to all practitioners inside the field, and familiar to many others. The justification for reviewing them on the present occasion lies in the fact that concepts have a habit of changing over time, and that sometimes these changes escape wider notice. Most of us practicing researchers exhibit a remarkable tendency to become imprinted on and remain attached to the initial formulation of a concept, despite changes, sometimes radical changes, that it undergoes as a result of further work and thought. A periodic reexamination of the status of ideas and concepts in a field need not be a total waste of time.

I classify the concepts to be discussed into two broad categories: processing concepts and classificatory concepts. Processing concepts have to do with processes that comprise individual acts of memory; classificatory concepts represent ideas about different kinds of learning and memory, or memory systems.

PROCESSES OF REMEMBERING

One of Ebbinghaus's numerous contributions was the adoption of the study/test paradigm for the study of memory. The paradigm has remained a successful standard ever since. In the study phase, experimental subjects

are presented some information or learn a task; in the test phase, the retention of the information or the task-based skill is assessed. We take the study/test paradigm for granted and do not always realize its influence in shaping our approach to and thoughts about our subject matter. Memory is inextricably intertwined with other cognitive functions of the brain in the ceaseless flux of behavior and experience. The study/test paradigm allows the experimenter to create a multitude of laboratory analogues of single *acts* of memory that constitute the flux in real life, and makes the individual discrete acts the objects of observation and analysis. From this perspective, to study memory is to study acts of memory; to understand memory means to understand the mechanisms and component processes whose workings and interactions determine the course and outcome of an act of memory. The identity of and relations among the component processes demarcate the conceptual structure of an act of memory.

General Abstract Processing System

A conceptual structure of a single act of human memory, dubbed General Abstract Processing System (GAPS), is schematically represented in Figure 1.1 (Tulving, 1983). It depicts the stages of encoding, storage, and retrieval of an item of information, and interrelations among them, within the conventional study/test paradigm.
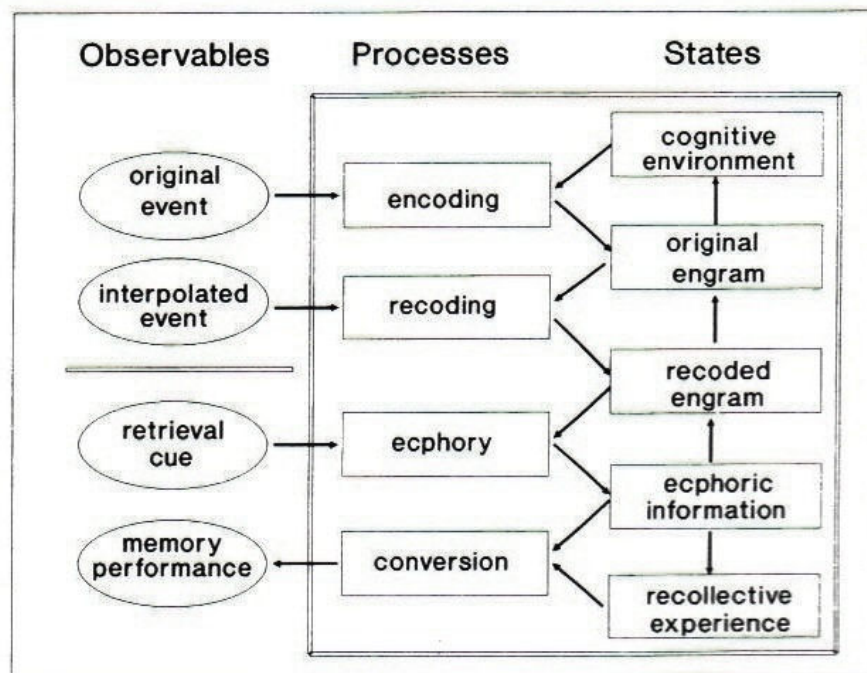

FIGURE 1.1. General Abstract Processing System (GAPS): A conceptual structure of component processes of an act of remembering. (From Tulving, 1983)

GAPS specifies three different kinds of concepts: observable components, hypothetical processes, and hypothetical states. States represent the end products of the processes. The arrows in the diagram represent the relations among the concepts; each arrow can be interpreted as "influences".

The central concepts of GAPS are *encoding, engram, ecphory,* and *ecphoric information.* Encoding is the process that converts the event information into an engram (memory trace or representation); ecphory is the process that combines the information in the engram and the retrieval cue into ecphoric information. Ecphoric information determines recollective experience, the end product of an act of cognitive memory.[1] Encoding and engram are the principal components of *storage* of information in memory; ecphory and ecphoric information are the principal components of *retrieval* of the stored information.

The act of remembering begins with the encoding of a perceptual or conceptual event within a given cognitive environment that represents all aspects of the state of the system that are relevant to the event and its encoding. It ends with the creation of a cognitive state referred to as ecphoric information. It is constructed on the basis of both the (usually recoded) engram and the retrieval cue. In episodic memory, ecphoric information determines the nature of recollective experience, the conscious re-experience of the original event. In semantic memory, the ecphoric information determines the contents of the retrieved bundle of knowledge. In laboratory studies, and frequently though not always in real life, the cognitive contents of recollective experience and retrieved knowledge are converted into overt behavior, usually in verbal or some other symbolic form. Such conversion is, strictly speaking, not a component of the act of remembering. A person's verbal description of the retrieved cognitive contents is a postecphoric, nonmemory process; its relation to ecphoric information and recollective experience can take any one of a number of different forms (cf. Buschke, 1987, Fig. 22–1).

The structure of GAPS is abstract. It does not constrain the treatment of the component processes that comprise the storage and retrieval of information about experienced events in formal modeling or their analysis at the physical and physiological levels. It neither prescribes nor proscribes the specific nature of component processes. It is compatible with many particular theoretical ideas or physiological characterizations of the underlying mechanisms and processes. GAPS does, however, make explicit the general categories of component processes of remembering. By postulating the existence of these processes, it points to the necessity of their analysis at *all levels.*

The outcome of any act of memory is generally useful to the individual to the extent that ecphoric information and recollective experience accurately reflect the original extent of or correspond to the originally stored fact. A great deal of evidence exists showing that the correspondence between the original event or fact and its ecphorized form may be highly variable, from near-perfect reproduction to glaring discrepancies. In cognitive psychology

of memory this correspondence defines the dependent variables of primary interest.[2]

GAPS has been shaped by what is known about the factors and variables that determine remembering as it manifests itself at the level of cognition and behavior. The component processes of GAPS reveal the sources of multiple determinants of the nature and contents of recollective experience and its correspondence with the original event or comprehended fact. It explicates the variability of this correspondence, from highly accurate recreation of the original experience to remembering of events that in fact did not occur or retrieval of facts that are not true. It summarizes the types of experimental interventions that are not only possible in the study of memory but whose omission from the analysis would necessarily result in an incomplete understanding of memory.

