I. INTRODUCTION

The experimental study of human learning and memory began in 1879–80, when Hermann Ebbinghaus initiated experiments on himself. Although he did not use Fechner’s psychophysical methods in his studies, Ebbinghaus was influenced by Fechner’s work, with its emphasis on precise experimentation and quantitative treatment of data (see Littman, Chapter 2, and Hochberg, Chapter 3, this volume). Ebbinghaus’ interest in memory, however, probably developed during a period of residence and study in England, as the English philosophy had much to say about memory and its laws. Ebbinghaus’ experiments were published in 1885 in a monograph entitled *On Memory*. He published no further major work on memory, but his monograph had an enormous impact, one that is felt to this day, as indicated in this chapter.

Ebbinghaus employed nonsense syllables and poetry in his studies, and he read and recited these materials. Other tasks were also introduced early in the study of human learning, such as telegraphy, typewriting, mechanical puzzles, archery, and mirror tracing (see Woodworth, 1938). These studies introduced the topic of motor skill into the study of human learning. Mazes were adapted for work with humans, in part to allow comparisons of human performance with that of lower animals, like the rat. The rationale for such studies reflected the influence of the theory of evolution (see Gottlieb, Chapter 4, and Jenkins, Chapter 5, this volume).

Early work with animals has had implications for the analysis of human learning and memory. Thorndike (1898) proposed basic laws of learning as a result of his studies of the behavior of animals learning to escape from puzzle
similarity, and contrast. What they mean is that elements will be associated if they occur together in time or space (contiguity), if they resemble each other (similarity), or if they contrast with one another. The secondary laws modify the effects of the primary laws "in inducing one association rather than another [quoted by Warren, 1921, p. 73]." Three of these laws indicate factors that promote the formation of associations:

1. Duration; that is, how long the objects to be associated are "dwelt upon"—the longer the "dwelling", the stronger the association.
2. Liveliness; that is, the more lively the reactions to the objects, the stronger the association.
3. Frequency; that is, the more frequently the objects occur together, the stronger the association.

Together with contiguity, these three laws have received much empirical study, and they have often received empirical support. Brown's next law (recency) states that associations formed recently will be remembered better than those formed earlier, and the fifth law states another condition for remembering: The event with fewer alternative associates will be remembered better than one with many associates. This law resembles modern interference theory, which would predict good or bad remembering on the basis of the number of interfering associations. Recency of experience also figures in modern accounts of memory.

Brown's sixth, seventh, and eighth secondary laws are concerned with differences among people (constitutional differences) and variations in an individual in time, either because of emotions and moods or because of states like ill health or intoxication. These laws have received less subsequent attention than the other secondary laws. The last law, the influence of one's prior habits of life or thought, might be taken as paralleling the modern concept of transfer, which holds that learning may be affected, positively or negatively, by what one already knows.¹

B. Some Issues in the Study of Human Learning and Memory

The associative doctrine has had its opponents, from Binet (1900), through the Gestalt psychologists and Bartlett (1932), to the cognitive psychology that has arisen since about 1960 (see Anderson & Bower, 1973; Posner & Shulman, Chapter 9, this volume). The major charges are that expectations

¹The history and points of view of the association doctrine are summarized by Warren (1921), and a more recent evaluation of associationistic principles is provided by Robinson (1932). Postman (1968b) has identified several ways in which the term association has been employed in the literature.
observation, did not figure in the accounts of memory given in the first 80 years of the century. Perhaps this neglect was due to the fact that memory was studied through the acquisition and retention of lists too long to be remembered after a single repetition.

