6

Encoding and Retrieval of Information

SCOTT C. BROWN & FERGUS I. M. CRAIK

The purpose of this chapter is to outline some recent developments in our understanding of human memory processes—specifically, encoding and retrieval processes in long-term episodic memory. A brief history of work in this area is provided, followed by a discussion of memory codes. The nature of encoding and retrieval operations is then explored, with a discussion of how these two types of processes interact. The chapter concludes with a description of some factors that lead to enhancement and impairment of memory performance.

The Information Processing Framework

The terms *encoding* and *retrieval* have their origins in the information-processing framework of the 1960s, which characterized the human mind/brain as an information-processing device (see also Bower, chapter 1, for a more detailed history of memory research). In this model, the mind—like the computer—receives informational input that it retains for a variable duration and subsequently outputs in some meaningful form. *Encoding*, therefore, refers to the process of acquiring information or placing it into memory, whereas *retrieval* refers to the process of recovering previously encoded information. However, this early work focused less on encoding and retrieval than it did on storage or retention of information. In one of the more prominent variants of information-processing theory, sometimes called the multistore or modal model, information is presumed to flow through a series of mental stores (Atkinson & Shiffrin, 1971; and see also Bower, chapter 1). In this model, information enters the processing system through modality-specific sensory stores and then proceeds to a limited short-term or primary memory before entering a permanent and extensive long-term or secondary memory. The key to successful encoding in this model is attention—that is, in order for information to proceed to progressively more capacious and durable stores, the learner has to pay conscious attention to the information. The more rehearsal that the individual engages in, the greater the likelihood that the information will be transferred from short-term to permanent storage (Atkinson & Shiffrin, 1968). So, for example, when processing language, the "literal" sensory input decays rapidly unless selected by attentional mechanisms that transform it into short-term auditory or visual representations. Further processing usually transforms the short-term information into long-term semantic representations that can be recovered minutes or even years later. This information-processing model of memory has been very influential and is still in use some 30 years later.

However, the three-store model is not without its problems: For example, subsequent research showed that the capacity, coding, and forgetting characteristics of short-term memory varied as a function of people, materials, and tasks (e.g., Naveh-Benjamin & Ayres, 1986; Shulman, 1972). Moreover, models appealing to both passive stores and active processes were considered less parsimonious than one appealing solely to active processes. That is, if the experiential and behavioral aspects of memory can be accounted for by considering the characteristics of various encoding and retrieval processes themselves, the concept of a "memory store" loses theoretical meaning and thus becomes superfluous. As an alternative framework, Craik and Lockhart (1972) proposed that incoming stimuli were processed to different levels, or depths, within the cognitive system, from "shallow" or sensory levels to "deep" or meaningful levels of analysis. Memory is considered to be the byproduct of such active perceptual and cognitive processes; the more deeply or meaningfully the information is processed, the more well retained the information will be. This levels-of-processing (LOP) view thus emphasizes the role of mental operations in memory, particularly encoding processes. Clearly, retrieval processes are also important and, as discussed later, a more complete model incorporates the LOP view of encoding with views emphasizing the compatibility of encoding and retrieval operations (e.g., Morris, Bransford, & Franks, 1977).

The Nature of Memory Codes

It seems likely that our memory for personally experienced events, along with accrued knowledge and skilled procedures, must ultimately be represented in the brain by complex networks of neurons. In this sense, specific neural networks represent various life experiences in a coded form, and the assumption is that when a particular network is active, we reexperience the event or recollect the fact. However, it is also possible to talk about memory codes at a cognitive level. That is, different aspects of an experienced event are encoded—for example, an object's shape, texture, location, and function—and part of the cognitive researcher's task is therefore to classify these qualitatively different dimensions of encoding, to work out their interrelations, and to specify their implications for later memory of the original event (Bower, 1967). If these different aspects of an encoded object or event are stored in somewhat different regions of the brain, an important problem concerns how the aspects are bound together during the encoding and retrieval processes to yield the experience of a single coherent object or event. This "binding problem" is ubiquitous in cognitive theorizing (see, e.g., Chalfonte & Johnson, 1996; and Johnson & Chalfonte, 1994).

One possibility is that all sensory modalities first represent and store rather literal copies of the surface aspects of objects (e.g., color, size, shape), and that subsequent interactions with the same objects reveal the relations among the sensory elements, as well as "deeper" aspects such as function, significance, and value. By this view, the cognitive system is organized hierarchically, with lower levels representing sensory aspects and higher levels representing derived aspects ("significance" or "meaning") of objects and events. The lower, shallow levels of processing may be driven predominantly by perceptual inputs (bottom-up or data-driven processing) and the higher (deeper) levels driven either by the same perceptual inputs, or activated "top down" by expectations and intentions (Norman, 1968). If shallow levels of representation are *not* well accessed by top-down processes, this may be one reason sensory codes are difficult to maintain and rehearse (e.g., Posner & Keele, 1967). A further difference between sensory and conceptual codes is that sensory codes are likely to be reused in many different combinations, just as the 26 letters of the alphabet are recombined to form many different unique words; conceptual codes, on the other hand, are more usually specific and differentiable (Moscovitch & Craik, 1976).