Synergistic Ecphory

GAPS makes explicit the synergistic nature of retrieval. Retrieval in earlier times meant the "utilization" of traces, or stored information (Melton, 1963), or "the use of memory in neuronal and behavioral operations" (Dudai, 1989, p. 6). These definitions, widely accepted even today, embody the strong "storage bias" that characterized psychological thinking about memory for a long time, and still does so for most laypersons. The storage bias leads people to identify retrieval with the performance of what the individual has learned, or with the output from the memory system. In the traditional thought, performance is determined by past learning: the output from the memory system depends on the earlier inputs as represented by the informational contents of the engram. Even in early information-processing models of memory (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965), one of the basic assumptions was that of a one-to-one relation between what had been stored and what could be recalled. Thus, retrieval was thought to provide a nondestructive test of what has been stored. In theoretical terms the concept of retrieval as performance was conceptualized as "activation" of the engram. GAPS suggests that the matter is more complex. The antidote to the storage bias is synergistic ecphory.

I use the term *synergistic ecphory* to express and emphasize the idea that the outcome of an act of memory depends critically not only on the information contained in the engram but also on the information provided by the retrieval environment, or retrieval cues. "Synergistic" serves to remind us that ecphory, the main component process of retrieval, is governed by these two sources of relevant information, one derived from the past, the other one representing the present. Thus, synergistic ecphory as a concept differs from and supersedes the historically earlier concept of activation of engram. It also accents the contrast between the storage-oriented study of memory and the orientation in which retrieval plays an equally decisive role.

For over three-quarters of a century after Ebbinghaus's ground-breaking

work, strong storage bias prevailed. To study memory meant to study storage. In the associative orientation this meant the study of acquisition and loss, strengthening and weakening, transfer and interference of associations. Performance was little more than a device for measuring the changes in storage.

The thinking governed by the storage bias began to change in the 1960s, when storage and retrieval processes were analytically and experimentally separated and an explicit distinction drawn between *availability* and *accessibility* of stored information (Tulving & Pearlstone, 1966). Availability was determined by the same variables that determine storage; accessibility was a joint function of availability *and* retrieval cues. The distinction between availability and accessibility did not depart greatly from that between learning and performance, or between the engram and its activation, but it prepared the way for a more radical break with the past. This break came when it was discovered that different encoding operations performed on structurally fixed units of information could lead to large differences in the remembering of these units (e.g., Craik & Tulving, 1975; Hyde & Jenkins, 1969; Mathews, 1977), and that the effectiveness of structurally fixed retrieval cues could vary greatly with differences in these encoding operations (e.g., Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974; Fisher & Craik, 1977; Thomson & Tulving, 1970; Tulving & Osler, 1968; Tulving & Thomson, 1973; Watkins & Tulving, 1975). The idea of performance as activation of engrams was superseded by the more advanced concepts of encoding specificity (Tulving & Thomson, 1973), transfer appropriate processing (Morris, Bransford, & Franks, 1977), and synergistic ecphory (Tulving, 1982). A more complete story of these developments, together with a survey of relevant experimental evidence, is presented elsewhere (Tulving, 1983).

Synergistic ecphory, the idea that remembering occurs as a result of *interaction* between storage and retrieval, or between engram and ecphory, implies that to understand memory means to understand this interaction. It implies that any specification of an engram *independently* of ecphory is necessarily incomplete, as is any specification of ecphory independently of the engram. The specification of the engram has to refer to ecphory, exactly as the specification of the ecphory must refer to the engram. Synergistic ecphory also implies that any physical determination of the properties of the engram independently of ecphory may turn out to be impossible, inasmuch as the engram does not exist in the absence of ecphory: it cannot be distinguished from the rest of the neural aftereffects of the encoding process. Such *physical indeterminancy* of the engram is to be contrasted with its *biological determinacy*, as reflected in the products of the interaction between storage and retrieval.

Initial attempts have been made to identify storage and retrieval processes, or the engram and ecphory, at the level of brain activity, with success that augurs well for the future. One example is provided by Neville, Kutas, Chesney, and Schmidt (1986) who studied event-related potentials (ERPs) during both encoding and subsequent recognition of words, and found that

the amplitude of the late positive component (P650) recorded at encoding was different for words subsequently recognized and those not recognized. Another example of electrophysiological study of brain events correlated with memory processes is the study reported by Smith and Halgren (1989) who found rather large differences in the ERP patterns for words previously presented and recognized as such by the subjects and words not previously presented. They interpreted this "word-repetition" effect on ERPs as reflecting dynamic neurocognitive activity whereby the information provided by the retrieval cue (the test word) is brought into interaction with the information contained in the engram of the original presentation of the word—that is, synergistic ecphory. A third example, based on a different technique, is a preliminary study of regional cerebral blood flow that showed different patterns of cortical activation correlated with retrieval of episodic and semantic information (Tulving, 1989; Tulving, Risberg, & Ingvar, 1988).

CLASSIFICATION OF MEMORY

A relatively recently adopted new approach to the study of memory has to do with the classification of memory (Sherry & Schacter, 1987; Tulving, 1985c, 1986). The classification approach *complements* the process-oriented approach to memory; it is not an alternative to it. The general purpose of the classification enterprise is analysis and description of memory as a structured assembly of separable but normally closely interacting brain systems and subsystems whose collaborative functioning is expressed in behavior, cognition, and conscious awareness. A basic premise of classification research is that all nontrivial empirical generalizations about learning and memory necessarily hold only within certain boundaries. Classification research attempts to define these boundaries in terms of different memory systems and subsystems.

The objectives of classification research are threefold. Classifiers seek to construct a classificatory scheme that (a) identifies major systems and subsystems of memory, (b) specifies their properties and characteristics, and (c) delineates the nature of the relations among them. The pursuit of the classification enterprise also includes the search for the solutions of a variety of related methodological and pretheoretical problems. These include issues such as the rules and principles of classification research, the nature of relevant empirical evidence, the logic of acceptable inferences from the data, the relations between memory tasks and memory systems, and the creation and adoption of suitable terminology (Tulving, 1985c).

