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HUMAN LEARNING AND MEMORY

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CONTENTS

We consider four general topics in this review of recent work in human memory: the representation of knowledge, relations among memory measures, unconscious and nonstrategic processing, and constraints on acquisi-

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tion and remembering. In a final section, we also discuss examples of the expanded domains of research on human memory. Together, these research areas illustrate a number of important and interrelated themes and issues.

The issue of the relation between generic and specific knowledge appears in several contexts and remains a challenging theoretical question. Following earlier efforts to carve up memory into components, investigators continue to look for evidence of functional subsystems of memory. Findings from work on memory deficits have become central to this pursuit. Also important in this regard is the increasing variety of topics investigated. Each year, research in learning and memory comes closer to reflecting the wide range of functions that memory serves. Acquisition and forgetting are studied with direct measures of memory such as recall, recognition, frequency judgments, and source discrimination, as well as with indirect measures such as lexical decision, perceptual identification, and word completion tasks. Explaining the pattern of differences among these measures is currently a major concern. Research on such difficult topics as text processing, spatial cognition, affect and memory, and autobiographical memory also highlights the complexity and flexibility of memory. Memory theories are not likely to capture this complexity and flexibility fully in the near future but should do so sooner as a consequence of current efforts from these many directions.

THE REPRESENTATION OF KNOWLEDGE

This section provides an overview of work in four areas (lexical access, semantic decisions, concepts, and schemas) that grew from the assumption of a semantic system or generic knowledge with properties different from those of episodic memories (e.g. Tulving 1983). Recent work raises two major questions: (*a*) How abstracted is the representation of generic information, and (*b*) is there a context-free, relatively stable (transituational) set of relations among elements in a generic memory system? Substantial methodological or conceptual problems have also arisen in each area in recent years.

Lexical Access

An important subset of our knowledge is our understanding of words. Work on word recognition is directed at characterizing both the "lexicon," including the relations among its units, and the process by which a presented word makes contact with its representation. The literature is somewhat confusing because the term lexicon is used to refer sometimes to a set of entries specified by their orthographic, phonetic, or morphophonemic characteristics (Taft 1984), sometimes to a set of associative relations (e.g. Fodor 1983; Kintsch & Mross 1985), and sometimes to a set of more extensive semantic relations among lexical units (e.g. Kiger & Glass 1983; Seidenberg et al 1984). We focus here on studies of access to word meaning.

Researchers agree on the importance of three facts: (*a*) Relatively stable differences exist in availability among units—differences tied to frequency of occurrence in the language, or, more specifically, to the subject's experience (Gernsbacher 1984); (*b*) a recent presentation may temporarily increase a unit's availability by activating or priming it (repetition priming); and (*c*) a unit may be primed by the activation of related units (semantic priming). There is less agreement on how to characterize the lexicon on the basis of these findings (see the review by Simpson 1984).

The appropriate interpretation of both repetition and associative priming effects has been a focus of recent debate. One issue is whether repetition-priming effects come exclusively from activation of semantic memory or whether they reflect episodic traces as well (Feustel et al 1983; Salasoo et al 1985; J. C. Johnston et al 1985; Ratcliff et al 1985).

Another controversy surrounds the role of context in semantic priming. Does the occurrence of a word prime all its direct associates (e.g., Kintsch & Mross 1985; Oden & Spira 1983; Onifer & Swinney 1981; Whitney et al 1985) or only those that fit within the current semantic context (Glucksberg et al 1986)? According to the "modularity" hypothesis advanced by Fodor (1983), the lexical system is "encapsulated" and so should be immune to external influences; it is assumed that associative relations are in the lexicon and semantic ones are outside it. Thus, the issue is whether context effects come exclusively from within the lexical system itself (e.g. from associates) or can also come from other levels of language processing—e.g. syntactic constraints, or thematic levels of meaning (Glucksberg et al 1986; Kintsch & Mross 1985; Sanocki et al 1985; Seidenberg et al 1982; Stanovich & West 1983a,b; Tanenhaus & Donnenwerth-Nolan 1984; Wright & Garrett 1984). Interpreting results from such studies depends on whether or not one accepts the notion that associative and semantic relations differ in kind rather than in history.

Underlying much work on lexical access is the assumption that certain tasks (e.g. lexical decision, word naming, Stroop color naming) provide indexes of automatic activation processes within the lexical system that are uncontaminated by subjects' strategies or episodic memories. If this assumption (currently being challenged) is valid, the duration and spread of priming would give a picture of the organization of the lexicon. One problem is that tasks that should all reflect lexical access do not necessarily respond the same way to manipulations of the same variables. Word frequency has a large effect on lexical decisions and a negligible effect on a category verification task (Balota & Chumbley 1984), and it may or may not have an effect on naming, depending on whether words are presented alone or mixed with pseudo-words (Hudson & Bergman 1985); syntactic relations between words produce priming in the lexical decision task but not in the naming task (Seidenberg et al 1984); unassociated but semantically related words produce priming in a lexical decision task but not in the naming task (Huttenlocher & Kubicek 1983; Lupker 1984; but see Seidenberg et al 1984); increasing the proportion of related stimuli in a list increases the associative priming effect in lexical decisions (den Heyer et al 1983; Tweedy et al 1977; Tweedy & Lapinski 1981) but not in naming (Seidenberg et al 1984); and backward associations between the target and the prime affect lexical decisions but not naming (Kiger & Glass 1983; Seidenberg et al 1984).

A potential explanation of this complexity in patterns of findings is that some effects reflect the operation of postlexical, strategic factors that take time to emerge. One way to decrease strategic effects is to restrict the time available for processing the prime. The technique of varying the interval between the onset of the prime and the onset of the target (stimulus onset asynchrony, or SOA) is directed at discovering the relative roles of automatic (lexical access) and attention-demanding (postlexical) processes in context effects (de Groot 1984; den Heyer et al 1983; Onifer & Swinney 1981; Simpson & Burgess 1985; also see Seidenberg et al 1982). Lexical decisions that are made after very brief prime-target intervals (< 200 msec) may reflect automatic activation processes. Another way to reduce strategic effects is to use a methodology of masking the prime to eliminate conscious processing of possible relations between the prime and the target (de Groot 1983; Forster & Davis 1984; also see Henik et al 1983).

In any event, the most commonly used task, lexical decision, is so much more complicated than it first appeared that it might more appropriately be thought of as a complex decision task than as a simple lexical-access task (Hudson & Bergman 1985; Balota & Chumbley 1984; Chumbley & Balota 1984; Lupker 1984; Gordon 1985). As the lexical-decision task appears increasingly complex it becomes tempting to begin to rely on other, seemingly simpler tasks to explore lexical organization—e.g. naming, or perhaps perceptual identification. However, the more we use tasks the more we discover their complexity. In fact, there is already some evidence that naming, too, is not a pure index of lexical-access processes (Balota & Chumbley 1985).