It is natural enough to regard these various coded representations as the *product* or residue of processing operations; that is, as *structures* of the mind and of the brain. Some theorists have taken a more radical position, however, and argued that the coded representations of experiences are the *processes* themselves (e.g., Kolers & Roediger, 1984). By this account, the activity of remembering is similar to the activity of perceiving; the mental experiences of perceiving and remembering occur only when the relevant processing operations are themselves occurring. It is even possible to think that the similarity between perceiving and remembering is more than an analogy; that memory encoding processes are identical to those processes carried out primarily for the purposes of perception and comprehension, and that memory retrieval processes represent the cognitive system's best efforts to reinstate the same pattern of mental activity that occurred during the original experience (Craik, 1983; Craik & Lockhart, 1972).

Of course, there must be *some* physical change in the brain that corresponds to the formation and storage of each new memory, but this material basis of memory may again be different from the pattern of neural activity that is the correlate of the mental experience of remembering. A videotape recording may provide an analogy here. The tape itself contains a static coded representation of the filmed events; the tape has the potential to give rise to a specific pattern of electromagnetic activity when run through the VCR, and this activity in turn causes the dynamic images (the "phenomenal experience") to appear on the video screen. When analyzing and researching memory codes we may, therefore, have to consider three very different levels of representation: a structural level of neurochemical changes in the brain, a pattern of neural activity that is triggered and guided by the first level, and the mental experience that is a correlate of activity at the second level. Each level of representation will have its own rules and characteristics, and there will also be "mapping rules" by which adjacent levels communicate. A comprehensive science of memory will, therefore, have to provide an account of memory codes at these various levels, as well as an account of how one set of codes maps on to the other sets (see Konorski, 1967; Velichkovsky, 1994, for similar ideas).

Types of Memory Code

This chapter is concerned with codes at the psychological level only; other chapters of the handbook deal with the neural correlates of these codes. Most memory research by cognitive psychologists has dealt with language or alphanumeric materials—numbers, letters, syllables, words, sentences, and texts—so the study of encoding processes has concentrated substantially on verbal codes. Pictures have been studied to a lesser extent, and some important contrasts have been drawn between pictorial and verbal codes. For example, Paivio (1971) proposed an influential dual-code hypothesis in which he suggests that many events are represented in two very different ways: an analogue code that preserves the physical features of the object or scene (e.g., an image of a cat under a table), and a symbolic code that provides a verbal description of the event (e.g., "the cat is under the table"). In support of this hypothesis, researchers have shown that visual perception interferes with visual imagery (both sets of processes presumably utilizing the pictorial coding system), but that visual perception of scenes or objects interferes only negligibly with the mental manipulation of verbal material (Baddeley, 1983; Brooks, 1968). Paivio (1971) has also demonstrated that memory is enhanced when an event can be encoded by both systems; thus concrete nouns like TABLE and HORSE are readily encoded imaginally as well as verbally, whereas abstract nouns (e.g., TRUTH, JUSTICE) do not easily yield a pictorial image. The finding is that concrete nouns are better recalled than are abstract nouns; two codes are better than one.

The dual-coding hypothesis seems very much on the right track, but probably does not go far enough. There must also be codes for voices, melodies, textures, tastes, smells, and many other aspects of our perceptual experiences. But there is no reason to think that their memory codes obey different laws; it seems likely, in fact, that such stimuli encoded only in terms of their surface features will not be remembered well, and that those encoded "deeply" in terms of domain-relevant meaning will be well retained. It is important to note that "meaning" does not refer to linguistic meaning only; a familiar face, a well-known voice, an evocative picture, a spectacular chess move or football play—are all examples of stimuli that are meaningful and thus likely to be encoded deeply and well remembered. From this point of view, expertise in the domain of encoding under investigation is a prerequisite for attaining deeper levels of processing (Bransford, Franks, Morris, & Stein, 1979).

Some examples of investigations of these less usual encoding dimensions include studies of face recognition (Moscovitch, Winocur, & Behrmann, 1997) and voice recognition (Read & Craik, 1995). Pictures are extremely well recognized (e.g., Standing, 1973), presumably because we are all "experts" in visual perception. There is relatively little work on memory for touch, taste, or smell; Herz and Engen (1996) provide a useful review of studies of memory for odors. On the other hand, Wilson and Emmorey (1997) have recently examined the nature of representation in sign language: it appears that deaf signers employ memory codes similar to hearing subjects (i.e., articulatory and phonological representations), albeit within the visuo-spatial domain. Finally, studies of musical memory (see Levitin, in press, for a review) suggest that melodies are encoded abstractly; that is, we tend to recall the relative frequencies and durations of musical notes rather than their absolute frequencies or durations. However, some absolute information is retained, as when nonmusicians sing their favorite song from memory and approximate the tones used in the original recording (Levitin, 1994). In summary, it appears that memories may be coded along a multitude of dimensions and that several codes may be retained from a single experienced event.