The Concept of "System"

What do we mean by "memory system"? The concept of "memory system" itself is still evolving, and undoubtedly will be modified, refined, and sharpened as classification research unfolds. In an early formulation (Tulving,

1984a). I tried to make explicit what I perceived as rather broadly held tacit assumptions as to what memory systems are and what they do, notions that I thought reflected the views on the issue by most researchers. As these general ideas about systems have not been substantially challenged or changed greatly in the intervening years, and as they are not widely known, they may be worth re-recording here:

(1) Different systems serve separate, largely nonoverlapping behavioral and cognitive functions. They mediate the acquisition and retention of different kinds of information and knowledge. ... (2) Different systems operate according to different laws and principles. Although all learning and memory systems share some features—they all enable the organism to make use of information acquired on an earlier occasion—all the processes of different systems need not be the same: what is true of one system is not *necessarily* true of another. (3) The behavioral and cognitive functions of different systems are represented in the brain by different neural structures, different neural mechanisms, or both. Each such structure or mechanism is specialized for a particular set of behavioral or experiential functions. It is sometimes possible for one neural learning and memory system to substitute for another, albeit at a less efficacious level; it is also possible for the activity of one of the neural systems to modulate that of another. (4) Different systems have developed at different stages in the phylogeny of the species, representing the responses of the species to changes in environmental demands for survival. Analogous changes may occur in the ontogeny of individual members of the species in some cases: depending upon the time course of the maturation of the brain, different kinds of learning and memory functions become possible at different ages of the developing individual. (5) Different systems differ from one another with respect to the format of representation of acquired information. ... The after-effects of a behavioral event registered in a more primitive system may carry minimal information about the past event, although sufficient information to determine or modify future behavior or experience. On the other hand, representations (engrams, memory traces) laid down in a more advanced system may preserve a good deal of detailed information about the past event. (6) In the course of an organism's interaction with its environment, several systems may participate in the storing of information, use of information, or both, in a particular situation. The cooperation among the systems may be so smooth that casual observation of behavior creates the impression of a single system in action. (Tulving, 1984a, pp. 177–179)

In this formulation, a memory system is defined by its brain mechanisms, type of information it handles, and the principles of its operations, with a good deal of overlap in all three aspects envisaged among different systems. Sherry and Schacter (1987), in their discussion of the concept of memory system, endorse the ideas that different memory systems are characterized by different modes of operation and different brain structures. They also elaborate on the evolutionary rationale for the emergence of different memory systems, arguing that different systems evolve in response to the need for information storage and retrieval devices for specific purposes,

under conditions where the needs satisfied by different systems are said to be *functionally incompatible*. But Sherry and Schacter (1987) reject the notion that the type of information is different in different systems (Tulving, 1984a). This kind of disagreement is a symptom of the developing understanding of classification; its resolution is one of the many tasks awaiting memory classifiers. One solution is to postulate that a given system may indeed process different kinds of information, but that each of its subsystems deal with only one type of information. An example of this idea is provided by the word-form and the structural description subsystems of the perceptual representation system (PRS) that has been postulated to mediate perceptual priming effects (Schacter, 1990; Tulving & Schacter, 1990). The mode and rules of operation of the two subsystems are assumed to be the same, but the types of information on which the two subsystems operate are diffeent, as are presumably their neural underpinnings.

The systems approach has been criticized in cognitive psychology, primarily because of perceived lack of evidential support and because the whole idea is thought to violate the principle of parsimony. Some cognitive psychologists indeed seem to be greatly alarmed at the prospects of what they view as "proliferation" of memory systems, such alarm being caused by as few as four systems (Zacks, 1984). One fear frequently expressed is that if postulation of different memory systems is accepted as a legitimate scientific practice, there is nothing to prevent any investigator, on finding a new dissociation, from declaring the existence of yet another system, or a pair of systems. The principle adopted by these believers in unitary memory is that the movement towards multiple memory systems has to be stopped before it is too late. Roediger (1990a) has compared the postulation of multiple systems with the listings of instincts and Gestalt "principles" of perception, and has predicted the same dire fate for memory systems that befell these other sorry scientific misadventures.

Five Memory Systems

A number of classificatory schemes of human memory have been described and discussed. Initially these took the form of various dichotomies, such as those between short-term and long-term memory (e.g., Shallice & Warrington, 1970; Warrington & Shallice, 1969), episodic and semantic memory (Kinsbourne & Wood, 1975; Tulving, 1972; Warrington, 1975), and procedural and declarative memory (Cohen, 1984; Cohen & Squire, 1980; Squire & Cohen, 1984). Now, however, more comprehensive structures have been proposed (e.g., Johnson, 1990; Squire, 1987; Tulving, 1983, 1987; Warrington, 1979; Weiskrantz, 1987, 1990).

One such tentative general classification scheme for human memory systems is presented in Table 1.1. It includes five major learning and memory systems: *procedural* memory, perceptual *priming*, *short-term* memory, *semantic* memory, and *episodic* memory. Each of the five systems is large

TABLE 1.1 Major Human Memory Systems—1990

1.	Procedural memory: Skills; simple conditioning
2.	Perceptual representation system: Perceptual priming of identification of objects
3.	Short-term memory: Highly accessible information from recent cognitive inputs
4.	Semantic memory: General knowledge of the world
5.	Episodic memory Conscious recollection of the personal past

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: many 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 ones.

The scheme in Table 1.1 does not include primitive forms of learning, such as sensitization and habituation, because little work has been done with them in humans, and sensory (iconic and echoic) memory (Coltheart, 1983), because little is known about their relation to forms of memory other than short-term memory. Two entries in Table 1.1, semantic and episodic memory, are sometimes categorized together as *declarative* (Cohen, 1984; Cohen & Squire, 1980; Squire & Cohen, 1984) or *propositional* memory (Tulving, 1983), as they share a number of features. Another frequently used distinction is that between implicit and explicit memory (Graf & Schacter, 1985; Roediger, 1990b; Schacter, 1987b). 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 short-term and episodic memory, expression of what the person consciously *remembers* as a personal experience. In Table 1.1, procedural, PRS, and semantic memory would be classified as implicit; short-term and episodic memory would be classified as 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 connec-

tions are examples of tasks that depend heavily on the procedural memory system. The general model of procedural memory is provided by what Hirsh (1974) called "performance line storage," characterized by the kind of learning that is preserved after hippocampectomy, differentiating it from "contextual retrieval," which requires representational storage and depends on the integrity of the hippocampal system.

