10 Paradigms in Human Memory Research

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The purpose of this chapter is to survey the experimental paradigms that have been used to study human memory. Because this is a large and somewhat unstructured brief, a considerable amount of selection is exercised to focus on paradigms with certain characteristics. I concentrate on those paradigms which (in my view) have been particularly useful in revealing details of memory processes and structures, those of current theoretical interest, and those that may help to bridge the gap between human and animal work. For the most part, I *comment* on the paradigms rather than simply describe them, and thereby hope to make contact with other chapters (e.g., by Cohen and by Crowder) that discuss theoretical issues in current work on human memory.

DESCRIPTION VS. ANALYSIS

In general, it may be suggested that paradigms in human memory research have been devised for two broad purposes: first, to provide a refined description of some phenomenon of memory, and second, to test some theoretically devised postulate about how memory operates. The two purposes thus serve, on the one hand, to enrich our descriptions of memory, and on the other to broaden our understanding of the processes that mediate memorial performance. Most current paradigms have been developed for the second purpose, and this review concentrates on them. Before turning to analytical methods and procedures, however, some brief consideration is given to descriptive paradigms.

Natural-history studies are more in the tradition of biology, and this tradition spills over into some areas of biological psychology. The interesting work on birds' ability to cache and later find seeds (Sherry, Krebs, & Cowie, 1981; Shettleworth & Krebs, 1982) is a case in point. Students of human memory have rather neglected descriptive paradigms, even though few would contest the notion that adequate theories can only be constructed on a base of careful, rich and valid observations and description. This neglect has been alleviated to some extent in recent years in response to theorists such as Bruce (1985) and Neisser (1982) who have argued for greater "ecological validity" in our work; my personal impression is that our field could profit by paying rather more attention to exploration and description.

It is still perfectly possible to describe striking phenomena of memory that come as a surprise to workers in the field. The "tip-of-the-tongue" (TOT) state explored by Brown and McNeill (1966) and the "flashbulb effect" investigated by Brown and Kulik (1977) are good examples. Such systematic observations of real-life remembering can often have important implications for theory, too. In the early 1970s it was widely believed that human subjects extracted the meaningful "gist" of written or spoken discourse, that the gist was remembered but the sensory or surface form was rapidly lost. Against this background, the demonstration of excellent memory for the exact words used in conversations 24 hours earlier (Keenan, MacWhinney, & Mayhew, 1977) or for the typescript in which passages were originally read, after weeks and months (Kolers, 1976; Kolers & Ostry, 1974) was both interesting and theoretically important.

The actual methods used in these descriptive studies have ranged from case histories (e.g., Luria, 1968) through questionnaire studies (Brown & Kulik, 1977; Harris, 1978) and the use of diaries (Linton, 1982) to measurements of number of items recalled and recognized under various experimental conditions—for example, Shepard's (1967) work on picture memory, studies of eyewitness testimony (Loftus, Miller, & Burns, 1978) and of story recall (Bower, 1976; Kintsch, 1974). By their nature, descriptive studies tend to use descriptive measures to assess performance, rather than to use standard paradigms; they also tend to focus on naturally occurring phenomena and on practical issues. My main point here is that descriptive studies have been relatively neglected by most students of memory—greater attention to the "natural history" of our area would help to keep our experiments focused on important issues and to enrich the basis of our theories.

In the more rigorously controlled studies that form the bulk of the human experimental literature, a number of basic paradigms recur in various forms. These studies typically involve linguistic materials, and are usually designed to test some hypothesis about the structures and processes that have been proposed to underlie memory performance. The common paradigms are free (unordered) recall of a list of items (e.g., words, pictures, objects), serial recall—in which the items must be recalled in the order of presentation, cued recall, recognition of the presented items among similar distractors, relearning of the materials to some criterion, and paired-associate recall and recognition. Whereas the first-named paradigms are tests of item information, the last two are tests of associative information. Specific forms of these basic paradigms have been designed to test various theoretical points arising from different models of human memory. These points address such questions as the type of representation (e.g., acoustic, semantic, procedural) relevant to a particular store or system, the nature of encoding processes, transfer from one part of the system to another, the capacity of various stores or structures, the time course and mechanisms of forgetting, and the nature and characteristics of retrieval processes.

Such analytical paradigms have clearly played the major role in extending our knowledge of human memory; however, all too often they depend for their usefulness on the validity of the underlying theory that they were designed to test. If the theory collapses, or becomes less relevant to prevailing views, the data may be of little value in their own right. One salient example is the colossal amount of work that was done on the Sternberg paradigm in the decade of the 1970s. Whereas the original demonstration and analyses of Sternberg (1966, 1969) represent the very highest level of thinking and empirical work in experimental psychology, I would say that the great bulk of subsequent work using the paradigm has made a relatively slight contribution to our understanding of human memory processes. This is not to argue that all paradigms must necessarily involve "ecologically valid" materials or situations; I believe with Tulving (1983) that important general principles can be elaborated and refined as well with artificial materials in the laboratory as they can be deduced from real-world phenomena. The important point, however, is that the principles themselves *must* reflect central, general aspects of memory functioning in the person's day-to-day life.

If some paradigms have told us rather little about how human memory works, there is even less reason to apply them routinely to animal research. "Because it is there" may be a perfectly sound reason for climbing Mount Everest, but it provides a less satisfactory rationale for measuring, say, short-term memory in the pigeon—unless of course it can first be demonstrated that pigeons use that type of short-term retention in their natural environment. The point is that satisfactory paradigms must be theoretically motivated, and the theoretical motivation in turn must be founded in valid general principles. Similarly, in order to bridge the gap between the areas of human memory and animal learning, the continuity should be at the level of principles, not paradigms. The paradigms themselves may well be modified in light of the particular organism's knowledge and capabilities, but the same general point can be attacked across species. The importance of the general points that merit this type of effort must be assessed in the context of what specific organisms use memory for.