Divisions of the memory function into parts appeared early but, as indicated, did not exert influence until about 1960. For example, James (1890) suggested that there are primary and secondary memories. An event that had passed but was still present in consciousness—that was, as James said, "in the rearward portion of the present space of time"—was assigned to primary memory. Events that are no longer represented in consciousness, that have to be recollected, were said to be in secondary memory. Meumann (1913) made a similar distinction, but it was the formulation of Atkinson and Shiffrin (1968) that captured the thought of the preceding decade and influenced that of the following decade. Atkinson and Shiffrin suggested that there is a very short-term store (a primary memory), which retains a close copy of the input for 1 or 2 seconds, a short-term store, in which recoded material remains for a longer time (perhaps as long as 30 seconds), and a long-term store, in which material endures indefinitely. The primary memory was said to have a large capacity, with its contents subject to decay; the short-term store a smaller capacity, with its information subject to either decay or displacement; and the long-term store an unlimited capacity, with its contents subject either to interference or to failures of retrieval. Not all investigators were convinced (e.g., Melton, 1963) that short-term and long-term stores differ in these ways and they thought that the idea of a multiplex memory system was unnecessary. This disagreement underlies a good deal of research in this period.

The term "capacity" was introduced in conjunction with the compartments of memory, and this word reflects an influence on the work of the last vigilentennium. The influence is that of communication theory, and the word is a central one there, as well as in an approach known as information processing. Communication theory is concerned with the transmission of information through channels of communication (e.g., telephone lines) from a source to a receiver. The channels and the receiver have limited capacities—that is, they can transmit or receive only so much information at a given time. That the human memory has a limited capacity for handling information was a central thesis of Miller (1956) and Broadbent (1958). The compartmental model of memory is an expression of the information processing view, which Broadbent once characterized as being concerned with the flow of information through the organism. The limited-capacity, short-term store is a bottleneck to this flow.

In the 1970s, dissatisfaction with the compartmental model of memory began to arise, and some of the phenomena that this model incorporated were reinterpreted in terms of a depth or levels of processing viewpoint.
To solve the materials problem, Ebbinghaus “hit upon” a method for forming nonsense syllables. He constructed all possible three-letter syllables by using 11 vowels and diphthongs and 19 consonants, using the rule that each syllable would consist of a consonant, a vowel or diphthong, and a final consonant. He constructed over 2300 such syllables, and for a particular learning experiment he selected a suitable number of syllables more or less at random. The advantages Ebbinghaus saw to these materials were that there were numerous homogeneous syllables and that most of them are meaningless. These features enabled him to construct lists that were comparable to one another or that varied from one another in the number of syllables employed.

Ebbinghaus solved the measurement problem by counting the number of repetitions or the time in seconds necessary to master a list. For other studies he used the savings method. As a way of measuring retention (or forgetting), he relearned a list previously learned and compared the time or repetitions necessary for relearning with the scores for original learning. If the scores for relearning were better than for original learning, then there was a saving, and the savings score (calculated as a percentage of the original score) indicated how much he had remembered or, alternatively, how much he had forgotten.

Ebbinghaus used a method we may call serial reproduction. Some writers (Irion, 1966; Postman, 1968a) have observed that in using nonsense syllables Ebbinghaus employed a unit that is an analogue to the simple ideas of the associationists. Postman (1968a) also suggests that “the serial task was an obvious choice for the experimental investigation of memory, for serial memorization would reflect directly the underlying process of successive association [p. 153].” As mentioned earlier, successive or sequential association had been a major interest of the associationists.

What problems did Ebbinghaus study with his methods? He compared the number of repetitions required to learn lists of several lengths and made comparisons with the learning of poetry (Byron’s *Don Juan* in English). He studied retention as a function of the number of repetitions in original learning and also a function of the time since learning was complete (forgetting). He found that relearning lists over several successive days was advantageous in comparison to the case in which all the practice was massed on one day. Finally, he studied savings when the lists were systematically derived from lists learned earlier. Here he found evidence that associations were formed not only between adjacent syllables but also between nonadjacent syllables (remote associations) in both the forward and reverse directions.

Ebbinghaus’ investigations provided a model of how to study the learning and retention of associations according to the law of contiguity and the principle of frequency, the third of Thomas Brown’s secondary laws. Ebbinghaus’ influence on later generations of researchers is reflected in their
preference for the paired associate method in the vast majority of relatively recent studies. Ebbinghaus' example has remained, in this area, a model that has guided the procedures for research, the choice of problems to be studied, and some of the ways in which the results have been interpreted.

Ebbinghaus (1885) recognized that lists of syllables "exhibit very important and almost incomprehensible variations as to the ease or difficulty with which they are learned [p. 23]." He observed that the "mother tongue" created dispositions "for certain combinations of letters and syllables [p. 24]."