The other four are *cognitive* systems. They mediate changes in cognition, or thought. 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, as we already noted about GAPS, is not an obligatory part of memory. Rather it is an optional postmemory, or postecphoric, process. Indeed, in the laboratory the products of cognitive memory systems are analyzed in the form of "pure" experience or thought, with behavioral responses serving merely as indicators of properties of cognitive processes.

Perceptual priming is a specific form of learning that is expressed in enhanced identification of objects as structured physical-perceptual entities. Perception of an object at Time 1 primes the perception of the same or a similar object at Time 2 in the sense that the identification of the object can require less stimulus information or less time than it does in the absence of priming.

Short-term memory, also referred to as *primary* memory (Waugh & Norman, 1965) or *working* memory (Baddeley, 1986; Baddeley & Hitch, 1974), registers and retains incoming information in a highly accessible form for a short period of time after the input. Short-term memory 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.

Semantic memory makes possible the acquisition and retention of factual information in the broadest sense; the structured representation of this information, semantic knowledge, models the world. Semantic knowledge provides the individual with the necessary material for thought—that is, for cognitive operations on the aspects of the world beyond the reach of immediate perception. An example of the capabilities of semantic memory is knowledge of location of objects in the nonperceived space; another is classification of objects, events, or situations—or symbolic descriptions of them—into higher-order conceptual categories depending on their functions and uses.

Episodic memory enables individuals to remember their personally experienced past—that is, to remember experienced events as embedded in a matrix of other personal happenings in subjective time. It depends on, but transcends, the range of the capabilities of semantic memory. The most distinctive aspect of episodic memory is the kind of conscious awareness that characterizes recollection of past happenings. This awareness is unique and unmistakably different from the kinds of awareness that accompany

perceptual experiences, imagining, dreaming, solving of problems, and retrieval of semantic information. To distinguish the episodic-memory awareness from these other kinds, I have referred to it as autonoetic consciousness (Tulving, 1985b). It has been successfully brought under experimental scrutiny by Gardiner and his coworkers (e.g., Gardiner, 1988; Gardiner & Java, 1990; Gardiner & Parkin, 1990).

The evidence for the distinction between and among different forms of memory, and memory systems, are derived from *dissociations* between outcomes of tests that are known or can be assumed to rely differentially on different systems. Outcomes of tests are said to be dissociated if they differ as a function of an independent variable, or with subjects and their brain states. Evidence for separate or separable systems is provided by different *convergent* dissociations. Despite the fears and misgivings expressed by unitarians, it is unlikely that a competent classifier would propose a new memory system, or a new pair of systems, after observing a single novel dissociation. The logic of the dissociation methodology has been thoroughly discussed by Shallice (1988). The dissociation evidence that bears on the issues of classification of memory is growing by leaps and bounds. It has been reviewed by Richardson-Klavehn and Bjork (1988), Schacter (1987b), Shallice (1988) and Shimamura (1986).

Classification of memory requires a multilevel approach. Functional analysis of memory systems must necessarily be combined with neuroanatomical and neurophysiological analyses. Behavioral data on their own are seldom sufficiently compelling to allow preclusion of alternative interpretations. Differentiation of systems at the level of neural pathways and networks, and eventually perhaps even at the level of cellular and synaptic mechanisms, is an important part of the classification research. Although the available knowledge on neuroanatomical localization of function is still fragmentary, a good deal of progress has been made in recent decades in identifying the regions of the brain that are critical for the operations of different systems. Reviews of relevant evidence include those by Squire (1986, 1987) and Weiskrantz (1985, 1987).

In the remainder of this chapter, I will consider two issues that have emerged in classification research and that illustrate the role of concepts in the study of human memory. The first issue is the recently discovered phenomenon of perceptual priming and the perceptual representation system (PRS) that has been postulated as the system subserving such priming. Perceptual priming represents a relatively recent discovery; it is under vigorous investigation today, and it holds every promise of becoming an even more acute focus of study in the future. The second issue is the distinction between episodic and semantic memory. The current thinking about the nature of, and especially the relation between, these two forms of memory have changed since the introduction of the distinction some 20 years ago, and the reality of the distinction has been energetically denied by some. (For one set of objections, see Baddeley, 1984; McKoon, Ratcliff, & Dell, 1986; Ratcliff & McKoon, 1986; Roediger, 1984).

PERCEPTUAL PRIMING AND PRS

A perceptual representation system (PRS) is the latest addition to the developing list of memory systems (Schacter, 1990; Tulving & Schacter, 1990). It consists of several known and probable subsystems, which mediate perception of different objects as structural entities and facilitate such perception through priming. *Perceptual priming* was identified as a distinct form of memory only recently, although the basic phenomena have been known for some time. It differs from two other major forms of priming, *semantic* priming (Meyer & Schvaneveldt, 1971; Neely, 1977) and *conceptual* priming (Hamann, 1990; Roediger & Blaxton, 1987; Roediger, Weldon, & Challis, 1989; Srinivas & Roediger, 1990; Tulving & Schacter, 1990), in that perceptual priming operates on physical-perceptual *appearances* of objects, including words, and has little to do with their *meaning*, whereas both semantic and conceptual priming operate at the level of meaning, and have little to do with the perceptual appearance of the words.

The idea that priming might be subserved by a system other than those already known was suggested by Tulving, Schacter, and Stark (1982), at a time when the distinction between perceptual and conceptual priming was not yet appreciated. The tentative priming system was initially referred to as the QM (for "quasi-memory") system (Hayman & Tulving, 1989; Tulving, 1985a), to reflect the assumption that in some sense it seemed to belong somewhere "between" perception and memory. Kirsner and Dunn (1985) explicitly suggested that priming was a form of perceptual learning. The term PRS was adopted from the neuropsychological literature on disorders of reading and of object perception as historically prior, more comprehensive, and more appropriate (Schacter, 1990; Schacter & Tulving, 1990).