Another class of code is memory for contextual detail, as opposed to memory for the focal event itself. One example of context memory is memory for the source from which information was learned. Memory for the event itself and its source are often dissociable (Schacter, Harbluk, & McLachlan, 1984). Thus a person may remember some newly acquired fact but forget where he or she learned it. Older people are particularly vulnerable to this type of forgetting (McIntyre & Craik, 1987; Spencer & Raz, 1995), resulting in their "telling the same story twice" (Koriat, Ben-Zur, & Sheffer, 1988). Another common experience is what George Mandler (1980) referred to as "the butcher on the bus" phenomenon: when a person's face encountered in an atypical context seems very familiar, yet the perceiver cannot recollect where or when he has met the person. But does contextual information utilize a different type of memory code? It seems most likely that it does *not*; contextual or source information is qualitatively similar to focal event information and is classified as "context" merely because it is of lesser interest to the perceiver. The greater vulnerability of contextual information to forgetting is most likely attributable to its receiving less attention and less comprehensive and elaborate processing.

Encoding Operations

From the preceding discussion it should be clear that several factors are important ingredients of good encoding. Some factors are internal—for example, motivation, strategies, and relevant prior knowledge—and others are external, such as to-be-learned materials and experimental instructions. Some highlights are discussed in the present section.

First, it is important to bear in mind the goals and purposes of the learner. If a person wishes to hold a verbal sequence only briefly—retaining a string of numbers to make a telephone call, for example—then it may be more efficient to encode the string as a speech-motor sequence. This type of short-term articulatory code (the "articulatory loop" in the terminology of Baddeley, 1986) is excellent for short-term retention but poor for longer term memory, as most people know in connection with remembering the names of new acquaintances at a party! Clearly "paying attention" to new information is crucial. However, more than simply attending to something, we must also process it at an abstract, schematic, and conceptual level. For example, Craik and Tulving (1975) showed that when participants were asked questions about a series of words, semantic questions (e.g., "Is the word a type of fish?"—SHARK) led to higher levels of memory in a subsequent surprise test than did questions relating to phonemic ("Does the word rhyme with *park*?") or orthographic features ("Does the word start with *S*?"). Figure 6.1 shows subjects' mean recognition levels for these three conditions (Craik & Tulving, 1975, experiment 1). This result suggests that "paying attention" is not an end in itself; rather, what is crucial is the qualitative nature of the processing operations fueled by attentional resources.

Put another way, the type of rehearsal that the individual engages in determines the success of his or her encoding efforts. There are two main types of rehearsal that are pertinent to the LOP framework: maintenance rehearsal, in which information is kept passively in mind—for example, through rote repetition—and elaborative rehearsal, in which information is meaningfully related to other information, presented either previously or currently. The general finding is that the greater the elaboration—or extensiveness—of one's encodings, the better the subsequent memory (Craik & Tulving, 1975). For example, Craik and Tulving (1975) asked participants to decide whether a word would fit meaningfully in either a simple, medium, or complex sentence. Although all three types of sentences involved conceptual processing, the most complex sentences were remembered best,

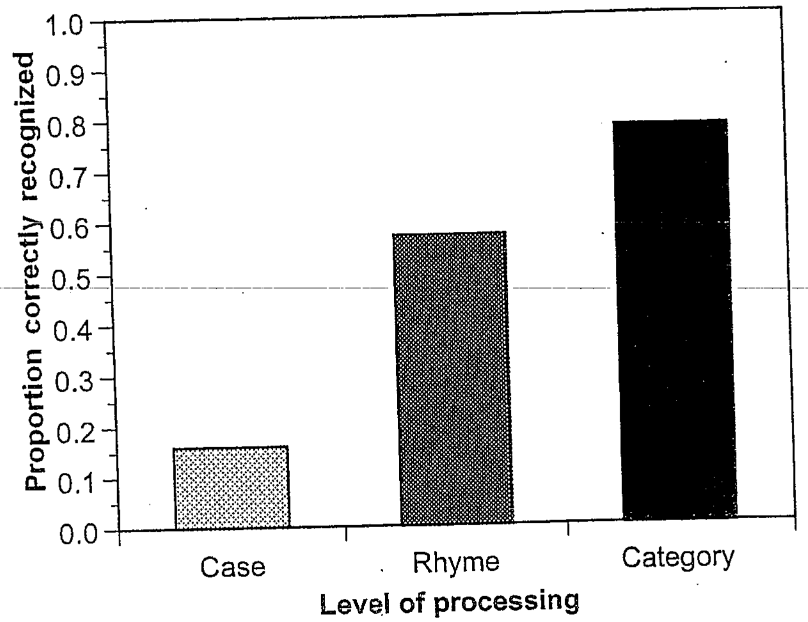

Figure 6.1 Mean proportions of words recognized as a function of processing condition (data from Craik & Tulving, 1975, experiment 1).

presumably because the complex sentences activated larger, richer cognitive structures than did the simpler sentences.