Ultimately, much research was devoted to the calibration of nonsense syllables and other units in terms of properties that relate to ease of learning (see Cofer, 1971; Paivio, 1971). The first work was performed by Glaze (1928), who studied the association value of nonsense syllables. The association value of a syllable was assessed by determining the proportion of subjects who gave or thought of an associate to the syllable. Noble (1952) introduced the concept of meaningfulness \( m \), applicable to both nonwords and words. He counted the number of associates produced by a group of people to an item in a standard period of time (e.g., 60 sec.); \( m \) is defined as the average number of such associates. Noble's (1963) review shows that rate of learning of lists is predicted by \( m \) and other measures of meaningfulness and by various other characteristics of verbal materials. Examples are: rated familiarity, pronounceability, and frequency of occurrence (see Thorndike & Lorge, 1944) in the language. Correlations among these different measures are high, and correlations between values for the same measure over substantial intervals of time (e.g., 30 years) also tend to be high (see Underwood & Schulz, 1960). Paivio (1971) has found that rated imagery correlates well with learning, as does the concreteness (as opposed to abstractness) of words. He argued that imagery-concreteness may be a more fundamental property than meaningfulness or association value, and he has proposed that there are two codes, a verbal and a nonverbal imaginal one. Easily imaged verbal items can be coded in both ways, whereas abstract items can be coded only verbally. The presence of two codes confers high learnability on the easily imaged, concrete items. A highly concrete, easily imaged pair of words is exemplified by tiger-lion, an abstract pair by justice-beauty.

All of these measures correlate well with rate of learning in both serial and paired associate tasks. One interpretation of this relation is that there are two stages in the acquisition of such tasks. One stage involves the integration of the units to be learned. An easily imaged, meaningful, and pronounceable unit (e.g., cat) does not require integration and can thus enter directly into association formation with other items in the list, the second stage. A set of poorly integrated items (e.g., volvap) would, however, have to be learned as such before they could effectively be associated with one another (see Mandler, 1954; Underwood, Runquist, & Schulz, 1959).
These authors asked their subjects to use either a trochaic or an iambic rhythm and found the former more effective for learning. (The trochee and the iamb are two-element or two-beat feet or units; the first beat is accentuated in the trochee, the second in the iamb.) Rhythm affords a way of grouping the materials to be learned. Subsequent work (see Bower, 1972) has fully supported the role of grouping as an aid to learning. For example, the letter string PTZLQN BWD is much harder to remember than the same letters grouped in sets of three: PTZ LQN BWD.

Recitation during practice on verbal materials (Gates, 1917) is beneficial to immediate recall. Gates had school children study either 16 nonsense syllables or short biographies for 9 minutes. He compared the divisions of the study time. Thus some children were told to give all of it to reading, but others spent 80%, 60%, 40%, or 20% on reading. When the subjects were not reading, they were asked to recite the material and could prompt themselves by looking at the material. Performance on nonsense syllables was best for those who spent 20% of the study time in reading and 80% in recitation. Recall of the biographies also was somewhat improved when either 80% or 60% of the study time was devoted to recitation. Somewhat similar results were found for adults. These findings highlight the importance of active rehearsal as a condition for learning. Studies of notetaking, outlining, and question asking during periods of study are modern, applied variants of Gates' research.

To learn a poem by heart, one can attempt to learn the entire poem (the whole method) or learn it by parts (e.g., stanzas), and later put the stanzas together. Following Steffens' (1900) work, which suggested an advantage for the whole method, there was further research concerning the relative advantages of the two procedures (and variations on the part procedure). However, neither method showed a consistent superiority. Kausler (1974) says that "the studies are difficult to interpret, and the conflicting findings reported in them are hard to reconcile [p. 201]."