Nor is it clear when the additive-factors logic (Sternberg 1969) is appropriate for isolating the stage (e.g. lexical access) at which a variable has an effect. The rationale for inferring that two variables interact when they affect the same process and do not interact when they affect different processes depends on assuming that the processes in question occur in a discrete serial order. If a later process can begin before a prior one ends (in cascade), then an interaction need not imply that two variables affect the same processes (McClelland 1979; Shoben 1982). Even assuming a stage model, the pattern of results (additive and interactive factors) across different experiments presents a more complex picture than was once assumed. For example, in lexical decisions, visual degradation interacts with semantic relatedness of primes (Becker & Killion 1977) and with stimulus repetitions (Norris 1984). According to additive-factors logic, if all three variables affect the same stage of processing, semantic relatedness and repetitions should interact as well; but they do not (den Heyer et al 1985). At the least, these results imply that one (or more) of these variables affects more than one stage of processing.

Semantic Decisions

If one assumes that semantic memory is a distinct system, it is reasonable to attempt to specify its structure and the processes that operate on that structure. Through the 1970s, the most influential models characterized semantic structure either as a network of nodes connected by labeled links specifying relations or as sets of features (see Chang 1986 for a review). These models helped to generate interest in the difficult problem of the representation of knowledge. However, reservations have been expressed about both the methodology and the underlying conceptualization of semantic memory that guides much of the work in this area (Kintsch 1980; Johnson-Laird et al 1984; Shoben 1982).

Several problems arise from the inherently correlational nature of the designs used to investigate semantic decisions, such as verifying the statement that *A robin is a bird*. For example, the controversy over which factor determines response time (i.e. category size, nesting relationship, semantic similarity between exemplar and category, or familiarity) is unresolved because it is impossible to control all relevant aspects of natural language stimuli except the one of immediate interest (Shoben 1982; also see Chumbley 1986). Furthermore, as Shoben notes, researchers cannot agree on what must be controlled (but see Chang 1986).

Investigations of semantic memory rely heavily on response time as a direct measure of the duration of mental processes. There are drawbacks in this practice. Because a subject's speed-vs-accuracy criterion may vary from item to item or with experimental conditions, response latency may not only be an unsatisfactory measure of absolute duration of a mental processes, it may give an inaccurate picture of the relative duration of mental processes engaged by two conditions or tasks. A response-signal, speed-accuracy tradeoff method might solve this problem (Dosher 1984a; Pachella et al 1978; Ratcliff & McKoon 1982; Reed 1973; Wickelgren 1977). The function relating accuracy (e.g. d') to amount of processing time before a signal to respond should yield a picture of the continuously accruing information necessary for a task. Like variations in prime-target interval (SOA) used in lexical access research, the response-signal method can be used to explore potential differences between early and late components in activation and/or decision making. Although the prospect of being able to track the revival of a memory is exciting, speed-accuracy functions do not yield unambiguous information (Meyer & Irwin 1981; Wickelgren 1977), and Meyer & Irwin's (1981) further modification of the speed-accuracy trade-off technique ("speed-accuracy decomposition") may prove useful.

Work on semantic decisions has been criticized on conceptual grounds as well (Johnson-Laird et al 1984). Johnson-Laird et al point out that semantic networks (and feature-set theories) are largely concerned with the relations among words (intentional relations) rather than with the relations between words and their referents (extensional relations). Disambiguation cannot be explained solely by selection restrictions operating within a sentence: for example, in "He planted them on the island," disambiguating "them" requires information that is outside the sentence. As Johnson-Laird et al also point out, it is inconceivable that all potential relations (e.g. tomatoes are more squashable than potatoes, except if potatoes are cooked and mashed and tomatoes are frozen solid) are represented within a network of labeled links.

Semantic networks were initially compelling ways to represent knowledge because they provided a mechanism for inference generation. Even if never told that canaries breathe, we can deduce the fact by traversing links in the network—canaries are birds, birds are animals, animals breathe; therefore, canaries breathe. The traversal of links is a formal mechanism that does not need to "know" what any of the words refer to. But, if we are talking about ceramic canaries, then canaries do not breathe. Thus, an inferential system needs to know what is being referred to in order to make appropriate inferences.

Concepts

In the 1970s, new views about abstraction processes involved in category representation helped to stimulate interest in semantic memory. According to such views, processes of feature averaging or feature counting result in the abstraction of typical characteristics of category exemplars; these are represented as a schema or prototype (Medin & Smith 1984; Mervis & Rosch 1981; Smith & Medin 1981). Current alternatives to the abstractionist approach emphasize the importance of specific event information (exemplars) for categorical information (Brooks 1978; Jacoby & Brooks 1984; Hintzman 1986; Medin & Schaffer 1978). At issue here is whether abstract concepts are directly represented in memory (associated as well with some corresponding loss of information for individual events) or whether abstract knowledge is derived when needed from memory representations of unique events. If the latter, there may be no need to postulate a semantic storage system separate from an episodic storage system.

In exemplar models, classification is based on the retrieval of information about exemplars in memory. Category judgments are made by analogy to a similar known exemplar or are based on a number of exemplars weighted according to their similarity to the stimulus. For example, in Hintzman's (1986) theory, each event, represented as a feature list, is copied into memory. Similarity of any two events is determined by the number of features they have in common. When a probe event occurs, each trace in memory is activated, in parallel, by an amount related to its similarity to the probe. The activated traces, in concert, create an "echo." The intensity of the echo, related to the total amount of activation to the probe event, can be used as a discriminative cue for recognition (cf Gillund & Shiffrin 1984) or frequency judgments. The content of the echo can be used to categorize the probe. Hintzman uses a series of computer simulations to demonstrate that a number of phenomena usually taken as support for schema-abstraction can be accounted for by a multiple-trace exemplar theory. Hintzman's paper is a particularly readable example of the growing trend toward evaluating a theory by computer simulation.

A related development is the increasing popularity of distributed-memory models (Knapp & Anderson 1984; McClelland & Rumelhart 1985; also see Eich 1982, 1985; Murdock 1982, 1983; Pike 1984; and chapters in Hinton & Anderson 1981). As in Hintzman's model, the Knapp & Anderson and McClelland & Rumelhart models do not require a separate semantic memory. In distributed-memory models, traces consist of patterns of excitation across units representing features in memory. A given event (pattern of activation) changes the strength of the connections among units which co-occur. Because a particular unit may be involved in many events, the memory for an event does not have a location, or separate existence, but is distributed across feature units. Retrieval is the partial reinstatement of a pattern of activation, using a cue that is a fragment of the original pattern of activation. Concepts or prototype-like patterns develop through the "superimposition" of many similar activation patterns during acquisition: The resulting change in values of connections between units creates a composite trace that functions like an abstraction. These models are similar in many ways to Hintzman's, but the abstraction takes place at retrieval in Hintzman's model and at storage in McClelland & Rumelhart's.

Distributed-memory models represent a sort of middle-ground between prototype theories and Hintzman's multiple-trace theory in that some exemplar information is preserved and recoverable (with sufficiently specific cues). Some information is simply lost ("washed out") in the creation of the composite trace. Both distributed-memory and exemplar models account for the flexibility of meaning that characterizes human behavior by making context part of the probe that determines which traces (or patterns of units) are activated. This flexibility of meaning is harder to capture in a fixed-network or feature-list representation of semantic structure. It is presumably gained at some cost in processing efficiency compared to models in which abstractions are directly represented.