A prototypical perceptual priming experiment, consisting of two stages, resembles a prototypical explicit memory experiment. In the first (study) stage, the subject is presented with a stimulus object (target), such as a word, a face, a picture, or a line drawing of an object. In the second (test) stage, separated from the first by a shorter or longer interval, the subject is presented with a cue containing incomplete or impoverished *perceptual* information about one of the target objects. The subject's task is to identify the cued target, or to assign it to a larger category. Thus, for example, in the test stage, the subject might be given a graphemic *fragment* of a word, such as P – I – I – G, or — AG – EN –, and asked to name the word. Other kinds of perceptual cues that have been used include word *stems, n* initial letters of words (e.g., Warrington & Weiskrantz, 1970), incomplete line drawings of the target objects (e.g., Snodgrass & Feenan, 1990; Warrington & Weiskrantz, 1968), and tachistoscopic presentations of targets (e.g., Jacoby & Dallas, 1981; Musen & Treisman, 1990; Schacter, Cooper, & Delaney, 1990). It is the perceptual similarity between cue and target that defines the phenomenon as perceptual priming. In conceptual priming the relation between the cue and the target is specified in terms of their meaning. The subject's objective is always to identify the target.[3]

The *priming effect* is measured in terms of some function of the difference between the probabilities of identifying words encountered and words not encountered in the study stage of the experiment. The priming test differs from explicit memory tests in the question posed to the subject: "What is this word?" versus "What did you see in the study list?" Answers to both questions are influenced by the study episode, and in this sense represent aftereffects of the same original event, but the aftereffects are radically different, in a number of ways, and thus suggest they are expressions of different memory systems.

First, unlike the expression of other kinds of cognitive memory, priming is nonconscious. An individual perceiving an object more efficiently because of priming is not aware that the act of perception has benefited in any way from earlier exposures to the same or a similar object. In the laboratory, priming effects occur regardless of whether subjects know or do not know anything about the relation between the study and test stages of the experiment, or whether they know or do not know that their memory is being tested (Bowers & Schacter, 1990). Second, even when subjects are aware of the relation between the study and test stages, priming effects are as large for the stimulus items that they consciously remember having seen earlier as they are for the stimulus items that they do not remember (e.g., Jacoby & Witherspoon, 1982; Tulving et al., 1982). Third, unlike episodic and semantic memory, perceptual priming is sensitive to the compatibility between the perceptual format of the studied item and the test cue. Priming effects are considerably reduced or even absent if the priming test is given in a format different from the presentation format, as when auditory presentation is followed by a visual test (e.g., Jacoby & Dallas, 1981; Morton, 1979), when pictorial presentation is followed by a verbal test (e.g., Roediger et al., 1989), or when bilingual subjects are presented words for study in one of their languages and tested for corresponding translations in the other (e.g., Kirsner & Dunn, 1985; Roediger & Blaxton, 1987). Fourth, again unlike episodic and semantic memory, perceptual priming is little affected by variations in the semantic encoding operations performed on target items at study (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981). Fifth, priming is preserved in anterograde amnesia, whereas episodic memory is not (e.g., Graf, Squire, & Mandler, 1984; Tulving, Hayman, & Macdonald, 1991; Warrington & Weiskrantz, 1970, 1974). The most natural interpretation of this fact is that priming does not require brain structures or mechanisms whose damage in amnesia results in a severe impairment in the patient's ability to consciously recollect recent happenings. Sixth, perceptual priming is largely invariant across developmental stages (young children to adults to elderly people), which are correlated with systematic differences in episodic memory performances (e.g., Light, Singh, & Capps, 1986; Mitchell, 1989; Naito, 1990; Parkin & Streete, 1988). These findings suggest that the neural pathways that subserve episodic remembering, maturing late in childhood and deteriorating early in old age, are not necessary for priming, and that their functioning does not contribute anything substantial to the operations

of the priming system. Seventh, perceptual priming is less affected by alcohol and drug treatments than are other forms of cognitive memory (e.g., Hashtroudi, Parker, DeLisi, Wyatt, & Mutter, 1984; Nissen, Knopman, & Schacter, 1987), again suggesting differences in the brain mechanisms underlying the operations of the two forms of memory. Finally, although it has sometimes been asserted that priming effects are short-lived (e.g., Squire, 1986) at least some priming effects are long lasting. In one experiment it was found that a single presentation of a familiar word for a few seconds in a list of 100 other words produced priming effects that could be readily detected more than 16 months later (Sloman, Hayman, Ohta, Law, & Tulving, 1987). In another study it was found that the amnesic patient K.C., about whom more later in this chapter, exhibited virtually undiminished priming effects in fragment completion a year after repeated exposures to the target words. Thus, he could "read" fragments such as $- - RCR - - T$, $- A - G - YL -$, and $- E - I - W$, which can give difficulties to nonprimed normal readers, 12 months after having been repeatedly primed with the target words (Tulving et al., 1991).

There are other characteristics of perceptual priming that distinguish it from other forms of cognitive memory, but the given summary includes the major features and illustrates the overall nature of dissociation evidence that bears on the classification problem. The main point to be made is that the evidence (a) comes from a variety of sources, and (b) presents a complex picture, any component of which would have been difficult or impossible to predict, on the basis of what was known about other forms of memory, before the facts were discovered in the laboratory.

Some independent observers of classification research have expressed reservations about the force of dissociation evidence. Weinberger (1990), for instance, has suggested that dissociations could simply reflect differential thresholds of different behavioral manifestations of a single underlying process. He has also wondered about how one can go beyond the conclusion that a dissociation implies anything other than just lack of identity. These concerns may be reasonably raised in connection with any one single dissociation, but they lose their potential relevance when confronted with the totality of evidence. The idea of differential thresholds may account for, say, differential effects of drugs on explicit memory and priming, but it is directly at variance with the many findings of stochastic independence between explicit recognition and implicit priming (e.g., Jacoby & Witherspoon, 1982; Musen & Treisman, 1990; Schacter, Cooper, & Delaney, 1990; Tulving et al., 1982). As to the idea that dissociations point to lack of identity, there is no problem there. The concept of multiple systems includes, and transcends, the notion of lack of identity. It provides an explication of how the dissociated task performances are not identical, as well as how they are.

The multiple contrasts between priming and the phenomena of explicit memory, plus some others discussed elsewhere (Schacter, 1990; Tulving and Schacter, 1990), converge on the idea that perceptual priming is subserved by a distinct memory system, the PRS. The PRS integrates perceptual inputs

into highly specific neurocognitive representations of objects to which, as a result of priming, access can be gained on the basis of diminished stimulus information. It can do so independently of episodic and semantic memory (Tulving et al., 1991) and probably independently of short-term memory, although, like all other memory systems, it normally interacts closely with other systems, receiving inputs from them and sending outputs to them. It reaches its optimal functional capability in development before other cognitive memory systems do. Finally, it consists of a number of subsystems. One such (word form system) mediates priming of visual words, another (structural description system) mediates priming of natural visual objects (Schacter, 1990).