Extensive work has been devoted to comparisons of massed and distributed practice in serial and paired-associate learning. In these cases the typical way of distributing practice has been to increase the intertrial interval. There is some advantage to this kind of distribution for serial learning (Underwood, 1951), but the findings for paired-associate learning are inconsistent (Underwood, 1961). Where there is an advantage for distribution in these situations, the advantage is small. Greater effects are seen in the free recall situation. In this case, a long list of words is presented, and the subjects are free to recall the items in any order. Massing and distribution are achieved by repeating items during list presentation. If an item is presented a second time immediately after its initial presentation, there is massing; if other items intervene between the presentations of the same item, there is distribution.

Figure 8.1 shows the effects in free recall of repeating items two or more times under conditions of massing and distribution (Underwood, 1969). As
associations. Increased duration of exposure of stimulus and response and liveliness (or vividness) of the elements, as Thomas Brown said, could augment the rate of association formation. This associative model has been named a stimulus–response or S–R model, and the experimental procedures have been likened to those used in establishing conditioned responses (see Jenkins, Chapter 5, this volume). To many investigators, given these several assumptions, the problem for research was to establish the functional laws that relate independent experimental variables to the acquisition of associations and to their retention and transfer. An example of one such relationship is given in Fig. 8.2, which shows idealized types of learning curves similar to those often obtained in actual experiments.

As indicated earlier, there have been objections to this approach. Perhaps the most important objections are that the learner is active, not passive, that contiguity and frequency do not guarantee that learning will occur, that associations are bidirectional, and that associations may form quickly, rather than incrementally.

In learning lists, subjects engage in strategies. As mentioned before, they may group the materials. Further, they do not always use the stimulus that the experimenter provides. They may select some part of that stimulus, the first letter of a nonsense syllable, for example, in paired-associate learning, if that letter distinguishes the syllable from other stimulus syllables. This strategy is known as stimulus selection (Underwood, 1963). Subjects will also attempt to recode the pair in some way. In the case of the pair XBN-RAT, one subject (Underwood & Schulz, 1960, p. 299) reported that X suggested poison and so the pair learned was poison-rat. Subjects will also sometimes use mnemonic devices, such as imaging the pair members as interacting. The number of strategies that have been identified (Battig, 1968) is large, and this fact does not accord well with the conception of the passive learner.

**FIG. 8.2.** Idealized learning curves, one for correct responses (the rising curve), and one for errors (the declining curve).
view of transfer postulated that the mind is composed of faculties, like reason, imagination, and memory. It was further presumed that these faculties could be strengthened by exercise, as is true of muscles. These claims arose from the doctrine of formal discipline, which held that the harder the subject the more strength the faculty would gain. This argument was used to justify the emphasis in the curriculum on mathematics and classical language (Monroe, 1905). Study of such subjects, it was believed, would exercise and thus strengthen the reason and the memory.

William James (1890) made the first tests of this doctrine. Using himself as a subject, he devoted part of 8 successive days to learning 158 lines of a poem by Victor Hugo. Then he gave himself practice in memorization by learning the first book of Paradise Lost; he studied it for 20 minutes or so a day for 38 days. He then learned another 158 lines of Hugo’s poem. Compared to the original learning, there was no positive transfer from the training. James also reports data from four other observers that show either no or very little transfer. Thorndike and Woodworth (1901) also presented evidence concerning the doctrine of formal discipline. They studied tasks like estimating the lengths of lines and the areas of rectangles. They found little transfer to similar tasks and attributed such transfer as was obtained to identical elements shared by the tasks. Thorndike (1924) examined transfer from Latin, mathematics, physics, and chemistry studied in high school to scores on intelligence tests. He found a slight advantage for students who had taken these courses as compared with those who had taken nonintellectual courses, but he did not believe that the gain was due to the specific courses taken.

Studies like those conducted by James and by Thorndike and Woodworth may be regarded as being concerned with ability training (Postman, 1971). Little transfer occurs except where tasks possess common features or elements. Woodworth (1938, p. 195) indicates that by common or identical elements (also called components) Thorndike meant “specific movements and associations, ideas of aim and method, an attitude of confidence or of care, habituation to distraction or strain.” Common components, then, need not be highly specific elements. On the other hand, they may not be as broad as Judd’s (1908) general rules or principles as the basis for transfer. What Judd meant is indicated by an often-cited experiment. Judd studied 10- to 12-year-old boys who were asked to throw a dart at a target 12 inches under water. After initial training on this task, Judd instructed one group of boys in the theory of refraction. Then both groups returned to the original task but with the target only 4 inches under water. The instructed group performed well almost immediately, whereas the uninstructed group performed as poorly as it had at the beginning of the original task. Judd called the use of rules and principles “generalization,” a concept broader than identical elements.
Postman (1971). This research shows that transfer is affected by stimulus similarity and by response similarity, but it is difficult to apply these and other generalizations beyond the paired-associate task itself.