Similarity is a problem at the center of exemplar and distributed-memory (and other) models. A probe activates traces with the same features or one event activates some of the same "units" as another; hence similarity is a function of the number of features or units events have in common. What are these features or units? In both experiments and simulations, similarity is made tractable by using artificial stimuli such as dot patterns or feature lists where each feature has a binary value. This is a reasonable strategy for concretizing certain ideas (such as the echo) or demonstrating the viability of certain general approaches (such as a system without semantic memory). The success of these theories as psychological models will depend on whether they can successfully be applied to memory for natural, complex events.

The sufficiency of similarity for holding together the members of a category is questioned in a recent paper by Murphy & Medin (1985). They point out that similarity depends largely on what is assumed to be a relevant attribute (Tversky 1977) and that this in turn is determined by people's interests, needs, and goals. Thus, things seem similar because a person has a theory that relates them. Murphy & Medin's (1985) ideas here resemble those of other investigators (e.g. Bransford & Johnson 1973, Clark & Gerrig 1983, Johnson-Laird 1983; van Dijk & Kintsch 1983) who emphasize the importance of whether subjects are able to build sensible stories out of the elements of their experience.

Murphy & Medin emphasize another (and possibly prior) problem for determining similarity based on feature overlap. Because we do not know what to count as a feature, attribute, or property in the first place, we cannot define the variables that should enter into the analysis or computation of similarity. In judging the similarity between plums and lawn mowers, what attributes are relevant? Both weigh less than 10,000 kg, cannot hear, can be dropped, take up space, etc.) Models that are based entirely on attribute matching usually do not deal in any detail with the problem of what counts as an attribute (but see Nelson 1984).

Schemas and Scripts

Schema theory is another example of the ongoing tension in cognitive psychology between the specific and the general. Schema-based theories emphasize the general, typically proposing that memory for a particular event is guided at encoding and retrieval by organized clusters of generic knowledge relevant to the immediate situation. In some schematic views, any particular episode will leave little mark on memory except for its theme, a few salient and/or atypical details, and the activation of the generic schema (see Alba & Hasher 1983; Brewer & Nakamura 1984; Thorndyke 1984, for reviews).

One line of work in prose memory suggests that subjects abstract meaning from the flow of verbal information and store only a general representation of that meaning (Alba & Hasher 1983). However, there is now increasing evidence that such surface-structure details as syntax, lexical items, and orthography are not necessarily lost to memory (e.g. Kolers & Roediger 1984; Levelt & Kelter 1982; Masson 1984; but see Brewer & Hay 1984) and that memory for thematic and specific information depends on type of initial processing (Hunt et al 1986). Furthermore, a full picture of memory for prose cannot be had by simply using a recall test; variables that influence recall may not influence recognition (Kintsch & Young 1984). Indeed, performance on recall and recognition tasks, even in combination, may not provide a complete picture of the representations that result from encoding processes (see Locksley et al 1984). For such a picture, especially for one that eliminates strategic components, as Seifert et al (1986) argue, speeded decisions may also be required.

Script theory (Schank & Abelson 1977) is a particularly popular variant of schema theory that asserts the existence of highly structured underlying representations of familiar events (e.g. eating in a restaurant). It continues to stimulate research (Barsalou & Sewell 1985; Abbott et al 1985), and modifications of the original theory have been proposed and explored (e.g. Graesser & Nakamura 1982; Nakamura et al 1985; Schank 1982). It now seems unlikely that an entire scripted representation is activated whenever a script is relevant (Walker & Yekovich 1984), and subjects may fail to spontaneously recognize the thematic similarities across stories (Seifert et al 1986; see also Spencer & Weisberg 1986). Also, the presumably invariant underlying units can be altered by changes in such surface-structure details as punctuation in passages that activate scripts (Mandler & Murphy 1983). Prior knowledge even for such highly familiar categories of experience as scripted activities may be a good deal more flexible in its application to new events (Abbott et al 1985) than was once believed. Schema theory is adapting to such findings by placing more emphasis on specific-event memory as well as on higher-order organizing structures that help create scripts as needed out of lower-order components or "scenes" (e.g. Schank 1982). Other issues that were especially important for schema theories, e.g. inferences, have become active research areas and are described below.

The Episodic-Semantic Distinction Reconsidered

Recent attempts to test directly the proposition that episodic and semantic memories represent isolable systems (e.g. Dosher 1984b; McKoon et al 1985; Neely & Durgunoglu 1985; also see Watkins & Kerkar 1985) have largely not supported the distinction. Criticisms of the semantic-episodic distinction can be found in the commentaries in *Behavioral and Brain Sciences* (Tulving

1984) on Tulving's recent book (1983), in McKoon et al (1986), and in Ratcliff & McKoon (1986). To address some of these issues, Tulving (1984, 1985a,b) has proposed a modified framework in which episodic memory is a subsystem of semantic memory (also see Tulving 1986).

Conclusions

Studies of lexical access, semantic decisions, schemas and scripts, and concepts have independently generated many important facts. Unfortunately, these results have not converged to yield a common picture of semantic memory, except of the most general sort. The solution may be more sophisticated paradigms (e.g. speed-accuracy decomposition) or more careful controls over processes operating in particular tasks (e.g. Glucksberg et al 1986). Another possibility is that the format in which generic knowledge is represented varies with particular knowledge domains; if so, we should not expect a unified solution to the problem of the representation of and access to generic information.

Semantic networks may characterize a subset of basic knowledge, but networks (like associations) are still much too limited to account for the range of cognitive functions that knowledge serves. If there is a theoretical role for a stable semantic structure that is separate from the representation of events, we need to specify how the elements (e.g. entries in a lexicon, nodes in a semantic network) of this structure are acquired and how they articulate with new events. On the other hand, there simply may be limitations upon what we can learn about the representation of knowledge by starting with the pretheoretical assumption of a separate semantic system. Distributed-memory and exemplar models provide an alternative approach. Ultimately, the value of these models will depend on whether they contribute to uncovering new facts or organizing a larger body of data than previous models. In this regard, it is encouraging that both exemplar models (e.g. Jacoby & Brooks 1984; Hintzman 1986) and distributed-memory models (e.g. McClelland & Rummelhart 1985), like earlier abstraction models, reach beyond categorization data to the domains of memory and perception for support, and that they, in turn, are useful to efforts to analyze other psychological phenomena such as surprise and social judgments (Kahneman & Miller 1986).

The idea that there is a single separate generic memory system and the idea that there is no generic memory are two extremes of a continuum. Characteristics of conceptual knowledge may vary with age of subject (e.g. Nelson 1984) or stage of learning. It is also possible that some types of knowledge may be better characterized in terms of abstractions (or symbols) and other types in terms of exemplars (or distributed connections among elements). Alternatively, task and situation demands may influence the particular type of representation that is generated and/or selected. Increased interest in mixed prototype and exemplar models (Busemeyer et al 1984; Fried & Holyoak 1984; Homa et al 1981; Lingle et al 1984; Medin et al 1984; Nakamura 1985) and in ad hoc or goal-defined categories (Barsalou 1983, 1985) reflects a growing recognition of such possibilities.