So what are these centrally important general principles? How have they been studied in humans, and how might the paradigms be modified for animal work?

The chapters in this volume by Cohen and Crowder provide some answers. My personal reaction necessarily depends on my own idea of what memory is and how it works; the next section provides an outline of my present views.

WHAT IS MEMORY? A PERSONAL VIEW

Over the past 10 years my ideas have moved progressively away from a view of memory as a structural system — a "thing" in the head—and towards the viewpoint, advocated by Bartlett (1932) and others, of *remembering* as an activity. That is, the memory trace is perhaps not a specific structure located at some point (or even diffusely) within the central nervous system, but is rather an altered potential of the system to carry out certain mental activities provided that the context, task, goals, mental set etc. present at the time of initial learning are also reinstated, either "driven" by external stimulation or reconstructed internally by the rememberer. By this account, remembering is essentially a form of perceiving. Just as perceiving reflects an interaction between the stimulus array and aspects of previous learning (as well as genetically determined aspects of brain functioning), so remembering also reflects an interaction between some externally provided stimulus (either a general context or a specific retrieval cue) and relevant aspects of previous learning. Remembering is thus viewed as a recapitulation of the original experience, either in its relatively literal imaginal form (e.g., How were people in the group standing relative to others and to the furniture? What clothes were they wearing?) or in terms of higher-order information abstracted from the experience (How many people were in the group? What was the mood of person X? What was the gist of the conversation between X and Y?)

One crucial aspect of this position is that remembering is thought of *essentially* as an interaction between external events and mental activities. Just as it is not very sensible or meaningful to talk about the percept as a function of mental activity only (rather, it is by nature an interaction between stimulus information and specific "mental skills" of the perceiver), so it does not seem too useful to regard memory as a function of mind alone. Similarly, it is not very meaningful to ask about the characteristics of the percept when perception is not occurring; the percept is not a preformed "thing" waiting to be activated by appropriate input, rather it reflects a potential of the neural machinery to interact with sensory information in a lawful way, and so give rise to specific mental experiences. In just the same way, it is not sensible to inquire about the characteristics of the memory trace when remembering is not occurring (the memory trace "in repose" as Crowder, chapter 2, describes it); the experience of remembering may not reflect the activation of some preformed memory record so much as the interaction of specific inputs with the potential of the mental machinery. A further implication of this view is that it may be no more sensible for neurophysiologists to look for the engram within some neural memory bank than it would be to look for pictures in the circuitry of a TV set. Of course the circuitry does have the potential to *produce* pictures in interaction with highly specific incoming information, but the pictures are neither in the circuitry itself, nor in the electromagnetic radiation itself.

An important difference between remembering and the production of pictures on a TV screen, however, is that whereas the TV system passively reflects changes in the pattern of incoming stimulation, the human rememberer can reconstruct previous experiences on the basis of quite fragmentary incoming information. As discussed later in the chapter, different retrieval tasks vary in the extent to which such self-initiated reconstructive activities are required—free recall demands a great deal of reconstruction; recognition of pictures requires considerably less. One way of expressing these self-initiated remembering operations is that human subjects clearly *intend* to remember; that is, they are aware of some desired goal of the mental activity, and use various strategies to aid the reconstructive processes. An interesting point in the context of comparisons between human and animal memory is the degree to which animals also intend to remember. Can animals, like humans, improve their memory performance by attempting to recollect previously acquired information, or are their remembering activities driven more passively by changes in the incoming stimulus array interacting with current knowledge, drives, and goals? Do they function more like TV receivers with a learning capability?

I have called this synopsis a personal view, but it clearly owes a great deal to many other current researchers. In particular, the views just expressed are similar in many respects to those suggested previously by Bartlett (1932), Bransford, McCarrell, Franks, and Nitsch (1977), Jacoby (1983), Jenkins (1974, 1979), Kolers (1973), Nilsson (1984) and Tulving (1983). To return to the point of valid general principles—the present viewpoint suggests three sets of important questions that require answers at both the human and the animal level. First, how is the underlying system modified by the initial experience; what are the factors that constrain and modify encoding processes, what are the roles of attention and "working memory" in acquisition, how is new information related to the existing knowledge base, and what genetic constraints exist to bias the system to assimilate various types of information more or less easily? Second, what factors affect the reinstatement of the original mental operations; how do "reconstructive operations" work and what gives rise to the feelings of "pastness" that accompany remembering (and presumably enable the organism to distinguish remembering from perceiving)? Third, how do encoding and retrieval processes interact, and what are the necessary relations between them? What role, for example, does context play at acquisition and retrieval? The rest of the chapter will consider a selection of recent studies that address these problems, and evaluate the adequacy of the experimental paradigms that have been used to examine them.

PARADIGMS AND ISSUES IN SHORT-TERM RETENTION

What is the role of short-term memory (STM) in perception and learning? Among the answers that have been given to this question is the notion that STM is essentially an input buffer that comes into play especially in situations of stimulus overload—STM holds "extra" information until the processing mechanisms are free to deal with the overload (e.g., Broadbent, 1958). With this point in mind, many early experiments used the dichotic listening paradigm in which two different strings of 3–4 digits, letters, or words were presented simultaneously, one string to each ear. In retrospect, the paradigm probably revealed more about attention than memory processes (e.g., Treisman, 1964) but work on dichotic listening was of great importance in formulating early views of auditory sensory storage, limited capacity processing mechanisms, and rehearsal processes (Broadbent, 1958, 1971).