Little is known about the neuroanatomical and neurophysiological correlates of PRS. Observations of preserved perceptual priming in amnesic patients suggest that priming is mediated by the brain structures outside the medial temporal and diencephalic regions that are damaged in amnesia. There is evidence that visual identification of words activates the extrastriate region of the occipital lobes bilaterally (Petersen, Fox, Posner, Mintum, & Raichle, 1988) and that object identification depends on the right posterior cortical region (Warrington & Taylor, 1978). It can be surmised that visual priming of words or objects also depends on these cortical areas.

EPISODIC AND SEMANTIC MEMORY

The distinction between personal and impersonal forms of memory has been around for some time, under different labels. More or less detailed characterizations of these two basic forms of memory had been provided by clinically oriented students of memory and memory pathology (e.g., Claparède, 1911; Nielsen, 1958; Reiff & Scheerer, 1959), as well as philosophers (e.g., Locke, 1972). In a report of his extensive clinical neurological investigations of memory and amnesia, Nielsen described the two forms as follows:

> A study of pathways of memory formation has revealed a basic fact not suspected when this study began—there are two separate pathways for two kinds of memories. The one is memories of life experiences centering around the person himself and basically involving the element of time. The other is memories of intellectually acquired knowledge not experienced but learned by study and not personal. (Nielsen, 1958, p. 25)

Corresponding to these two kinds of memories are two types of amnesia:

> Amnesia is of two types: (1) loss of memory for personal experiences (temporal amnesia), and (2) loss of memory for acquired facts (categorical amnesia). Either may be lost without the other. (Nielsen, 1958, p. 15)

In an essay that I wrote in 1972 I adopted the terms *episodic* and *semantic* as designations of the two forms. At the time, most of the evidence relevant

to the distinction within cognitive psychology was anecdotal. Since 1972 the database relevant to the distinction has expanded greatly, much more directly relevant information has become available, and considerable progress has been made in the understanding of the properties of the two systems and their interrelation.

The initial distinction between episodic and semantic memory served a largely heuristic function, and the two concepts are often used in this atheoretical sense. "Episodic memory" defined in this heuristic or "processing" sense designates acquisition and retention of a particular type of information, in a particular type of situation. The information is what has been denoted as *declarative* or *propositional*; the situation is one in which retrieval is said to be *explicit*. The GAPS framework discussed earlier in this chapter holds for episodic memory (or declarative memory, or explicit memory) defined in this heuristic sense. "Semantic memory" defined in the same sense refers to the acquisition and retention of associative, imaginative, factual, and semantic information independently of the particular circumstances surrounding its acquisition. This information, too, can said to be declarative or propositional.

The second sense of "episodic memory" refers to a hypothetical neurocognitive system. It represents a more recent development, and it is in this "systems" sense that I discuss it here. The episodic system confers on its possessor the unique capability of storing information about personal happenings in subjective space and time (Tulving, 1983, 1984b). This stored episodic information serves as the basis for the conscious recollection of aspects of the original events, in a distinctive form of awareness that has been labeled autonoetic awareness (Tulving, 1985a, 1985b, 1987). Episodic memory system subserves remembering of the temporal order of past events (e.g., Hirst & Volpe, 1982; Milner, Petrides, & Smith, 1985; Shimamura, Janowsky, & Squire, 1990), as well as the setting, or context, within which events occur (e.g., Mayes, Meudell, & Pickering, 1985). Although, because of lack of a suitable language, it is difficult to study autonoetic awareness in lower animals, some features of episodic memory—information about temporal order and place of happenings—have been investigated, and evidence for memory capabilities analogous to episodic memory found (e.g., Hirsh, 1974; Kesner & DiMattia, 1984; Olton, 1984; Ruggiero & Flagg, 1976; Thomas, 1984).

The initial idea concerning the relation between episodic and semantic memory was that they represented two parallel subsystems of declarative memory (Tulving, 1983), and some writers have retained this idea (e.g., Squire, 1987). A more reasonable current hypothesis, however, is that the episodic system is a unique system embedded within and supported by semantic memory in some of its operations (Tulving, 1984b). A corollary hypothesis is that semantic memory precedes episodic memory in ontogenetic development and phylogenetic progression. Episodic memory has evolved from semantic memory to acquire functional capabilities not possessed by an unvarnished semantic system, but in some of its operations it has remained

highly dependent on semantic memory (Tulving, 1984b, 1987). Thus, for instance, it looks as if no new information could be stored in episodic memory if semantic memory were totally dysfunctional (cf. DeRenzi, Liotti, & Nichelli, 1987), although new information could be stored in semantic memory in the absence of a functioning episodic system, as presumably happens in very young children and in lower animals without episodic memory.

Among other implications of these ideas about the relation between the two systems is the rejection of the popularly held assumption that information enters the semantic system *through* the episodic system, a sort of a "first episodic, then semantic" kind of a notion (e.g., Squire, 1987). New information enters semantic memory through the perceptual systems, not through episodic memory. The evidence for this hypothesis is derived from studies of amnesic patients.

Anterograde Amnesia and the Episodic/Semantic Distinction

The amnesic syndrome consists of a selective and severe impairment of certain forms of memory caused by lesions in the medial temporal lobe and midline diencephalic structures, as well as possibly other regions of the brain. (For reviews, see Markowitsch & Pritzel, 1985; Squire, 1986, 1987; Weiskrantz, 1985, 1987). The core of the syndrome is anterograde amnesia, characterized by highly deficient functioning of episodic memory. The amnesic patient is incapable of remembering any personal happenings and experiences beyond the period covered by short-term memory (Rozin, 1976). Yet amnesic patients typically are unimpaired on tasks that are heavily dependent on procedural memory, PRS, and short-term memory systems (Schacter, 1987a; Shimamura, 1986; Squire, 1987; Weiskrantz, 1987), and their other intellectual functions—perception, language, and thought—are completely or largely intact.

What is not yet clear is the relation between amnesia and semantic memory. Usually, although not always, an amnesic patient has retained much of the premorbidly acquired general knowledge, suggesting a dissociation between the preserved semantic memory and the impaired episodic memory (Cermak, 1984; Kinsbourne & Wood, 1975, 1982), but such comparisons are confounded, and therefore inconclusive. More revealing are studies in which experimentally controlled new semantic learning and episodic recollection of such learning are directly compared.

In a recently conducted extensive study of a densely amnesic patient, K.C., we obtained evidence of his ability to learn new semantic knowledge and to retain it, as far as we could tell, normally over a long interval of time. We also caught a glimpse of the reasons why such new semantic learning has been declared to be beyond the capabilities of amnesic patients in many previous studies (Tulving et al., 1991).