RELATIONS AMONG MEMORY MEASURES

How the relationships among different memory tasks should be characterized is currently a central question. Do various tasks tap different memory systems, draw on different aspects of the same trace, and/or represent different combinations of various processes?

Direct vs Indirect Measures

Striking differences have been reported recently between direct and indirect measures of the memory performance of both normal and amnesic subjects. *Direct* memory tasks (free recall, cued recall, recognition) require conscious expressions of remembering; *indirect* memory tasks (e.g. perceptual identification, homophone spelling, word completion, skill learning) do not. An illustrative example and a surprising new finding is Cohen's (1984) report of normal learning of the Tower of Hanoi problem by amnesics who fail to remember having seen the materials before. There is also some evidence that the pattern may be reversed; Martone et al (1984) found that patients with Huntington's disease were disrupted in acquiring the skill of mirror-reading, but not in recognition of repeated items.

Considerable effort has been focused on indirect measures in verbal tasks. Subjects who have recently been exposed to a word are more likely than under control conditions (*a*) to identify it when its presentation is degraded, (*b*) to produce it when asked to complete a word from partial letter cues (e.g. def-?), and (*c*) to have their spelling of a homophone influenced by the prior context in which the word was presented aloud (e.g. taxi *fare*). It is especially noteworthy that subjects may show "memory" for items on indirect tasks that is uncorrelated with their ability to recall or recognize the same items (Eich 1984; Graf et al 1982; Jacoby & Dallas 1981; Jacoby & Witherspoon 1982; Tulving et al 1982). In addition, decrements in performance as a consequence of alcohol ingestion (Hashtroudi et al 1984), aging (Light et al 1986), or posthypnotic amnesia (Kihlstrom 1985) occur on direct tests even though intoxicated, older, or previously hypnotized subjects may perform normally on indirect tests. Finally, whereas direct measures of memory are likely to be influenced by meaningful vs nonmeaningful orienting tasks, indirect measures are less subject to orienting task effects (Graf et al 1982; Graf & Mandler 1984; Jacoby & Dallas 1981; but see Graf & Schacter 1985 for results indicating that orienting tasks may influence whether context effects are observed in word-completion tests).

The view that there is a fundamental difference between memorial information assessed by direct and indirect tasks receives further support from research with amnesics. In perceptual-identification and word-completion tasks, amnesics show prior-exposure effects that are comparable to controls', even though their recognition, cued recall, or free recall of the same words may be disrupted (Graf et al 1984; Graf et al 1985; Jacoby & Witherspoon 1982; Squire et al 1985). Positive effects of prior exposure on indirect tasks is not limited to single words; pre-experimental associations between words (e.g. idioms such as *small potatoes*, or associates such as *stove–hot*) also benefit from prior exposure (Schacter 1985; Shimamura & Squire 1984).

One explanation for exposure effects is that presentation of a word temporarily activates an abstract lexical or semantic representation of that word (or other pre-experimental unit), making recently exposed items more accessible. Consistent with this is the finding that amnesics do not show an exposure effect in a perceptual-identification task for pseudowords, items for which there are presumably no lexical entries (Cermak et al 1985). However, several facts argue against the idea of temporary activation of a lexical entry as the only source of exposure effects: For normals, the benefit from prior exposure lasts from under two hours to seven days, depending on the task (Graf et al 1984; Jacoby 1983a; Shimamura & Squire 1984; Tulving et al 1982; Jacoby & Dallas 1981). The longevity of the effect might be explained by assuming that, in addition to experiencing lexical priming, normals engage in conscious recall in these tasks. However, amnesics, who presumably fail at conscious recall, also show benefits from prior exposure that last between ten minutes and two hours (Shimamura & Squire 1984), which is beyond the presumed duration of the temporary and purely lexical activation component of repetition or associative priming (Forster & Davis 1984; Ratcliff et al 1985). More important, amnesics can learn new associations between unrelated words, given an indirect test of what they have learned [(Graf & Schacter 1985; Moscovitch et al 1986); it is possible that only patients with milder forms of amnesia learn new associations (Schacter 1985)]. That amnesics learn new associations, and that their disruption on direct tasks is not uniform [recall is more disrupted than is recognition (Hirst et al 1986)], argues against characterizing amnesia in terms of disrupted episodic (Tulving 1983) or declarative (Cohen 1984) memory. The broader impact of these findings on theoretical approaches to memory is discussed below.

Recognition

Following earlier efforts to distinguish the mechanisms of recognition from those of recall, investigators continue to search for ways to characterize this seemingly simple task. Understanding recognition will certainly fit a major piece into the puzzle of the relations among memory tasks. Various suggestions are currently under consideration. Tulving (1982, 1983) has proposed that recognition and recall include the same type of "ecphoric" process but can be distinguished in the amount of "ecphoric information" required for the task. Two-process approaches to recognition remain influential (e.g. Atkinson & Juola 1973; Mandler 1980; Jacoby & Dallas 1981; W. A. Johnston et al 1985). In these theories it is assumed that a rapid, direct-access familiarity response (based on trace strength, perceptual integration, or perceptual fluency, depending on the model) is separate from a slower recall or search process based on associative or elaborative processing. Gillund & Shiffrin (1984) suggest that the search factor in two-process theories may have been overemphasized. They propose that familiarity responses underlying recognition are affected by the strength of inter-item associative relations and associations between items and context (cf Anderson & Bower 1972, 1974). In effect, they propose that the activation level of an item is determined by the amount of simultaneous activation of episodic traces (which Gillund & Shiffrin call "images"), a suggestion similar to Hintzman's (1986) that recognition is based on "echo" intensity.

Subsystems of Memory?

The patterns of relations among memory measures, along with the performance of amnesics, have been instrumental in the development of recent approaches to human memory which are organized around the idea of separable, functional subsystems. These are components of memory that deal with different types of information or involve different processes, are mediated by different underlying neural mechanisms, and may have different evolutionary histories (e.g. Cohen 1984; Johnson 1983; Squire 1982; Squire & Cohen 1984; Tulving 1985a; Warrington & Weiskrantz 1982; also see chapters in Cermak 1982). Animal-memory researchers have made similar suggestions (Olton et al 1979; Mishkin et al 1984; O'Keefe & Nadel 1978; and see chapters in Squire & Butters 1984; Lynch et al 1984).

A critical issue here is determining the criteria for inferring subsystems. Is it sufficient that two tasks respond differently to the same variable or does valid inference require stochastic independence on the same items tested differently (e.g. Hintzman 1980; Tulving 1985a)? A related question is how dissociations between two tasks should be interpreted if the tasks are presumed to tap the same system or subsystem (e.g. Roediger 1984). Although dissociations between tasks are often interpreted as evidence that task A engages one subsystem and task B engages another (e.g. Cohen 1984), dissociations might also be interpreted as evidence that task A engages processes from two or more subsystems and task B engages a somewhat different combination of processes from the same subsystems (e.g. Johnson 1983). Arguments against the need to infer subsystems have been made; such approaches emphasize the importance of task demands (e.g. Jacoby 1983b; Moscovitch 1984; Moscovitch et al 1986; Roediger & Blaxton 1986). At the least, we will have a better understanding of memory once we have understood the relations among various memory tasks. Characterizing task demands is clearly a first step, whether or not it is motivated by the belief that task demands and, hence, processes may eventually be grouped into classes according to the subsystems they draw upon.