But many (most?) information-processing situations do not appear to involve stimulus overload; does short-term storage play some further role? Two other suggested functions of STM are first, that it is a device to hold recently received information in a state of high accessibility so that the human or other organism can respond rapidly and effectively when some further event occurs (e.g., the warning provided by a bird's alarm call or by an orange traffic light). In the same vein, (Hollis, 1982) has suggested that a short-term storage mechanism is necessary for the successful association of stimulus and response in Pavlovian conditioning. Second, that STM serves to hold and integrate sequences of information that arrive over time—speech comprehension is a good example of an ability that requires such a device at the human level, and Harley's (1981) work on the learning of sequences of sites in foraging is an analogous case in the animal literature. Such views of STM lead to questions of capacity of the input buffer, the types of information that it can hold, the mechanism and time course of forgetting, and the characteristics of retrieval of information from the store. A great deal of research effort in the 1960s was expended on answering these questions, and appropriate paradigms were devised to tackle them. Capacity was assessed by span techniques, by Sperling's (1960) partial report method, and by measuring the size of the recency effect in free recall. The issue of coding was examined by means of the types of errors made (e.g., Conrad's, 1964, finding of "acoustic confusions" in recall of visually-presented letters), by considering the types of information that disrupt performance (Baddeley, 1966), and the types of retrieval information that are particularly effective at various retention intervals (e.g., Bartlett & Tulving, 1974). Retrieval characteristics were also studied by means of cued recall techniques, by the "release from PI" phenomenon (Wickens, 1970), and by Sternberg's (1966) recognition and sequential probe paradigms. The characteristics of forgetting from STM were explored using the Brown-Peterson paradigm (Brown, 1958; Peterson & Peterson, 1959), digit probe techniques (e.g., Waugh & Norman, 1965), the suffix effect (e.g., Crowder & Morton, 1969), and the displacement of items from recency positions by interference from further items (Glanzer & Cunitz, 1966).

Full reviews of this work are given by Craik and Levy (1976), Glanzer (1972), and Murdock (1974). The picture of STM that emerged from this decade of research was essentially one of a rather passive input buffer, dealing primarily with linguistic material and serving to prolong perceptual experience for a few seconds until the incoming material could be comprehended and integrated with existing knowledge. The term "primary memory" (James, 1890) was revived to describe this form of short-term storage (Waugh & Norman, 1965).

What role would the concept of STM play in a comparative psychology of learning and memory? Presumably, the study of primary memory in animals would explore interspecies differences in capacity, the types of codes used, forgetting functions, and so on. But would this be a useful exercise? Personally, I very much doubt it. One reason is that characteristics of primary memory that were originally considered structural and fixed, were later seen to depend heavily on the task and materials used (Craik & Lockhart, 1972). In this sense, "primary memory" might be better viewed as a set of related mental abilities rather than as a single structure to be measured and catalogued (Crowder, 1982).

A second reason for not applying the paradigms of 1960s STM research to animals, is that human memory researchers have adopted a progressively more active view of short-term retention since the late 1960s. Atkinson and Shiffrin's (1968, 1971) influential model of memory developed the notion that the short-term store was a structure within which various control processes were executed. By 1971 these control processes—rehearsal, coding, decisions, and retrieval strategies—were the essential stuff of the model, leaving the structural components with a rather vestigial role. This view of short-term retention involving a set of related active *processes* had been predated by Neisser's (1967) description of primary memory as "active verbal memory" and was developed more fully in Baddeley and Hitch's (1974) model of "working memory." (Interestingly, Atkinson and Shiffrin gave the short-term store the subtitle "temporary working memory" in their 1971 model.)

The idea of working memory emphasizes an active, functional role for short-term retention. Incoming information can be held, manipulated, and integrated with existing knowledge in a variety of ways, some quite novel. Thus working memory can be viewed as a forum in which a variety of higher-level cognitive functions—comprehending, learning, thinking, problem-solving, and remembering—can take place. It can also be viewed as a set of related processes, or (taking a somewhat more structural position) as "a heterogeneous array of independent storage capacities intrinsic to various subsystems specialized for processing in specific domains" (Monsell, 1984).

Whether working memory is regarded as a relatively fixed structure, albeit with a flexible "central executive" and several peripheral subsystems (Baddeley, 1983; Baddeley & Hitch, 1974; Hitch, this volume), or as an umbrella term for a set of storage capacities or processes, the concept has strong functional implications. Working memory is *for* something; it is a necessary component in a variety of complex cognitive functions such as reading (Daneman & Carpenter, 1980), comprehension of prose (Kieras, 1981; Kintsch, 1974; Miller, 1981) and problem-solving (Baddeley & Hitch, 1974). It also seems likely that working memory is crucially involved in learning—especially in cases in which the new information has to be held and comprehended prior to its integration with existing knowledge.

Because it is a relatively new concept, paradigms to assess working memory functioning are still few in number. My colleague Meredyth Daneman at the University of Toronto has suggested some methods for measuring working memory in the context of individual differences in language processes. In one paradigm, subjects read a series of sentences for comprehension and also attempt to remember the last words from each sentence. "Reading Span" is then the longest list of last words that the person can reproduce; this measure correlates well with results from tests of reading ability, especially with measures involving integration and inference (Daneman & Carpenter, 1980). In a related paradigm that Daneman calls "production span," subjects are first given a short list of unrelated words which they hold in mind; their task is then to produce a series of sentences, each successive sentence containing one word from the original list. Again "production span" is the longest sequence of sentences that the subject can produce. Daneman argues that whereas reading span taps complex receptive processes of reading and comprehension, production span assesses the ease with which subjects can access and produce words in discourse.