A related issue with rehearsal concerns the timing of the rehearsals: retention after a delay is best when rehearsals are distributed or spaced out over time, rather than massed together in a short period of time. The spacing of rehearsals may be mimicked by actually presenting items to be learned twice, either at short or long intervals. The finding here is that longer spaced repetitions are associated with higher levels of subsequent retention (e.g., Madigan, 1969). Why should this be? One suggestion is that items re-presented after longer intervals are more likely to be encoded somewhat differently from how they were on their first presentation. This encoding variability may be associated with a richer, more elaborate encoding of the item, which in turn supports better retention (Martin, 1968).

In addition to elaborative and distributed rehearsal, organization has been shown to be helpful when learning new information. Organization refers to the grouping together of items into larger units, usually based on meaningful relationships between items. One type of organization is called chunking, which involves grouping items into larger units on the basis of previous experience. Thus, a series of numbers may be recoded into chunks of adjacent numbers from dates, repetitions, or simple arithmetic sequences; as an example, the series 771968246333 can be broken into 4 chunks, namely 77-1968-246-333. This strategy of chunking may be quite useful during the initial stages of encoding, given claims about the limited capacity of short-term memory (e.g., Miller, 1956). Tulving (1962, 1968) extended the notion of grouping on the basis of previous learning to that of "subjective organization," measured by the consistency of a subject's responses in a series of recall trials from the same list. Tulving's argument was that "similar" items (however defined by the subject) will tend to be recalled together, and the growth of learning over a series of trials will be correlated to the strengthening of inter-item associations and thus to subjective organization. In fact, the results showed a correlation between subjective organization and learning (Tulving, 1962, 1968).

Finally, the distinctiveness of encodings, or the processing of stimulus-specific characteristics, has been shown to improve memory. Moscovitch and Craik (1976) had subjects encode words either shallowly or deeply, and either each word was given its own unique encoding question or groups of 10 words shared the same encoding question. These encoding questions were later presented as retrieval cues, and the finding was that the benefit of unique cues relative to shared cues was greater for deeper levels of encoding. Moscovitch and Craik concluded that deeper encoding establishes a higher ceiling on *potential* memory performance, and that the extent to which this potential is realized depends on the specificity of the cue-target relation. It therefore seems that, ideally, information should be encoded in terms of both item-specific features (characteristics that are unique to a particular stimulus) and associative features (characteristics shared with other information presented either concurrently or previously). In fact, several researchers (e.g., Ausubel, 1962; Einstein & Hunt, 1980) have suggested that both distinctive processing, or the encoding of differences among stimuli, and organization, or the encoding of similarities, are important for successful remembering.

There is also ample evidence that encoding may be guided by an individual's prior knowledge, values, and expectations (e.g., Bartlett, 1932; Bransford & Johnson, 1972). In particular, individuals call upon semantic memory or general world knowledge when encoding and retrieving new information (Neisser, 1998). The implication of these factors for memory is that subjects typically encode more than is presented to them in the stimulus, especially if the stimulus is rich in meaning—a sentence or a picture, for example. Barclay (1973) demonstrated that subjects encode inferences from meaningful sentences, and Barclay, Bransford, Franks, McCarrell, and Nitsch (1974) further showed that different contexts biased a word's encoding in different ways. In a related demonstration, Anderson et al. (1976) showed that people tend to encode particulars rather than generalities; after encoding the phrase, "Fish attacked swimmer," for example, SHARK was a better retrieval cue than FISH for later recall of the phrase.

Similarly, expertise may provide an important mental framework to which incoming information may be attached. For example, in a study of expert versus novice chess players, experts were better than novices at remembering the positions of chess pieces on a "legal" chessboard, but were no better than novices when recalling a "random" chess layout, where pieces' positions did not conform to the rules of chess (e.g., Chase & Simon, 1973; see also Bransford et al., 1979; and Kimball and Holyoak, chapter 7).

With regard to the role of external variables in encoding, much research has supported the notion that the type of material employed also determines the effectiveness of an encoding. In particular, there is the finding that pictures are typically remembered much better than words, known as the *picture superiority effect.* As described previously, Paivio (1971) has argued that this is the case because pictures are more likely to be encoded and stored in two independent codes (e.g., both verbal and imaginal codes) than are words (but see, e.g., Pylyshyn, 1973, for an alternative view). Instructions also play an important role, as most people are not fully knowledgeable about optimal learning strategies. Therefore, instructions to process items coherently and meaningfully (transforming word lists into stories or interacting images, for example) are typically beneficial (Bower, 1970; Paivio, 1971). On the other hand, the *intention* to learn something does not seem to be a factor in its own right, but simply a means of ensuring that some efficient encoding strategy will be used. This conclusion follows from studies showing that incidental (nonintentional) learning can be as effective as, or even more effective than, intentional learning provided that the incidental orienting task induces the learner to process the information in a meaningful, elaborate, and distinctive fashion (Craik & Tulving, 1975; Postman, 1964).