UNCONSCIOUS AND NONSTRATEGIC PROCESSING

A growing interest in nonconscious cognitive processes can be seen in research in perception, attention, social cognition, and memory. In the field of learning and memory, one manifestation of this trend has been a switch in research emphasis from voluntary, strategic mental activities (e.g. organization, mnemonics, elaborative processing) to less effortful, involuntary, automatic, and even unaware or unconscious processes. Generally speaking, two questions have been asked: Are there long-term effects of unconscious processing of stimuli? What do people learn without strategic effort?

Effects of Unconscious Processing

The intriguing question of whether unconscious stimuli influence thought and behavior surfaces periodically in psychology (e.g., Dixon 1971; Erdelyi 1984, 1985; Kihlstrom 1984). Dramatic demonstrations of meaningful processing of unconscious stimuli have been reported (Marcel 1983; Fowler et al 1981; McCauley et al 1980). Lexical decisions concerning suprathreshold words are facilitated by prior exposure of the subject to related, masked subthreshold words. While the results of Marcel (1983) and Fowler et al (1981) may be startling in their implications about how much processing can be initiated by minimal perceptual stimuli, the idea that much perceptual processing proceeds without awareness has long been well accepted.

Do such unconsciously experienced stimuli produce effects that last more than a few seconds? If so, the effects do not appear to be tapped by direct tests of memory (recall, recognition). In contrast, indirect tests do seem to reveal long-lasting consequences of unconscious processing. For example, Eich (1984) found that subjects' spelling of homophones was consistent with an interpretation previously implied in the unattended ear while subjects followed (shadowed) speech in the other ear, even though subjects did not show reliable recognition of the homophones. Consistent with this are recent replications of earlier reports by Kunst-Wilson & Zajonc (1980) showing that exposure durations (2–8 msec) too brief to produce above-chance recognition increase preferences for visual stimuli (Seamon et al 1983, 1984; though see Mandler & Sheebo 1983). Similarly, Lewicki (1986a) reported that subjects can learn to use stimuli they cannot consciously identify to guide visual search.

Memory Without Strategic Processing

Investigators have also been interested in the fate of stimuli that are consciously perceived but not accorded elaborative, effortful, or strategic processing. Early statements of the levels-of-processing framework (Craik & Lockhart 1972) implied that non-elaborative "maintenance" rehearsal should keep information temporarily active without producing long-term memory traces. It is now relatively clear that incidental rote rehearsal of words promotes long-term recognition memory (Glenberg & Adams 1978; Glenberg et al 1977; Naveh-Benjamin & Jonides 1984a,b).

Another illustration of interest in nonstrategic learning is the Hasher & Zacks (1979, 1984) proposal concerning the automatic encoding of such fundamental information as the frequency with which events occur. According to this view, automatic processes code some attributes of consciously experienced stimuli whether or not the person is trying to code that attribute. By definition, automatic processes do not get better with practice or feedback, do not show individual differences or age differences, and are not disrupted by stress or other simultaneous processing demands. Hasher & Zacks (1979, 1984; Hasher et al 1986) showed that frequency judgments are remarkably stable across a range of such variables. These claims have not gone unchallenged. One alternative interpretation of the absence of developmental trends and of improvement with practice is that necessary skills are acquired rapidly; another is that subjects find it difficult to discover test-appropriate strategies (Postman 1982). Furthermore, frequency judgments may vary as a function of age (Kausler et al 1984; Warren & Mitchell 1980), incidental vs intentional instructions (Greene 1984; Williams & Durso 1986), and with competing demands (Fisk & Schneider 1984; Naveh-Benjamin & Jonides 1986). Although the automaticity issue is unresolved, the data show that subjects are sensitive to differences in frequency of occurrence. This sensitivity can be used by people to acquire knowledge of their environment (Hasher & Zacks 1984) and can be exploited by investigators to answer questions about a range of human abilities (Hock et al 1986; Marshall et al 1986).

It has also been proposed that many of the complex rules underlying perception, language, and social conventions are learned nonstrategically. Having studied of the acquisition of artificial grammars, Reber and colleagues (e.g. Reber 1976; Reber et al 1980; also see Broadbent et al 1986; McAndrews & Moscovitch 1985) emphasized the importance of implicit learning. When stimuli are complex and the patterns of invariance in stimuli are not obvious, subjects may acquire a better abstract representation of the structure of a language if they do not consciously try to discover rules. Recently, Carlson & Dulany (1985; Dulany et al 1985) argued against the idea of implicit learning and suggested that subjects consciously learn informal grammars: these are not equivalent to the formal grammars that generated the language items but nevertheless provide a basis for making judgments about the appropriateness of new items. Along with Anderson (1983a), Carlson & Dulany emphasize that once-conscious knowledge can become automatic with practice, but this phenomenon does not mean that the original learning was unconscious (see reply by Reber et al 1985; also see Lewicki 1986b). Whether this alternative characterization of a conscious-to-automatic transition in knowledge is appropriate for the wide range of apparently implicitly learned rules (e.g. natural grammars, social conventions) is not clear.

Some of the controversies in this general area stem from the fact that terms such as consciousness, awareness, effort, attention, capacity, resource, and controlled processes are not used consistently. There is some consensus that automatic processes are involuntary, do not draw on general resources, are not interfered with by attended activities, and do not interfere with attended activities or with other automatic processes (Kahneman & Treisman 1984; but see Shiffrin 1986; Navon 1984; Hirst 1986). The relation between automatic processes and consciousness is less clear. In spite of these definitional and conceptual problems, the general issue of what type of initial processing is necessary for what type of memory test provides a productive focus for future research.

CONSTRAINTS ON ACQUISITION AND REMEMBERING

In this next section we focus particularly on limitations upon inferences made during initial processing and limitations produced by mechanisms of forgetting.

Text Processing

WORKING MEMORY Working memory can be conceived of as a limited resource system that allocates capacity between two major components, a central executive responsible for the processing of ongoing information and a buffer that briefly maintains information (Baddeley & Hitch 1974; Baddeley 1981, 1983; Hitch 1980). This view seems to meet the requirements of discourse processing, which is widely believed to require ongoing analysis (e.g. pattern recognition, word identification, sentence parsing, and so on) as well as integration of the products of this analysis with preceding text information and with general knowledge. Both sources of information are thought of as being held in a state of heightened accessibility by the buffer component of working memory. Thus it is not surprising that many views of text processing (e.g. Aaronson & Ferres 1984; Ackerman 1984; Bock & Brewer 1985; Spilich 1983; van Dijk & Kintsch 1983; also see Glanzer et al 1984) have at their core the assumption of a limited-capacity working-memory system.