The fact that Daneman has developed two tasks (so far) to tap different aspects of working memory, reflects the assumption that "working memory" is not one structure or one process with fixed characteristics to be measured, but may be better thought of as a set of related cognitive skills (see also Crowder, 1982). Other tasks that involve holding, manipulating, and integrating information may also be considered working memory tasks, although they may again reflect somewhat different skills and abilities. For example, asking subjects to sort playing cards into suits, not with respect to the current card but with respect to the card one or two back in the series (Welford, 1958), might be considered a test of some aspects of working memory. Appropriate paradigms should reflect the particular function that the researcher is interested in.

If both "primary memory" and "working memory" are better regarded as descriptive categories rather than as separate stores or structures, what is the relation between them, if any? My suggestion is that primary memory tasks and working memory tasks may involve some of the same cognitive components, but whereas primary memory tasks stress the passive holding of information, working memory tasks involve more active manipulation and integration of information. But the two sets of tasks (or abilities) should probably be thought of as lying on a complex continuum as opposed to reflecting two separate systems, or discrete types of memory. By this account "appropriate" paradigms would be those tapping processes that are thought to be used in some real-world cognitive activity—reading, retrieval from long-term memory, problem-solving, or the like.

With respect to animal studies, my argument is that there seems very little point in simply adapting human memory paradigms to study the same aspects of short-term retention across very different species. The comparisons, rather, should be at the level of cognitive abilities with clear functional or adaptive significance for the animals studied, and the paradigms used should be designed specifically to assess these abilities or their hypothesized components. An excellent example is provided by Olton's studies of working memory in rats (Olton, Chapter 5; Olton & Samuelson, 1976). Olton's technique assesses the rat's ability to remember which arms of a radial maze it has already visited to retrieve food rewards. This type of temporary spatial memory appears to be trivially easy for the rat (although it might pose severe problems for human subjects!) presumably because it is highly compatible with the rat's specific cognitive abilities or "knowledge system" (Gallistel, 1980).

Two final comments on working memory: First, it may be more revealing to study the *knowledge systems* of various species directly, rather than various memory abilities; the latter may well be a function of the former (cf. Craik & Lockhart, 1972). Second, the "working memory" abilities revealed by Olton's tests appear to be somewhat different in kind from working memory abilities assessed in humans. In the human case, "working memory" almost always implies holding the information "in mind," and the ability is disrupted if the subject is severely distracted. This does not appear to be the case in Olton's paradigm; the animal can be confined to the central platform for several minutes halfway through its performance and then released to complete the task successfully (Olton & Samuelson, 1976). Perhaps a better parallel with human abilities would be the apparent skill of experts to remember some relevant set of information temporarily—for example, waiters remember complex sets of food orders over minutes or hours, real-estate agents remember detailed sets of facts about clients and houses on their current listings, chess masters can hold several games in mind at the same time. But these experts are clearly not rehearsing the current information continuously; it seems as if a subset of their knowledge can remain "primed" and thus easily accessed over minutes, hours, or days. Following Olton's work with rats, appropriate paradigms should be designed to evaluate this type of "working memory" in human subjects.

TRANSFER FROM SHORT-TERM TO LONG-TERM MEMORY

In multistore models of memory (e.g., Atkinson & Shiffrin, 1968; Murdock, 1967), an important issue concerns the transfer of information from one store to the next, especially transfer from the temporary short-term store (STS) to the permanent long-term store (LTS). Atkinson and Shiffrin's suggestion was that transfer depended on time in STS and the amount of attention paid to the information while in STS. They therefore developed paradigms in which these factors were varied and indeed they demonstrated lawful relations between time and attention on the one hand and LTS strength on the other (Atkinson & Shiffrin, 1968). However, this account turned out to be incomplete. Later work (Craik & Lockhart, 1972; Craik & Watkins, 1973; Woodward, Bjork, & Jongeward, 1973) suggested and showed that the *qualitative* type of rehearsal in the short-term store was crucially important as a determinant of later long-term retention. Maintenance rehearsal, involving for example the simple repetition of a word's phonemic characteristics, has little or no effect on later recall performance (although it does serve to increase *recognition,* as shown by Woodward et al., 1973) whereas elaborative rehearsal, involving "deeper" semantic and relational information, does enhance both recall and recognition.

This pattern of results was demonstrated in a recent, as yet unpublished, study by Zhu, Craik, and Olson. Subjects rehearsed groups of three unrelated words for intervals of 2, 4, 8, 16 and 20 sec and were later tested for both recall and recognition of the words. Four groups of subjects treated the words differently during the initial rehearsal intervals; one group held the words "incidentally" ostensibly to prevent them rehearsing lists of digits (after Glenberg, Smith, & Green 1977, and Rundus, 1977), a second group repeated the words for 2–20 sec, a third group formed a sentence involving the three words, and a fourth group constructed a visual image involving the words—all groups except the first were aware that a later memory test would be given. The results are shown in Fig. 10.1. In general, both recall and recognition benefitted from inten-

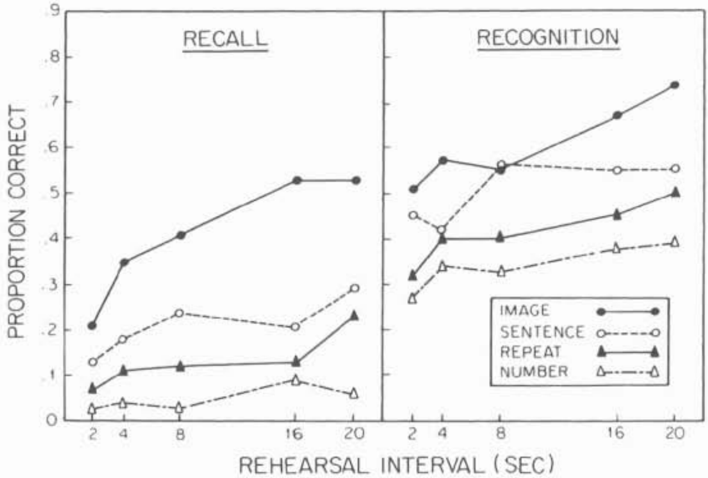

FIG. 10.1. Recall (left panel) and recognition (right panel) as a function of type and duration of rehearsal (Zhu, Craik, & Olson, unpublished data).