K.C., a 40-year-old man, suffered closed-head injury in a traffic accident in 1980, with extensive damage to several regions of the brain, especially

in the left hemisphere (for further details, see Tulving et al., 1991). One consequence of this damage was extremely dense anterograde amnesia and a total absence of any autobiographical recollections from the time before his accident. Thus K.C. is one of the few amnesics described in the literature whose episodic memory is completely dysfunctional (Tulving, Schacter, McLachlan, & Moscovitch, 1988). In the study of his ability to learn new semantic information (Tulving et al., 1991), we taught him 64 three-word sentences (such as REPORTER SENT REVIEW, and STUDENT WITHDREW INNUENDO) over a number of widely distributed learning trials. At the time of subsequent retention tests, he was given the first two words of the sentence as a cue (e.g., STUDENT WITHDREW) and asked for the third word that would complete the sentence. At the end of the training, he was capable of producing 38 of the 64 target words. After a 12-month interval, during which K.C. was not exposed to any of the materials, this number had fallen to 25, still demonstrating considerable retention over such a long interval. Data from another experiment with K.C. (Hayman & Mcdonald, 1990) suggested that the success of K.C.'s semantic learning was at least partly attributable to the method we used. The tests administered to K.C. *during* the multiple distributed learning trials were such that they largely eliminated incorrect, potentially interfering responses to sentence frames, resulting in "errorless" learning. As normal subjects suffer less from interference than do memory-impaired individuals, these results suggest that normal subjects' intact episodic memory allows the learners to overcome interference and to correct errors in a fashion not possible for amnesic subjects. At any rate, minimization of interference seems to be an important determinant of semantic learning by amnesics. In one formal attempt to teach H.M. new vocabulary words (Gabrieli, Cohen, & Corkin, 1988) it was found that he was not capable of doing so. It is not inconceivable that this outcome, too, is at least partly attributable to rather large amounts of interference engendered by the method that these investigators used.

The fact that a densely amnesic subject such as K.C. can learn new semantic information illustrates the conclusions that Nielsen (1958) drew about two types of memory and two types of amnesia. But it may appear surprising in light of the widely held belief that amnesic patients are incapable of such learning (e.g., Rozin, 1976; Squire, 1987). Even if surprising, our findings do not stand alone. A number of other recent studies have demonstrated under controlled conditions that amnesic patients *can* learn new semantic information, even if slowly and laboriously in comparison with nonamnesic control subjects (e.g., Glisky & Schacter, 1988; Glisky, Schacter, & Tulving, 1986a, 1986b; Kovner, Mattis, & Goldmeier, 1983; Mattis & Kovner, 1984; McAndrews, Glisky, & Schacter, 1987; Schacter, Harbluk, & McLachlan, 1984; Shimamura & Squire, 1987, 1988). Thus, amnesic patients who cannot recollect the learning episode any more than they can recollect any other postmorbid personal happenings can nevertheless acquire new semantic knowledge. Our findings with K.C. fit well into this general pattern.

These facts contraindicate statements sometimes made to the effect that amnesia is a condition characterized by the impairment of "only one type of memory," declarative memory, which stores "facts and episodes" (Squire, Shimamura, & Amaral, 1989, pp. 212–213), and statements like "We favor the view that the defining feature of amnesia is an impairment in the ability to establish declarative memory, whereas the ability to establish procedural memory is preserved" (Shimamura & Squire, 1987, pp. 471–472). These statements reflect the fact that amnesics' performance on semantic learning tasks is decidedly subnormal: although they can learn new facts, they do so less effectively than do normal subjects. The inference drawn from this fact is that amnesics' semantic learning ability is subnormal, together with a further generalization that, as both semantic learning ability and the ability of episodic recollections are impaired in amnesics, amnesia consists of impairment of declarative memory.

Although these inferences appear to be quite straightforward and reasonable, they overlook the fact that semantic learning, even if slow in comparison with normal subjects, is possible in anterograde amnesia, whereas conscious recollection of any personal episodes, including the learning episodes, is not possible. The comparison between semantic learning and episodic recollection is one between some and none. What could such a dissociation—some versus none—mean? To pursue this matter, let us briefly examine two widely used concepts in neuropsychological studies of memory. One of these is "normal memory." The other one has no specific designation; for ease of reference I will label it as "codetermination of task performances by different systems," or simply "codetermination."

Normal Memory and Codetermination of Tasks

"Normal" memory in today's clinical neuropsychology is defined in terms of performance on a battery of psychometric tests or conventional laboratory experiments that conform to the study-test paradigm. Amnesic patients' performance on these measuring instruments is very poor in comparison with that of the normal standardization group, hence "subnormal." From the point of view of the systems approach, however, the concept of "normal" memory would be defined in terms of normal functioning of all memory systems and subsystems. The "normal memory" baseline of any brain-damaged person with impaired memory is defined by the same person's premorbid functioning. As this information is usually not available, "normal memory" usually refers to the levels of performance of people without brain damage who are comparable to the patient or patients in other intellectual respects. These "normal" subjects perform "normally" on memory tasks, because their various memory systems, some of which contribute to or codetermine such performance, are unimpaired.

One of the most fundamental assumptions of neuropsychology is that the carrying out of any cognitive task is complexly determined. In the systems

rientation, the assumption is that any cognitive task is codetermined by the operations of a number of different systems and subsystems. Impaired performance on a task by a brain-damaged individual, under otherwise *optimal processing* conditions of encoding, storage, and retrieval (Buschke, 1987), implies dysfunctioning of one or more of the relevant systems or subsystems. If a system is damaged, the person's performances on memory tasks suffer, commensurately with the extent of the damage to the system and the extent that the system normally contributes to, or codetermines, the performances in question. I refer to these ideas collectively as the *concept of codetermination.*

Codetermination helps us to interpret properly various kinds of findings resulting from comparisons of brain-damaged patients and normal subjects. If we know that a patient is amnesic and that episodic memory is dysfunctional, and we observe that the patient's short-term and perceptual priming performances in various tasks are normal, we can draw *two* closely interrelated conclusions: (a) the brain pathways necessary for episodic memory are not necessary for short-term memory and perceptual priming (mediation of performances by different systems), and (b) the intact episodic system of the normal subjects does not codetermine short-term and perceptual priming performances (independence of short-term and perceptual priming systems from episodic memory).