The view that working-memory capacity constraints text processing is strengthened by the development of a measure that assesses the joint operation of storage and processing components of working memory (Daneman & Carpenter 1980; see also Daneman & Green 1986). Strong correlations exist between this measure and performance on text processing and memory tasks (Baddeley et al 1985; Daneman & Carpenter 1980, 1983; Daneman & Green 1986; Masson & Miller 1983; although see Light & Anderson 1985).

Constraints related to working-memory capacity [or efficient utilization of that capacity (Case et al 1982)] have also been invoked by investigators interested in cognitive development across the lifespan (Brainerd 1983b; Smith et al 1983; Wingfield & Butterworth 1984; Zacks & Hasher 1986). Verbal ability—which may be associated with variations in capacity—makes a major contribution to age differences in prose memory (Dixon et al 1984; Hultsch & Dixon 1984; Mandel & Johnson 1984), as do processing demands made at the time of testing (Reder et al 1986).

INFERENCES: TAXONOMY AND MEASUREMENT Since few texts make all necessary information explicit, another set of constraints on text processing—at least for comprehension—involves the capability of forming inferences. Insofar as inferences require that previously acquired information (whether from the text or elsewhere) be available for integration with text information, working-memory capacity has a role to play.

Research on working-memory constraints on inference generation joins with other work to reveal that making inferences is not nearly so reliable as 1970s schema theories supposed (see Barclay et al 1984; Corbett & Dosher 1978; Singer 1981, Singer & Ferreira 1983). Such findings helped to trigger an intense examination of inference making by memory psychologists who joined in pursuit of this issue with others interested in reading comprehension and language processes.

Consensus has not yet been reached on how to categorize inferences (see, e.g., McKoon & Ratcliff 1986; Seifert et al 1985; Singer & Ferreira 1983). Nor do researchers agree about which measure (or combination of measures) is best for detecting the formation of an inference and determining when it was made. One set of procedures tests for the existence of inferences after subjects read a text. Such measures assess the rate of false recognition of implicit information (Seifert et al 1985); the usefulness of an inferred word as a retrieval cue (McKoon & Ratcliff 1986); the accuracy and speed with which subjects answer questions (Singer & Ferreira 1983); and most recently, speeded item recognition comparing primed with unprimed targets (Guindon & Kintsch 1984; McKoon & Ratcliff 1986).

Other procedures test for the formation of an inference during reading. These procedures include such measures as word-by-word or sentence-by-sentence reading or comprehension times (Corbett 1984; Haberlandt & Graesser 1985; Lorch et al 1985; Murphy 1984) and detection of spelling errors during reading (Garrod & Sanford 1985). As well, speeded recognition tasks have been embedded in ongoing reading tasks (Dell et al 1983). A consensus seems to be emerging that multiple measures are required for a complete picture (e.g. Keenan et al 1984; O'Brien & Myers 1985).

Inference making is not an obligatory consequence of text comprehension processes. A number of task variables affect the probability of drawing an inference—e.g. backward vs forward referents (Singer & Ferreira 1983), the distance between a referent and its antecedent (Murphy 1984), the degree of causal relation between events (Keenan et al 1984), and the likelihood that information is in working memory (Malt 1985). Subject variables such as expertise (Arkes & Freedman 1984), age, and verbal ability (Hultsch & Dixon 1984) are also implicated. Whether or not constraints on working-memory capacity alone can accommodate these findings remains to be seen.

MORE THAN ONE TEXT REPRESENTATION? One framework for describing discourse comprehension and memory (van Dijk & Kintsch 1983) proposes that two independent representations of a text are formed: (*a*) a text memory that includes both specific detailed text-level information and summary information; and (*b*) a situation model that integrates information from the text with existing world knowledge. This view is similar to Johnson-Laird's (1983) proposal that subjects create a mental model in addition to a representation close to the perceptual experience. In addition, Anderson (1983a) has added two types of memory representations—temporal strings and spatial images—to his model, a departure from his previous proposal that information is represented only in terms of abstract propositions. Again, we see the trend to posit multiple records of experience and, especially, to represent specific information in memory theories. By contrast with some characterizations of text representation, such models distinguish text-presented information from subject-generated information at least some of the time. They raise the issue of the functions of multiple representations and the conditions under which one representation might be mistaken for another ["reality monitoring" errors (Johnson & Raye 1981)].

Remembering

SOURCE DISCRIMINATION Confusion between inferred and stated information in text-processing studies is an example of the more general problem of source discrimination in remembering. People confuse self-generated information with perceived information, thoughts with actions, and information from one external source with that from another (Anderson 1984; Johnson & Foley 1984; Johnson et al 1984). Individual differences in source confusion are a function of age (Foley & Johnson 1985; Mitchell et al 1986; but see Kausler et al 1985), expertise (Arkes & Freedman 1984), personality (Durso et al 1985), clinical diagnosis (Harvey 1985), and memory disorder (Schacter et al 1984). Furthermore, source discrimination and recall or recognition may draw on different aspects of memories (Anderson 1984; Johnson & Raye 1981).

OVERWRITING According to one view of memory, new, inconsistent information will replace originally stored information—an Affect called overwriting (Loftus & Loftus 1980). In keeping with earlier research on the interference theory of forgetting (Postman & Underwood 1973), recent evidence suggests that rather than replacing original information, new, contradictory information can coexist in memory with original information (Alba 1984; Bekerian & Bowers 1983; Christiaansen & Ochalek 1983; Morton et al 1985; Pirolli & Mitterer 1984; Shaughnessy & Mand 1982). Other evidence suggests that the procedures used to demonstrate overwriting (e.g. Loftus et al 1978) may be missing a critical control (McCloskey & Zaragoza 1985). An alternative account of memory errors produced by misleading information can be framed in terms of source confusion (Lindsay & Johnson 1986); subjects may misattribute information from one source to another. The determination of the circumstances in which either overwriting or source confusion occurs is critical not only for theoretical models of forgetting, but also for such applied issues as the validity of eyewitness testimony (Loftus 1979; see also McCloskey & Egeth 1983) and decision making (Fischhoff 1977).

INTERFERENCE One consequence of the coexistence in memory of two or more sources of highly related information is an increase in the difficulty of remembering either (McGeoch 1942). This can be seen throughout the earlier literature on interference theories of forgetting and in recent demonstrations that similarity in meaning (Dempster 1985; Underwood 1983b), in input modalities (Glenberg 1984), and within the acoustic modality (Underwood 1983a) all disrupt retrieval. Parallel findings may be seen in the fan effect (e.g. Pirolli & Anderson 1985), where retrieval difficulty is indexed by an increase in time to recognize list items (see Nelson et al 1985). Work on the fan effect is guided by Anderson's model of spreading activation, the most recent version of which, ACT* (1983a,b), predicts a variety of important memory effects such as those related to distribution of practice, learning to learn, and interference. Furthermore, the potency of interference is demonstrated by evidence that some interference effects may not be eliminated even with substantial practice (Pirolli & Anderson 1985). By contrast with the strong evidence that multiple responses to the same cue disrupt memory, evidence continues to be weak (Postman & Knecht 1983; Toppino & Gracen 1985) for the widespread belief that multiple cues for the same response facilitate retrieval.