tionality and deeper processing (in this case from "sentence" and "image" processing). For recall, type of processing interacted with initial rehearsal interval in that performance improved differentially for the deeper processing groups; but this interaction was absent in the case of recognition. One explanation of this result is that recall depends on interitem processing (Mandler, 1979), and that further rehearsal time allows the formation of particularly rich relational encodings in the deeper processing groups. Recognition, in Mandler's view, depends more on intraitem processing, and thus all processing groups benefit equally from extra rehearsal time.

One further important factor relating to "transfer" of information from STS to LTS, is that the effectiveness of different types of processing depends on the specific retrieval information present at the time of testing. This effect was demonstrated by Geiselman and Bjork (1980) in an experiment similar to the study just described. In their experiment Geiselman and Bjork had subjects rehearse the word triads in an imagined voice. Under maintenance rehearsal (but not elaborative rehearsal) conditions, later recognition performance was enhanced when the test words were presented in the same voice. Thus, performance depends on the compatibility between encoding and retrieval processes (e.g., Tulving & Thomson, 1973), but that general statement has to be qualified somewhat when various types of initial processing are considered.

What exactly is "transferred" in such studies? As I have argued previously (Craik, 1983), I do not find the notion of transfer particularly useful. Instead, it seems preferable to talk directly about the different types of encoding that can be carried out, and the effects of different encoding operations on memory performance after short or long retention intervals, and under different conditions of retrieval. Human subjects, with their rich and complex knowledge structures, may have a greater number of processing options open to them than other animals do—that is, humans may choose to process incoming information in a variety of ways depending on their goals and purposes. This degree of "optionality" appears to be especially true of linguistic material which can be processed in terms of its sounds (or visual characteristics) or in terms of its meanings and implications at various levels of elaboration and associative richness. Thus, if a person wishes to hold information temporarily, he or she may choose to merely repeat the sounds; if longer-term retention is required, however, deeper and more elaborate processing is carried out. But this distinction is not very usefully described as "transfer" of information.

For the same reasons, the notion of transfer may not be particularly useful in animal studies either. Even if animals do not possess the same range of "processing options" that humans do, the general principle may still hold that specific stimuli tend to be encoded in a given way, in light of the knowledge and experience of the animal in question. By this argument, instead of studying "transfer" in animals, paradigms should be devised to study how different encoding operations are carried out within and across species, and how these various types of encoding affect performance in a variety of retrieval situations.

ENCODING PROCESSES

It is generally agreed that encoding and retrieval processes cannot be studied in isolation—good encoding conditions depend largely on specific retrieval conditions and vice versa (Tulving, 1974, 1979; Tulving & Thomson, 1973). These interactive effects are dealt with in a later section. However, I also maintain that some encoding conditions *are* associated with superior levels of retention, given that compatible retrieval conditions are provided. That is, some ways of encoding information are potentially better than others, provided that the potential is realised by means of appropriate retrieval cues (Craik, 1979; Fisher & Craik, 1977; Moscovitch & Craik, 1976). In general these "superior" types of encoding are those that relate new information to an existing body of well-organized knowledge, and yet form an encoding that is *distinctive* from similar, previously encoded information (Eysenck, 1979; Jacoby & Craik, 1979).

The distinctiveness of a particular encoded episode facilitates its later retrieval by specific cues, and presumably increases the probability that the retrieved information will be identified and remembered as the original episode. Such distinctiveness is often conferred by the integration of event and contextual information; at the time of retrieval, the encoded "event plus context" can then be accessed either by providing some fragment of the original context and asking for retrieval of event information (recall) or by providing some part of the event and requiring retrieval of context (recognition). Some types of memory failure reflect the dissociation of item and context information. For example, a person may retain the general knowledge accrued from a specific event, yet be unable to say where or when the information was acquired—"source amnesia" (Claparede, 1911; Schacter, Harbluk, & McLachlan, 1984). In an analogous (though less dramatic) fashion, it is possible to remember a context yet forget the information that was acquired there or some specific event that occurred (Reed, 1979).

Encoding variables may thus be grouped under two headings—those variables that affect the (potential) memorability of items or events themselves, and those that affect the integration of focal events with other events or with the surrounding context. This distinction has been captured by Mandler (1979) in his contrast between "intra-item" and "inter-item" encoding. Some recent paradigms that explore the former set of variables are described briefly before considering variables that affect the integration of item and context.

When the emphasis in human memory research changed in the 1970s from quantitative variables (e.g., rehearsal duration, number of repetitions) to qualitative variables (e.g., expertise, types of encoding), new paradigms were devised to illustrate the new theoretical notions. For example, Craik and Tulving (1975) explored the consequences for later retention of various "levels of processing" of linguistic material. In an incidental learning paradigm, subjects were asked various questions about single words—e.g., is the word in capital letters?

Does the word rhyme with X? Is the word in Y semantic category? Answering these questions required different types (or "levels") of processing, and it was found that subsequent recall and recognition varied markedly as a function of the type of question asked. "Deep" semantic questions were associated with higher levels of retention than rhyme questions, which in turn were superior to questions concerning typescript. Later work (Rogers, Kuiper, & Kirker, 1977) showed that questions involving self-reference—e.g., "does this adjective describe you?" were associated with higher levels of retention than those following questions concerning semantic categories. The general principle appears to be that memory performance is a function of the degree to which the new information is related to pre-existing, organized, meaningful knowledge—to the subjects' general or specific areas of expertise.