On the other hand, consider a situation in which we have good reasons to assume that (or in which in fact) two systems, M1 and M2, do codetermine the performance on a task. That performance will then be impaired in a patient suffering from damage to, or loss of, one of the systems, M1, in comparison with "normal" performance, even if the patient's other system, M2, functions normally. As an example consider the situation in which M1 and M2 are episodic and semantic memory, respectively, and the task is learning a list of unrelated paired associates. Assume that an amnesic patient's episodic system is dysfunctional whereas the semantic memory system is intact. Assume further that the learning of new associations is codetermined by both systems. If these assumptions are granted, then it follows that the amnesic patient will exhibit subnormal learning of paired associates despite the fact that the patient's semantic learning ability is preserved.

The logic of codetermination is simple and noncontroversial; it has been used (e.g., Cermak, 1986; Milner, Corkin, & Teuber, 1968) and explicitly discussed (e.g., Schacter, 1985; Schacter, Delaney, & Merikle, 1990) often enough in interpretations of outcomes of experiments comparing patient and subject populations. Yet the full implications of codetermination have sometimes been overlooked.

The concept of codetermination, applied to the results that have been obtained in experiments comparing amnesics and normal subjects learning new semantic information, including our recent findings with K.C. (Tulving et al., 1991), allows us to draw the following inference. Learning of new

semantic knowledge need not be impaired in amnesic patients even if their ability to acquire such knowledge appears to be subnormal; the superiority of normal subjects' performance on the semantic learning task may be partly or even wholly attributable to their intact episodic memory.

This conclusion or hypothesis, of course, is drastically different from the conclusion that amnesic semantic memory is impaired along with episodic memory, and that empirical facts from studies with amnesic patients do not throw any light on the distinction between episodic and semantic memory (e.g., Squire & Cohen, 1984; Squire, 1987; Squire et al., 1989). The hypothesis of partially or wholly preserved semantic memory in at least some amnesic patients may turn out to be wrong. It does, however, provide a viable logical alternative to the hypothesis that amnesia is an impairment of declarative memory, thus allowing comparative assessments of the validity of the two hypotheses in future research. It also provides an interesting demonstration of the close interaction between facts and ideas, a demonstration of how concepts must shape research in order to stay viable, and how they in turn must be shaped by the results of the research.

The hypothesis that semantic learning ability is preserved in some amnesics implies that these amnesics would perform normally in all semantic learning tasks in which normal subjects could not rely on their intact episodic memory. It is difficult to create such a situation. How can one make or instruct people not to remember something of which they are reminded by a cue? However, some indirectly relevant evidence has recently been reported by Dagenbach, Horst, and Carr (1990). These researchers found that previously unknown vocabulary words taught to university students showed no semantic priming effects when tested with very short intervals – stimulus onset asynchrony (short SOAs) – between primes and targets, although subjects were capable of fluently responding with the newly learned words to their synonyms as cues in paired-associate tests. Such semantic priming effects are simple to observe for pairs of words that are closely related in semantic memory (e.g., Meyer & Schvaneveldt, 1971; Neely, 1977), a finding once more confirmed by Dagenbach et al. (1990). The absence of similar effects with recently learned pairs of words therefore suggests that the integration of new associations between words into semantic memory requires many trials of practice even in normal subjects, and that the excellent recall of the associations in an explicit memory test may reflect the operations of the episodic memory system.

The matter will probably turn out to be more complex than the brief summary here suggests, but at least the hypothesis that the semantic memory system, in the absence of episodic memory, acquires information slowly is a novel one that is clearly worth pursuing. The clarification of the role that episodic and semantic systems play in learning of semantic information would add to our understanding of the nature of, and the relation between, the two systems.

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CONCLUSION

I have examined and discussed some ideas and concepts that figure prominently in contemporary research and study of human memory. Among the processing concepts, organized under the scheme of the GAPS, I concentrated on synergistic ecphory, the idea that the outcome of a single discrete act of memory is determined jointly by storage and retrieval processes, or by the interaction between the engram and the ecphory. The concept deserves attention because of its possibly far-reaching implications and consequences for the understanding of not only human memory but learning and memory in other species as well. One such consequence is the idea that storage and retrieval, or the engram and its ecphory, cannot be studied and characterized independently of one another.

Among the classificatory concepts, I discussed current ideas about memory systems, concentrating on perceptual priming, because of its novelty, and the distinction between episodic and semantic memory, because of the changes that these two concepts have undergone since their introduction. Perceptual priming is subserved by the PRS, an early system that operates on perceptual identification of objects, a vital prerequisite for an organism's interaction with its world. With respect to the distinction between episodic and semantic memory, recent work and thought have suggested that the two systems are interdependent in the sense that acquisition of episodic information depends on an intact semantic system, but that semantic information can be acquired even by people without functioning episodic systems. A recent study of new semantic learning in a densely amnesic subject, K.C., has reinforced other similar recent findings, and suggests that in some amnesic patients semantic memory is at least partially, or perhaps even wholly, preserved. The concept of codetermination of tasks by systems, when consistently applied to the findings from neuropsychological analyses of memory disorders, helps to clarify issues in classification of memory as well as issues in memory disorders.

It has been fashionable to declare that the ultimate objective of research on memory is the construction of a general theory of memory, or the working out of the chemical basis, or cellular basis, or neuroanatomical basis of memory. The theme of the discussion presented in this chapter has been that there is no such single *thing* as memory. Instead, there exist a number of different brain/behavior/cognition systems and processes that, through cooperation and interaction with one another, make it possible for their possessor to benefit from past experience and thereby promote survival. The known and as yet unknown memory systems deal with and operate on different aspects of the organism's environment, they function according to different principles, and they follow their own specialized laws of processing. To understand memory means to comprehend the structures and the underlying processes of this totality.

Notes

1. The concepts of engram and ecphory were originally proposed by Richard Semon, a German biologist, whose then unappreciated work anticipated many modern developments in memory research. For the story of Semon's life and contributions to the science of memory, see Schacter (1982) and Schacter, Eich, and Tulving (1978).

2. In experiments in which the target events can be reproduced with a high degree of fidelity, latencies (reaction times) of reproductive responses can also provide useful information.

3. In a popular task used to study perceptual priming, the lexical decision task, a string of letters is presented to the subject, and the objective is to determine, as rapidly as possible, whether the string represents a word or not. In this categorization task the determination of the string's identity constitutes just an intermediate stage. Perceptual priming was demonstrated early with this task (e.g., Scarborough, Cortese, & Scarborough, 1977).

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Memory: Organization and Locus of Change

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