CHANGES IN CONTEXT There have been several recent experiments on context changes and retention (Dolinsky & Zabrucky 1983; Eich 1986; Fernandez & Glenberg 1985; Saufley et al 1985; Smith 1982; also see Riccio et al 1984). By contrast with the well-established effects of meaning-based stimulus change, environmental changes in context appear to have a smaller effect on performance than might have been assumed (Fernandez & Glenberg 1985; Saufley et al 1985). Eich (1986) found that unless to-be-remembered items had been actively related to elements of the environmental context, change in environmental context between acquisition and a recall test had little effect. Underwood (1983b), too, has recently questioned the relative importance of contextual cues. Eich proposed that the underlying mechanism for apparent environmental context effects may be changes in internal state associated with different contexts. Although this is an interesting possibility, changes in at least one internal state, mood, may have limited effects on retrieval (see below).

EXPANDED RESEARCH DOMAINS

Learning and memory researchers are tackling an ever-wider range of problems—e.g. comprehension of and memory for metaphor (Gerrig & Healy 1983; Gildea & Glucksberg 1983; Marschark & Hunt 1985), creativity (Weisberg 1986), acquisition of skills or "procedural knowledge" (Anderson 1983a; Kolers & Roediger 1984; Ross 1984), educational (Glaser 1984; Lesgold 1984) and therapeutic applications (Wilson & Moffat 1984), developmental aspects of eyewitness testimony (Ceci et al 1986; Goodman 1984), decision making (Busemeyer 1985; Hoch 1984), metamemory (Bransford et al 1982; Lovelace 1984; Maki & Berry 1984; Metcalfe 1986; Nelson et al 1986), music (Halpern 1984; Serafine et al 1986), and the characteristics and timing of neural events that occur during learning and memory as reflected in event-related brain potentials (e.g. R. Johnson et al 1985; Neville et al 1986; Warren & Wideman 1983). By way of illustration, we review three areas that have grown substantially in recent years: affect and memory, spatial memory, and autobiographical memory.

Affect

Based on evidence that changes in the affective valence of words can produce release from proactive interference in the Brown-Petersons task (Wickens &

Clark 1968). Underwood (1983c) included an affective component in his listing of the attributes of memory. Bower (1981), too, proposed that emotional responses can be a component of memory, here conceived of as an associative network that represents an event (see also Clark & Isen 1982; Tyler & Voss 1982). Feeling states can serve as retrieval cues for events associated with that state. At least two related predictions have been explored: (*a*) Mood will be associated with state-dependency effects such that retrieval will be best if a person is in the same mood as at initial encoding; and (*b*) mood will give rise to "congruency" or "selectivity" effects such that elements of ongoing events that match a person's current mood will have a higher probability of being encoded than other elements.

Both predictions have been explored (see Blaney 1986 for a review). State-dependency effects tend to be small (Bower et al 1978; Gage & Safer 1985; Schare et al 1984) and are sometimes not found (Bower & Mayer 1985; Wetzler 1985). Selectivity effects are more consistently reported, but there are exceptions here as well (e.g. Bower 1981; Bower et al 1981; Hasher et al 1985). Positive and negative affect do not have symmetrical effects on performance; those associated with positive affect seem to be more systematic (Isen 1984). Negative affect is not without consequence. For example, it can alter people's perception of the risk associated with various sources of morbidity (Johnson & Tversky 1983).

The impact of depression on cognitive function has also received attention from investigators working within the framework of general-capacity models (Ellis et al 1984, 1985; Hasher et al 1985; see Craik & Byrd 1982; and Rabinowitz et al 1982 for an extension of a similar model to memory deficits with age). The basic notion is that depression reduces capacity or causes its reallocation away from learning and memory tasks, resulting in disrupted performance. Confirming evidence comes from the study of clinically depressed patients (Cohen et al 1982), college students (Ellis et al 1984, 1985; although see Hasher et al 1985), and school-aged children (Goldstein & Dundon 1986; Goldstein et al 1985).

Other aspects of the relationship between affect and cognition have been studied, including reflective and nonreflectively-based affect (M. K. Johnson et al 1985), arousal (Clark et al 1983; d'Ydewalle et al 1985), emotion (Mandler 1984; Stein & Levine 1986), stress (Jacobs & Nadel 1985), and consumer behavior (Gardner 1986). Contemporary cognitive psychology can no longer be accused of ignoring affect (Zajonc 1980, p. 152).

Spatial Cognition

Spatial cognition has attracted the interest of investigators in human memory, in part because it allows an exploration of naturalistic memory phenomena in a nonverbal domain (Byrne 1982). We review two lines of research here. One pursues the notion that location information has a special status in memory, possibly as an obligatory code established as a byproduct of visual experience with objects (Hasher & Zacks 1979; Mandler et al 1977). There is evidence of good incidental memory for location, but there is contradictory data on the question of whether intention to store location information improves performance (Cooper & Marshall 1985; Light & Zelinski 1983; McCormack 1982; Park et al 1982). As well, age differences are often found (e.g. Acredolo et al 1975; Light & Zelinski 1983). For text material, memory for location has proven to be an effective cue for content information and vice versa (Lovelace & Southall 1983). Similarly, there is a relation between object recall and location recall (Hazen & Volk-Hudson 1985).

Another line of work is concerned with identifying the underlying organization of spatial information. Research suggests that there are systematic distortions in memory for spatial arrays; for example, what is near in physical space is not necessarily what is near in conceptual space (e.g. Hirtle & Jonides 1985; McNamara et al 1984; see also Stevens & Coupe 1978; Tversky 1981). Spatial information may be organized into hierarchically ordered chunks created by perceived or imagined boundaries; spatial knowledge is different for objects that share a boundary than for objects that cross one (Acredolo & Boulter 1984; Hirtle & Jonides 1985; Maki 1981; McNamara 1986; Newcombe & Liben 1982).

Spatial cognition, an area of increasing concern to investigators in human learning and memory, is also studied by those interested in cognitive development (see e.g. Mandler 1983 for a review), animal behavior (see Kamil & Roitblat 1985; Menzel 1978), and the differences among individuals and between groups of individuals (Caplan et al 1985; Cooper & Mumaw 1985; Just & Carpenter 1985; Strelow 1985). Many methods are available to determine what people learn and remember about spatial information. Investigators have monitored subjects' navigation through space and the search strategies used to find missing objects (DeLoache & Brown 1983; Lockman 1984; Wellman et al 1984). They have asked subjects to make judgments of distance, orientation, and/or direction using either direct (e.g. drawings) or indirect (e.g. triangulation) measures (e.g. Bartlett et al 1983; Enns & Girgus 1985; Hanley & Levine 1983; Moar & Bower 1983; Presson & Hazelrigg 1984; Reed et al 1983). Finally, recognition, drawing, reconstruction and, most recently, reaction time have also been used as response measures (e.g. Dirks & Neisser 1977; Herman 1980; Light & Humphreys 1981; McNamara et al 1984). As is the case for item memory, alternative methods do not necessarily reveal the same patterns of effects across independent variables. Thus a complete picture of what people learn and remember about space will require (at least) a systematic analysis of tasks and measurement methods (see Newcombe 1985). The danger of underestimating the contribution of task variables to performance in spatial (as in other) tasks should not be ignored (Newcombe 1985; Presson & Somerville 1985).