Could this paradigm be usefully applied in animal studies? One drawback might be the restricted range of "processing options" in the animal's repertoire, but presumably higher mammals can deal with objects and events for different purposes and with different goals in mind. As a suggestion, monkeys can be trained to select the odd item in a group of three (Harlow, Meyer, & Settlage, 1951) and it may be possible to have the animal choose on the basis of different characteristics—e.g., color, shape, function, personal relevance. Performance on a later recognition test should then reflect the "depth" of the initial processing. If successful, this paradigm could be viewed as a means of exploring the animal's knowledge structures, as well as a way of assessing memory. The finding that rats have an excellent memory for the taste of "poisoned water" (Garcia & Koelling, 1966) is a good case in point.

Two encoding paradigms that have stimulated considerable interest in recent years are those giving rise to the "generation effect" (Jacoby, 1978; Slamecka & Graf, 1978) and the "transformation effect" (Kolers, 1973). In both cases, later retention is enhanced by an apparently trivial manipulation at the time of encoding. The generation effect is found in situations where subjects complete words with missing letters (e.g., R_BY) as opposed to simply reading them (e.g., PEARL); both recall and recognition levels are boosted by the act of generation. Kolers (1973) had subjects read passages of text that were transformed in various ways (e.g., inverted, mirror image) and again found superior retention of the transformed text relative to text that had been read in normal script. Kolers' original purpose was to demonstrate that recognition performance is a function of repeating the same pattern-analyzing operations (Kolers, 1973, 1979), but it seems likely that at least part of the effect is attributable to the more extensive *semantic* processes engaged by the reader attempting to decipher the transformed text (Graf, 1981; Masson & Sala, 1978). This account is supported by the finding that the transformation effect is not found with meaningless materials like anomalous sentences (Graf, 1981) or nonsense syllables (Glisky, 1983), but is not diminished when the recognition test is presented auditorily (Glisky, 1983). Given that the material was presented visually yet tested auditorily, there can be little if any overlap in the pattern-analyzing operations on the two occasions; the probable explanation is that more abstract, "semantic" operations are involved. Again, the generation and transformation effects appear to be cases in which greater involvement with the subject's knowledge systems are associated with higher levels of retention (Craik, 1981; Graf, 1981).

The generation effect, the transformation effect, and the "levels" effect of Craik and Tulving (1975) are examples in which the retention of single events is enhanced. What about paradigms to explore the integration of an event with its context? This important question has been relatively neglected, but there is evidence that interest in it is increasing (Mackintosh, Chapter 11). One relevant factor is the degree to which the context changes the interpretation of an event (Fisher & Cuervo, 1983; Godden & Baddeley, 1980). A second factor appears to be the amount of attention devoted to the situation. Preliminary evidence suggests that arousing or interesting events are better integrated with their contexts (Brown & Kulik, 1977; Rubin, 1984) and also that *reduced* attention is associated with poorer integration of event and context (Rabinowitz, Craik, & Ackerman, 1982). Other memory impaired groups also show poor memory for context (Huppert & Piercy, 1976; Schacter, Harbluk, & McLachlan, 1984; Stern, 1981) but whether these cases can also be attributed to attentional dysfunction or reduced processing resources remains problematical.

In any event, the role of context in both conscious recollection and in retention without awareness (Jacoby & Witherspoon, 1982) is not yet well understood, but seems likely to attract a lot of theoretical and empirical attention over the next few years. The topic appears to provide further common ground with studies of animal memory, and the distinction between intrinsic (interactive) and extrinsic (background) contexts is likely to provide further theoretical impetus (Geiselman & Bjork, 1980; Godden & Baddeley, 1980; Mackintosh, this volume).

RETRIEVAL PROCESSES

As outlined previously, I endorse the general view that the goal of retrieval processes is to reinstate the specific mental operations induced at the time of encoding the target event (Kolers, 1973; Tulving & Thomson, 1973). These encoding activities will typically include pattern analyzing operations reflecting perceptual aspects of the event and its context, but also operations that represent more abstract qualities concerned with the event's interpretation and significance in light of the organism's knowledge and previous experiences. It follows from this view that encoding processes and retrieval processes must be extremely similar, if not identical. Perhaps the major difference between the two sets of processes is their respective goals; that of encoding being principally to perceive and comprehend, that of retrieval being to reinstate aspects of some former percept, thought, or action (Craik, 1983; Craik & Jacoby, 1979; Jacoby & Craik, 1979). It is further suggested that the reinstatement of operations occurs partly through the system being "driven" by the current contextual and "cue" information, and partly by means of the subject's own reconstructive efforts, reflecting an *intention* on the subject's part to remember the previous event.

The helpful role of context in remembering is well documented (e.g., Godden & Baddeley, 1975, 1980); studies of state-dependent learning (Bower, 1981; Eich, 1980) make the same point. The ability to remember is clearly adaptive in that recurrence of a given set of circumstances will tend to evoke the operations (reflecting percepts, thoughts, conclusions, and actions) that occurred on similar occasions in the past, and thus provide some guidance with respect to present action. However, the present context may not provide sufficient guidance to "remind" the person (or animal) of the previous occasion, and further self-initiated reconstructive operations are then required to "jump the gap" between the current and desired states (Schank, 1982). To some extent the gap is closed by relatively automatic redintegrative processes; if retrieval cues plus background context drive the system close to some former state, there is a tendency for the system to move into that state. Although such redintegrative processes are not well understood they may be thought of as "pattern-completion" activities (Kintsch, 1974) in which a re-presentation of some fragment of a previously learned pattern serves to invoke the original pattern (Jones, 1976).