Retrieval Operations

Modern psychological research on memory developed from work on learning, and this shift resulted in an emphasis on the processes of encoding or acquisition; very little thought was given to the equally important problems of memory retrieval. This state of affairs was rectified by a series of studies from Endel Tulving's laboratory in the 1960s (see Tulving, 1983, for a summary account). First, Tulving distinguished two major reasons for forgetting—either the relevant memory trace was no longer *available* (i.e., it had been lost from the system) or it was still present but not *accessible* by means of the present cues (Tulving & Pearlstone, 1966). It is difficult to prove with certainty that a given trace is truly unavailable—it may be that the appropriate cues have not yet been provided—so Tulving's further work focused on the effectiveness of various types of cues. He proposed the notion that successful remembering is a joint function of trace information (reflecting encoding variables) and cue information (reflecting retrieval variables). That is, it is not possible to understand memory by considering either encoding or retrieval in isolation; remembering reflects the interaction between encoding and retrieval processes.

These ideas then led to the encoding specificity principle, which states in essence that a retrieval cue will be effective to the extent that information in the cue was incorporated in the trace of the target event at the time of its original encoding (Tulving, 1983; Tulving & Thomson, 1973). Thus, if the word BRIDGE is encoded as an engineering structure, the subsequent cue "a card game" will be ineffective, but the cue words "girder" or "span" would probably be quite effective. More subtly, if a certain characteristic of an object or event is stressed at encoding, then other salient aspects of the object will not function as effective cues. Barclay et al. (1974) demonstrated this by showing that if the word PIANO was encoded as "something heavy," then the later cue "a musical instrument" was not associated with high levels of recall.

Tulving and Thomson (1973) illustrated the encoding specificity principle in a 4-stage paradigm. First, target words were presented for subjects to learn in the context of a second word; for example, the target word BLACK was presented with the context word "train." In a second (ostensibly unrelated) phase, subjects were asked to generate 6 associations to a series of words; thus the word "white" might be provided and the subject might generate "sheet, snow, color, black, grey, crayon"). In a third (recognition) phase the subject was asked to circle any of his generated words that were on the initial list of target words to be learned. Finally, in phase 4, the original context words (e.g., "train") were re-presented as cues for a cued-recall test. The spectacular result of the study was that subjects recognized few (24%) of the target words from the words that they had previously generated, but were reasonably successful (63%) at recalling the target words when the context words were reprovided in phase 4. The conclusion is that BLACK in the context of "train" is encoded in a specific fashion, and this specific encoding is not "contacted" by BLACK in the context of "white." The result also casts doubt on the "generate-recognize" theory of recall (e.g., Bahrick, 1970; Kintsch, 1970), which states that recall reflects two processes: covert generation of plausible candidates based on the available cues, followed by selection of items for overt responses by means of a subjective recognition test. The generate-recognize theory predicts that memory performance should be worse when two processes are required of the subject (e.g., recall) than when only one process is required (e.g., recognition). However, Tulving and Thomson found the opposite result, suggesting that the degree of overlap between study and test conditions is more predictive of memory performance than is the requirement to generate a response. Nonetheless, as discussed later, it seems certain that constructive, reconstructive, and generative processes do play an important part in retrieval under certain circumstances (see, e.g., Jacoby & Hollingshead, 1990).

A further dramatic example of encoding specificity is provided by Nilsson, Law, and Tulving (1988). They had subjects learn lists of famous names (e.g., George Washington, Charles Darwin) and well-known cities (e.g., Toronto, Stockholm). At the time of study these names were encoded in the context of compatible phrases (e.g., "A well known building for music in VIENNA"). In a subsequent test of names in the absence of context, subjects failed to recognize many of the names, although they were able to *recall* the names later when reprovided with the study contexts. Thus the phenomenon of recognition failure of recallable words extends even to salient and well-known proper nouns.