Autobiographical Memory

Because investigators have begun to see the complexity of the underlying representations and/or processes supporting memory for naturally occurring events as a challenge rather than an obstacle, they are currently engaged in a lively exploration of issues, methods, and topics in autobiographical memory.

Like other workers discussed above, investigators of autobiographical memory must grapple with the relationship between general knowledge (e.g. of an airport) and event-specific information (e.g. a particular trip to the airport) (Bahrick & Karis 1982; Linton 1982; Neisser 1984; Reiser et al 1985). For example, Bahrick has studied several types of naturally acquired knowledge: recognition of college classmates, recognition by professors of names and faces of former students, learning and retention of the streets and buildings of a college town, and retention of Spanish learned in high school or college (Bahrick 1983, 1984a,b). Bahrick (1984b) suggests that as level of learning increases, some portion of this type of knowledge becomes permanent [perhaps partly through organizational restructuring (Bahrick 1984c)] and will be indefinitely maintained, even in the absence of further rehearsals, and regardless of potential interference encountered during the retention interval. (See Neisser 1984 for an alternative interpretation, and Slamecka & McElree 1983 for work on the retention of laboratory-learned lists as a function of degree of learning.) This, along with Salasoo et al's (1985) suggestion that letter strings become "codified" after a certain number of repetitions, indicates that the idea of a fundamental difference between stable knowledge domains and episodic memories continues to be compelling.

Schema theory-based interpretations of autobiographical memory also are relevant to the issue of the relationship between generic and specific information (Kolodner 1983; Nakamura et al 1985; Reiser et al 1985, 1986). For example, Reiser et al (1985) propose that script-like activities (e.g. going to restaurants, going shopping) are a major encoding level for memory. [Similar ideas include basic level concepts (Rosch 1978), basic level situations (Cantor et al 1982), and basic level scenes (Tversky & Hemenway 1983).] Reiser et al suggest that autobiographical events are represented by specific traces with "pointers" from the activity scripts used to encode them. Retrieval of a particular event involves first accessing the relevant activity script and using information in that structure that points to the specific experience.

Issues similar to those that have emerged from laboratory studies include: the problem of defining events or other units of experience (Linton 1986; Neisser 1986), remembering as active problem solving (Baddeley 1982; Reiser et al 1985, 1986), and possible multiple entries representing different kinds of information (Johnson 1983, 1985; Neisser 1986).

Recent papers (especially see Bahrick & Karis 1982 and edited collections by Gruneberg et al 1978; Harris & Morris 1984; Neisser 1982; Rubin 1986) illustrate the growing range of topics and methods in the area of naturally occurring memories—e.g. field studies of daily events (Thompson 1982) and dreams (Johnson et al 1984), single-subject studies (Wagenaar 1986), vivid memories (Rubin & Kozin 1984), remembering to do things ["prospective" memory (Harris 1984; Levy & Loftus 1984)], diary studies of tip-of-the-tongue states (Reason & Lucas 1984), commonplace slips and lapses or "absent-mindedness" (Reason 1984), and the general relation between attention and cognitive failures (Martin & Jones 1984). Questionnaires have been developed for assessing memory of public and private events and for assessing beliefs about memory (see Herrmann 1984 for a list; Morris 1984 for problems; Martin & Jones 1984). In addition, there have been attempts to systematically explore phenomenal qualities of remembered events (Johnson et al 1984; Johnson 1985; Nigro & Neisser 1983).

A major problem in studying autobiographical memory lies in verifying the accuracy and the age of memories. This perhaps partially accounts for the continued interest in memory for public events (for example, the assassination of President Kennedy) for which at least the retention interval is known (e.g. Winograd & Killinger 1983). Public events have been used to study temporal dating processes. The evidence suggests that temporal information is not directly retrieved: People use inferential processes in combination with other knowledge to date specific events. For example, the accessibility of information about an event is useful for dating because we tend to remember less about events as time passes. The result is a systematic bias: People tend to underestimate the time that has passed since events they know more about and overestimate the time since events they know less about (Brown et al 1985). People use personal experiences that happened around the same time to help date public events as well as general knowledge about when certain types of events typically occur (Friedman & Wilkins 1985); they can also use public events to increase their accuracy in dating personal events (Loftus & Marburger 1983). [For recent temporal order studies involving personal memories or laboratory events, see Barclay & Wellman 1986; Winograd & Soloway 1985; Zacks et al 1984; also see Glenberg & Swanson 1986.]

SUMMARY AND CONCLUSIONS

There have been several notable recent trends in the area of learning and memory. Problems with the episodic/semantic distinction have become more apparent, and new efforts have been made (exemplar models, distributed-memory models) to represent general knowledge without assuming a separate semantic system. Less emphasis is being placed on stable, prestored prototypes and more emphasis on a flexible memory system that provides the basis for a multitude of categories or frames of reference, derived on the spot as tasks demand.

There is increasing acceptance of the idea that mental models are constructed and stored in memory in addition to, rather than instead of, memorial representations that are more closely tied to perceptions. This gives rise to questions concerning the conditions that permit inferences to be drawn and mental models to be constructed, and to questions concerning the similarities and differences in the nature of the representations in memory of perceived and generated information and in their functions.

There has also been a swing from interest in deliberate strategies to interest in automatic, unconscious (even mechanistic!) processes, reflecting an appreciation that certain situations (e.g. recognition, frequency judgments, savings in indirect tasks, aspects of skill acquisition, etc) seem not to depend much on the products of strategic, effortful or reflective processes.

There is a lively interest in relations among memory measures and attempts to characterize memory representations and/or processes that could give rise to dissociations among measures. Whether the pattern of results reflects the operation of functional subsystems of memory and, if so, what the "modules" are is far from clear. This issue has been fueled by work with amnesics and has contributed to a revival of interaction between researchers studying learning and memory in humans and those studying learning and memory in animals. Thus, neuroscience rivals computer science as a source of interdisciplinary stimulation.

Research on topics such as memory for spatial location, the relation between memory and affect, and autobiographical memory reminds us that general theories of memory based on studies of verbal materials alone are limited. Investigating how people remember complex natural events should provide us with a larger set of memory phenomena to explain and consequently insight into a wider range of memory principles or a deeper understanding of the ones we already accept (e.g. the role of repetition, encoding specificity), including their functional significance for human behavior.

The major danger that we see for the field is a proliferation of paradigms, none of which is well understood. The studies reviewed here show that even the simplest task may involve a number of processes. Theoretical ideas based on incomplete task analyses are likely to be wrong. At the same time, a single task (no matter how completely understood) cannot reflect the astounding range of memory's capability. Rigid adherence to any standardized research technique is dangerous. Achievements in understanding human learning and memory in the last 100 years (Gorfein & Hoffman 1986; Klix & Hagendorf 1986) have not come from any single approach. There is hope in our collective eclecticism (Baddeley & Wilkins 1984; Bahrick 1984d; Postman 1968).

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