When contextual information is insufficient to drive the system back into the desired state, further constructive or reconstructive operations must be initiated by the subject (Bartlett, 1932; Neisser, 1967). I have previously suggested (Craik, 1983) that the degree to which such self-initiated activities are required, depends on the paradigm used. Free recall relies heavily on self-initiated reconstructive operations since very little guidance is provided by the request to recall. Cued recall provides more guidance, and recognition even more, and thus self-initiated processes are required less in these paradigms. In procedural memory tasks, self-initiated reconstruction of a previous episode is usually not required at all—the task calls merely for perception of a present event or execution of an action. Table 10.1 shows various memory paradigms ordered intuitively with respect to the degree of self-initiation required. The greatest degree of self-initiation may be needed when subjects must "remember to remember"; for example, when a person runs out of groceries he not only needs to remember the required items, but also (on the way home from work perhaps) to remember to stop at the store.

The scheme shown in Table 10.1 is in good agreement with the findings from studies of age-related deficits in memory. The large decrements shown by older people in free recall performance are typically reduced under cued recall or recognition conditions (Craik, 1977, 1983). Also, age differences are slight or nonexistent in procedural memory tasks such as priming (Howard, Lasaga, & McAndrews, 1980; Moscovitch, 1982). At the other end of the scale, everyday

TABLE 10.1
A Possible Classification of Retrieval Tasks

Task	*Self-initiated activity*	*Environmental support*
'Remembering to remember'	↑	increases
Free recall		
Cued recall		
Recognition		
Relearning		
Procedural memory	increases	↓

forgetfulness provides many examples of the failure to "remember to remember" or of "prospective remembering" as Meacham and Leiman (1975, cited by Neisser, 1982) have termed it. My earlier suggestion (Craik, 1983) was that the different degrees of memory impairment shown by older people in various circumstances reflect the degree of self-initiated activity demanded by a particular task or paradigm, rather than the involvement of different memory systems (Tulving, 1983, this volume). Speculatively, the scheme may also be applicable to at least some other cases of memory dysfunction.

These notions provide some interesting questions for students of animal memory. Are there systematic differences in redintegration across species, for example? How do differences between the encoding and the retrieval context affect the animal's ability to produce a previously learned response? The ethologists have provided some information on this question—for example, in Tinbergen's classic studies of the digger wasp, in which the insect's ability to find its burrow was affected when salient visual cues were moved (see Gallistel, 1980). However, it could be argued that the behavior here is more a case of pre-formed actions being released provided that the contextual support is sufficient. Mackintosh's work (Chapter 11) can also be regarded as demonstrating the necessary role of contextual support at retrieval—especially in the "intrinsic" case, in which the encoding context serves to modify the initial encoding. This work clearly falls under the rubric of Tulving's (1983) encoding specificity principle, thereby providing a further link between studies of animal learning and human memory.

There is some evidence at the human level that whereas the notions of encoding specificity and contextual support are relevant across the lifespan, older children are somewhat less "context-bound" than are younger children. Ackerman (1981), for example, has demonstrated that when objects were presented for children to learn either as pictures of the objects or their names, younger children's later recognition performance depended strongly on the item being represented in the same form (i.e., picture-picture or word-word), whereas older children and young adults were less dependent on the exact form being reinstated. Thus the "encoding specificity" interaction between form at encoding and form at test, itself changes with age. Of course, the *mental operations* during retrieval are still likely to mirror those at encoding, even in adult subjects. The point is that with increasing age the child is less dependent on environmental cues driving the system back into the appropriate state; in addition, events are encoded in a less literal and more abstract form. In these ways the older cognitive system acts to modify the environmental input at both encoding and retrieval.

This interpretation provides a further interesting comparative question for students of animal memory—to what extent do different species actively modify the information provided at retrieval to reconstruct some previous representation? Is there a role for *intentionality* in animal memory? The likely answer is "yes" for higher mammals at least. For example, work on recognition memory in monkeys (Gaffan, 1976; Chapter 13) shows that the animals can solve a present problem by retrieving information from a previous occasion; in some sense the animal "knows" that the previous information is relevant and "intends" to retrieve it (see Dennett, 1983, for a fuller discussion of intentionality in animals). At a more general level, it would be interesting to demonstrate an increasing role for intentionality and active reconstruction in memory as the evolutionary scale is ascended; such a demonstration would show that higher animals are less bound to the contextual "here-and-now" and would parallel similar demonstrations in human ontogeny (Piaget, 1952).

PROCEDURAL MEMORY

In this final section I briefly mention some recent work on memory for skilled procedures. Because the procedures in question are often nonverbal, this area offers particularly good opportunities for developing paradigms common to man and other animals. Also, the retention of skilled procedures does not require conscious recollection of the original event and this fact too should facilitate comparative studies. The older work on learning perceptual-motor skills focused on the conditions that facilitate their acquisition and retention, but recent interest in the topic has been boosted by dramatic findings from studies of amnesic patients, and the focus of interest has changed accordingly. It has been known for some time that amnesics can learn and retain motor skills despite being grossly impaired in their ability to learn new verbal information (see Baddeley, 1982, for a review). However, the essential distinction is not between motor and verbal skills, since amnesic patients also fall within the normal range on eyelid conditioning (Weiskrantz & Warrington, 1979) and in their ability to recognize drawings when prompted by fragments of the original picture (Warrington & Weiskrantz, 1968). It is also clear that the patients are not simply learning a general skill, since they retain information about specific items (Baddeley, 1982).