Perhaps the main message of the encoding specificity principle is that successful retrieval depends on the similarity of encoding and retrieval operations. This point is generally accepted, and is embodied in other current views of retrieval. For instance, Kolers (1973, 1979) suggested that recognition memory performance improves to the extent that the processing operations carried out during retrieval replicate those carried out at the time of encoding. In a similar vein, the concept of transfer-appropriate processing postulates that good memory performance is a positive function of the degree of overlap between encoding and retrieval processes (Morris et al., 1977; Roediger, Weldon, & Challis, 1989). But it does not appear to be the case that compatibility between encoding and retrieval operations is all that matters; the depth (or type) of initial encoding also plays a major role. For instance, Morris et al. (1977) demonstrated that when words were tested for recognition in terms of their rhyming characteristics, rhyme encoding cues were more effective than semantic encoding cues, but on the other hand, the combination of semantic encoding and semantic retrieval (standard item recognition) was superior to that of rhyme encoding and rhyme retrieval. The data from their Experiment 1 are shown in table 6.1. For target words associated with positive responses at encoding, the semantic-semantic and rhyme-rhyme encoding-test combinations yielded recognition scores of 0.84 and 0.49, respectively. Morris et al. argue that semantic processing is not necessarily superior to other types of encoding—memory performance will depend both on the compatibility between encoding and test, and on the purposes and expertise of the learner. Interestingly, table 6.1 also shows that the superiority of rhyme-rhyme over semantic-rhyme does not hold for targets associated with negative responses at encoding, perhaps because in this case the target words are not so richly encoded in terms of their rhyming characteristics. One way of summing up the situation is to say that the type of initial encoding sets limits on the probability of later retrieval; the degree to which this potential is realized then depends on the compatibility between encoding and retrieval information (Moscovitch & Craik, 1976).

One further salient characteristic of retrieval is its constructive or reconstructive nature. The cognitive approach to perception, learning, and the higher mental processes stresses the notion that the whole cognitive system is active and constructive, as opposed to the more passive and reactive view engendered by behaviorist approaches. Thus, even perception depends substantially on past experience and what we expect to perceive, and such "top-down" influences are particularly evident in memory (Bartlett, 1932). By and large these constructive influences are positive and helpful, but they can also lead to errors, some of which may occur during the initial encoding of an event (or in storage; see, for example, the work of Loftus, 1998), but most of which probably occur at retrieval. The best evidence for these false memories comes from the recent work of Roediger, McDermott, and their associates, and the reader is referred to that work for further details (Roediger, McDermott, & Robinson, 1998; Roediger & McDermott, chapter 10).

Encoding/Retrieval Interactions

State dependency is a special example of encoding specificity or transfer-appropriate processing. The notion is that, just as retrieval depends on the effectiveness of retrieval cues, it also depends on the person's "state" or mental condition when he or she was encoding information. Moreover, the person's state at retrieval should ideally match that at encoding in order to ensure retrieval of the encoded information. For instance, if a person has learned certain facts or experienced particular events while "high" on drugs or alcohol, or while in a certain mood, then he or she may be better able to recall the facts or events when in a similar state of mind. Interestingly, state-dependent effects appear to be strongest when retrieval cues are weakest—for example, with free recall as opposed to recognition memory (Eich, 1980). One possible interpretation of this finding is that the person's mental state

Table 6.1 Proportions of words recognized (hits minus false alarms) as a function of encoding and test conditions (Morris, Bransford, & Franks, 1977, experiment 1).

	Positive responses			*Negative responses*		
		Test			Test	
		Standard	*Rhyme*		*Standard*	*Rhyme*
Encoding	Semantic	.84	.33	Semantic	.86	.33
	Rhyme	.63	.49	Rhyme	.52	.18

Note. At encoding, subjects answered semantic or rhyme questions about target words. These questions led either to a positive response (e.g., "Rhymes with legal?"—EAGLE) or a negative response (e.g., "Rhymes with sound?"—EAGLE). Subsequent recognition scores for targets associated with positive and negative responses are shown on the left and right respectively. The recognition test was either for the target word itself (e.g., EAGLE ?) or for a word rhyming with any target word (e.g., REGAL ?).

influences and guides the constructive aspects of retrieval, and that top-down constructive operations play a bigger part in recall than they do in recognition, which is relatively more data driven.

Just as a person's mental state can apparently modulate the encoding and retrieval of information, so too can the external context, provided that it is sufficiently rich and distinctive. An interesting example of this phenomenon is Godden and Baddeley's (1975) finding that when scuba divers learned lists of words either underwater or on dry land, they subsequently recalled more words when they were tested in the study location, as opposed to the alternative location not used at study. Figure 6.2 shows subjects' mean recall performance as a function of encoding and retrieval condition (Godden & Baddeley, 1975, experiment 1). Reinstatement of the encoding context at the time of retrieval can thus be very beneficial to remembering—an effect encountered in daily life under the term "revisiting the scene of the crime" or less dramatically by returning to room A after failing to remember what it was you went to room B to fetch! This notion was developed by Craik (1983, 1986) into the concept of "environmental support" with the idea that older people are particularly dependent on help from compatible contexts when attempting to remember. Obviously people can remember facts and events when they are not in the original encoding context, and such remembering is therefore more reliant on "self-initiated mental activities." In fact, commonly used retrieval paradigms may be classified with respect to how much environmental support they provide and (in a complementary sense) how much self-initiated activity they require. Craik (1983) suggested that paradigms such as free recall and prospective remembering typically require a lot of self-initiated activity, whereas recognition memory and many procedural memory paradigms embody more environmental support and thus require less self-initiated activity. There is reasonable evidence to support the conclusion that adult age-related memory decrements are greatest in situations where environmental support is least available (see Anderson & Craik, chapter 26).