Cohen and Squire (1980) suggested that the crucial distinction is between "knowing how" (procedural memory) and "knowing that" (propositional memory). In their study, amnesic subjects learned to decipher sets of words presented in inverted typography (following Kolers, 1973). Over several repetitions the patients improved their ability to read specific words, even in the absence of any conscious recollection that they had seen the words before. Such findings have led some theorists to postulate different memory systems underlying the conscious recollection of specific episodes and the often unconscious retention of procedural knowledge (Cohen & Squire, 1980; Tulving, 1983), although not all researchers take this view (e.g., Jacoby, 1983).

Regardless of the outcome of this theoretical debate, the revival of interest in procedural memory has already given rise to several new experimental paradigms. Following Warrington and Weiskrantz's work on picture fragments, Tulving, Schacter, and Stark (1982) had subjects learn a list of long, uncommon words and later tested retention of the information in one of two ways. The method tapping conscious episodic recollection was a standard recognition test; in the other test the subject was given word fragments (e.g., A_ _A_ _IN, _H_O_EM) and the task was to complete the word. Tulving et al. found that fragment completion performance was greatly enhanced by previous presentation of the whole word, but that this "priming" effect was independent from performance on the recognition memory test. In a somewhat similar demonstration, Jacoby (1983) found that recognition memory and perceptual identification were also independent; in the perceptual identification task, words were flashed briefly (for 35 msec) on a tachistoscope and the subject's task was to identify the word. Again, prior presentation of the word facilitated or primed performance on the identification task. A further ingenious paradigm to assess procedural memory was developed by Jacoby and Witherspoon (1982). In this task subjects were again presented with words to learn in an initial phase and were later given words to spell. In the first phase, words were presented visually, and the list contained some homophones (e.g., REED, READ; HARE, HAIR); in these cases the less common member of the pair was presented. The spelling task was given auditorily, and the interest lies in how frequently the subject responds with the primed word. It was found that amnesics showed as much priming (i.e., the spelling bias was as great) as did normals despite the fact that the amnesics showed little conscious recollection of the words.

In light of Tulving's (1983; this volume) suggestion that procedural memory is a relatively primitive system in terms of both evolution and ontogeny, comparative studies in this area would be particularly useful. Even at the human level, memory for procedures may actually be more pervasive and important for everyday functioning than the more salient forms of memory involving conscious recollection (Kolers & Roediger, 1984). It would be relatively easy to develop paradigms applicable to humans and animals, and interesting to explore the same abilities across species. Two theoretical points that seem particularly worthwhile are first the degree to which procedural memory is context specific (see Mackintosh, Chapter 11)—that is, are words or actions *primed* in some general absolute sense by recent experience, or does priming again reflect an interaction between a learned potential on the one hand and a specific set of contextual circumstances on the other? My own bias is towards the contextualist view, although the evidence is still quite fragmentary. The second theoretical point of interest concerns the degree to which procedural memory reflects the general principle that memory performance is tied to specific knowledge and expertise. Do experts in some perceptual-motor domain show particularly strong priming effects? Do they show *increased* contextual specificity? Do animals possess strong procedural memory abilities as part of their repertoire of biological adaptations? An exciting area of comparative research is just opening up.

CONCLUSIONS

In this chapter, I have surveyed some current ideas in research on human memory and commented briefly on the paradigms that have been developed to assess these ideas. My personal bias is to think of human memory as an activity to be understood in the person's biological and social context; by this account, we should talk in terms of underlying processes, as opposed to structures, and view the processes in terms of their evolutionary and functional significance (see also Bolles, chapter 7, and Hitch, chapter 6). A further bias is reflected in the suggestion that we should attempt to model the *interaction* between the organism and its environment, rather than think of memory as a property of the organism alone. In this regard, the role of context is crucial, both at encoding and retrieval, and this view is also shared by several other contributors to the present volume (e.g., Mackintosh, chapter 11; Rescorla, chapter 3).

With respect to the formation of closer ties between the areas of animal learning and human memory, recent developments in both fields make this goal appear realistic and worthwhile. In human memory research, there is increasing interest in nonverbal paradigms and in concepts such as procedural memory. Correspondingly, animal learning researchers are now more inclined to take a "cognitive" view of animal memory, and adapt concepts from human memory studies to their own ends (e.g., Mackintosh, chapter 11; Olton, chapter 5). One aspect of the establishment of a truly comparative science of memory is the development of common paradigms, and there are signs that this is now happening—stimulated by research in both areas (e.g., Dickinson, chapter 9; Gaffan, chapter 13). In the present chapter I have pointed out situations in which further common paradigms might usefully be established; in general, these are cases involving nonverbal "propositional" materials (e.g., pictures, spatial and temporal information) and cases of skilled procedures. A further area that could provide linking paradigms is the field of memory research in infants and young children (see Moscovitch, 1984, for a recent review).

Although the establishment of common paradigms appears to be a worthwhile goal, some warnings are in order. First, in contrast to the earlier "learning set" approach (Harlow, 1949) in which it was assumed that the evolution of some general learning ability could be measured across different species, the view advocated in the present chapter is that different species develop different kinds of knowledge about the world, and that memory performance reflects the specific knowledge of the animal in question. By this view it is not sensible to ask which has the best memory—bird, rat or man? Each species may show superior performance on its own "natural" task. Thus, it is more important to develop common principles than common paradigms. The primary objective is the establishment of a common *conceptual* framework for animal and human memory, and the experimental paradigms used should reflect the appropriate expression of the animal's memorial abilities within its own functional context. The Umeå conference has left me feeling optimistic that there is now sufficient common ground between the two fields of research to make the objective of a common conceptual framework both desirable and realistic.

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