Earlier in this chapter, the importance of elaborate semantic processing operations was emphasized. Typically, the involvement of meaning at encoding, combined with the provision of compatible retrieval cues at the time

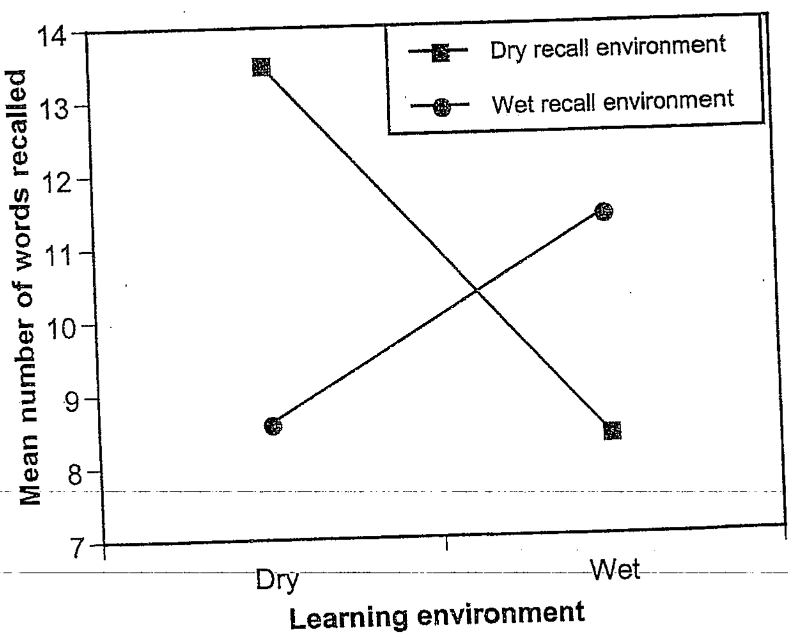

Figure 6.2 Mean number of words recalled as a function of learning and recall environment (data from Godden & Baddeley, 1975, experiment 1; adapted from Anderson, 1980, p. 210).

of testing, yields the highest levels of memory performance. However, a refinement to this general principle is suggested by investigations of paradigms that tap implicit memory (see Roediger & McDermott, 1993; Schacter, 1987; and Toth, chapter 16, for reviews). In these paradigms, subjects are not asked explicitly to recollect some earlier event; rather, the initial experience affects current performance, often in the absence of any conscious recollection of the original situation. In one such experiment, Jacoby and Dallas (1981) found that a levels-of-processing manipulation had no effect on later perceptual identification of re-presented words, although re-presented words were better identified than were new words, and the LOP manipulation did have the standard effect on explicit recognition memory. In a later study, Jacoby (1983) demonstrated that (visual) perceptual identification was sensitive to the amount of *visual* processing that had been done at the time of encoding. In general it seems that several implicit memory paradigms (e.g., word identification, word-fragment completion, word-stem completion) are positively affected by the compatibility of surface characteristics between study and test, whereas they are unaffected by semantic variables (Craik, Moscovitch, & McDowd, 1994). Other implicit memory tasks do deal with semantic or conceptual processing, however, and they are sensitive to the type and amount of conceptual processing carried out at encoding (e.g., Blaxton, 1989). Transfer-appropriate processing again appears to be the key in understanding variations in performance in these paradigms (Roediger et al., 1989).

A further interesting characteristic of at least some implicit memory tasks is that the compatibility effects between study and test are extremely long lasting. As one example, Tulving, Schacter, and Stark (1982) found very little "forgetting" in a word-fragment completion task between 1 hour and 7 days after initial presentation of the studied words. These long-lasting priming effects may be regarded as examples of perceptual learning rather than as episodic memory in the usual sense (Jacoby & Dallas, 1981), and they may be relevant to a puzzle in the literature on levels of processing. Craik and Lockhart (1972) postulated that shallow sensory codes were quite short-lasting, in line with current evidence from studies of sensory memory. However, Baddeley (1978) pointed out that some surface codes can be extremely *long* lasting; one dramatic example is Kolers' (1976) demonstration of savings in reading speed one *year* later in subjects reading texts in transformed typography. It now seems that the resolution of the puzzle may involve differences between implicit and explicit tests of memory. In the latter cases, when subjects are asked to recollect an earlier event, sensory or surface information appears to play little part after a few seconds—in line with Craik and Lockhart's suggestion. For implicit tests, on the other hand, surface information is often of primary importance (Craik et al., 1994; Jacoby, 1983) and is very long lasting.

Memory Enhancement and Impairment

This final section deals briefly with some selected situations in which memory performance is either increased or reduced. The more general question of what factors lead to memory improvement or memory failure is better answered after a consideration of all of the chapters in this handbook!

Slamecka and Graf (1978) showed that memory for words was enhanced by requiring subjects to complete fragments of the words at the time of learning. In most cases the completions were extremely easy, and might be helped by an associated context word. For example, the word SLOW might be presented in its entirety (the "read" condition) or with some letters missing (the "generate" condition); that is, fast-SLOW or fast-S___ W. Surprisingly, the generate condition is consistently associated with higher levels of recall and recognition (see, e.g., Hirshman & Bjork, 1988, for a review). What underlies the effect? One possibility is that the necessity to complete the word forces the subject to process its meaning to a slightly greater degree, and that the generation effect is therefore another manifestation of "deeper" processing. This account is speculative, however.

A somewhat similar phenomenon is found in a paradigm requiring subjects to perform simple actions with common objects. These "subject-performed tasks," or SPTs, are contrasted with a list of verbal commands, with the former condition yielding better later memory for the items. Thus commands such as "pick up the toy car," "point to the book," or "stamp your foot" are either given in a list to be learned or are acted out by the subject. Both recall and recognition are enhanced by the SPT condition (Cohen, 1983; Engelkamp, 1998). As with the generation effect, there is no final agreement on the mechanism underlying the SPT effect. It seems likely that some item-specific encoding enhancement is involved (Engelkamp & Zimmer, 1994), possibly either greater elaboration of the phrase when it has to be enacted or possibly the verbal information is enriched by the addition of further visual and motor information in the case of SPTs (see Nilsson, chapter 9, for further discussion).

Although it seems paradoxical at first, an act of retrieval can either benefit or impair subsequent memory performance. The positive effects of retrieval are easier to understand. Tulving (1967) showed that test trials were as effective as further study trials in boosting learning; similarly, the simple procedure of retrieving some newly learned fact repeatedly (a new name, for instance), preferably at progressively longer spaced intervals, boosts subsequent recall performance (Landauer & Bjork, 1978). This effect of retrieval practice may have two major underlying causes. First, repeated successful retrievals may somehow reinforce the appropriate sequence of retrieval operations. Second, it is arguably the case that any conscious mental operation acts as an encoding operation whatever its primary purpose; so by this principle, retrieval processes (like perceptual processes) will provide further encoding opportunities (Bjork, 1975). Further, an act of retrieval is likely to be more effective as a second encoding to the extent that the retrieval processes involve deeper, semantic processing operations.

On the other hand, retrieval processes can act to inhibit the subsequent recall of information *associated with* successfully retrieved target information. In one such demonstration, Brown (1968) had subjects study 25 of the 50 U.S. states, followed by a recall attempt of all 50 states. Relative to a control group that had no preliminary study session, the first group recalled more of the studied 25, but fewer of the unstudied 25. Apparently study had inhibited recall from the complementary subset. A similar phenomenon was observed by Slamecka (1968) and has been studied exhaustively under the heading of "part-list cueing inhibition" (e.g., Roediger, 1973). In more recent work, Anderson, Bjork and Bjork (1994) had subjects practice retrieving half of the items from each of several categories. The finding is that in a subsequent recall attempt in which all items must be recalled, the nonpracticed items' recall is inhibited relative to appropriate controls. According to Anderson and his colleagues, this is because nontarget items are inhibited or suppressed during the initial retrieval practice session, and this retrieval-induced inhibition persists to the second retrieval session. Apparently retrieval acts to facilitate the recall of wanted items by suppressing the recallability of associated but unwanted items.

Finally, several studies have now shown asymmetrical effects of divided attention on encoding and retrieval. Subjects in these studies carry out a secondary task while encoding or retrieving lists of words, say, and the finding is that division of attention has a strongly negative effect on later recall and recognition when the secondary task is performed during encoding, but relatively little effect when performed during retrieval (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Kellogg, Cocklin, & Bourne, 1982). This finding is of interest first because it may shed further light on the similarities and differences between encoding and retrieval processes (Craik, Naveh-Benjamin, & Anderson, 1998), and second because divided attention appears to have very similar effects to those caused by aging, intoxication, and sleep deprivation (Nilsson, Bäckman, & Karlsson, 1989). The common factor in these various conditions may be the temporary or permanent loss of processing resources (e.g., Craik & Byrd, 1982), but an alternative possibility is a breakdown of control of cognitive operations (Jacoby, 1991).

Conclusion

It seems likely that the next 10 years will see a clarification of several issues regarding encoding and retrieval processes. Specifically, investigators will continue to identify the similarities and differences between these two types of processes. In addition, recent developments in neuroscience (see, e.g., Nyberg & Cabeza, chapter 31; and Rugg & Allan, chapter 32) will likely provide us with a clearer account of the neural correlates of control or processing resources, and a fuller understanding of how they affect the processes of encoding and retrieval.

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