5. Retention and Forgetting. We retain or remember some of what we learn; what we do not retain or remember is said to be forgotten. Ebbinghaus was the first to study retention. He used the savings method, and he found rapid and pronounced forgetting, as seen in Fig. 8.3. Forgetting need not be as great as this. Retention of the content of a prose passage or of a list of words or of a poem is often very good. Furthermore, what we cannot recall we can often recognize. Bahrick, Bahrick, and Wittlinger (1975) studied recall and recognition of high school yearbook pictures over intervals ranging from 3.3 months to over 47 years. Except at the longest intervals, recognition memory declines very little, although the recall measures showed substantial losses (see Fig. 8.4). Shepard (1967) has also demonstrated excellent recognition memory (90%) for pictures over a 7-day retention interval.

Some of our “forgetting” is undoubtedly due to our not having learned well in the first place. If we have not learned something, it is inappropriate to say that we have forgotten it. This comment elaborates a point made earlier that retention is a function of degree of original learning. However, with degree of learning controlled, distributed practice during acquisition has large benefits for retention. Keppel (1964) used 24-hour intertrial intervals. Retention was 72% after 8 days under this condition but was only 7% when massed practice was employed. Such a marked difference suggests the practical value of distributed practice for retention.

Explanations of forgetting usually point to one of two broad classes of factors. One class holds the following view: A trace of a learning experience is left in the nervous system. This trace may decay with time or with disuse, or it may change in time. Under the first alternative, recall could not occur after

![FIG. 8.3. Ebbinghaus' forgetting curve. The savings score is plotted as a function of retention interval. After Ebbinghaus (1885.)](image-url)
task may involve a new response, C. Retroactive inhibition indicates that recall of the A–B pairs is inhibited because of the strength of the A–C pair. Proactive inhibition is seen when the recall of A–C is interfered with by the prior learning of A–B; the concept of proactive inhibition was first identified by Whitely (1927). This account of interference theory is restricted to essentials, many details and varying alternatives being omitted.

Both retroactive and proactive inhibition can be demonstrated readily in laboratory investigations of list learning. Their application to the retention of a single list illustrates how they could be employed to explain real-life forgetting. Activities we undertake after we learn a task interfere with the retention of that task. If this is true, then reducing activity during the retention interval ought to result in improved retention. Jenkins and Dallenbach (1924) tested this idea with two subjects who learned lists of 10 nonsense syllables and attempted to recall them after 1, 2, 4, or 8 hours of either normal waking activity or sleep. The results indicated substantially less forgetting after sleep than after waking activity. Subsequent research (Ekstrand, 1967) has confirmed these findings. Interference theory would also predict that if the waking activity is very different from the one learned and to be remembered, forgetting would be diminished. This condition, however, is difficult to assess in real life. Neither the good retention after sleep nor the prediction that forgetting is a function of the kind of intervening activity would necessarily be predicted from decay theories of forgetting.

For many years, retroactive inhibition afforded the major explanation of real-life forgetting according to interference theory, although it was never clear how the enormous forgetting of nonsense syllables shown by Ebbinghaus could be explained by interference from normal waking activities, which are so different from lists of nonsense syllables. Underwood (1957), however, showed that much of the forgetting reported by Ebbinghaus is due to proactive interference. It will be remembered that Ebbinghaus memorized many lists, all similar to one another. His forgetting curve is shown in Fig. 8.3. Underwood combed the literature for studies in which the retention of a single list was measured after 24 hours and in which the learning of the list had followed the acquisition of various numbers of other lists. Figure 8.5 shows the curve Underwood plotted for 24-hour retention of a list as a function of number of lists learned earlier. Figures 8.3 and 8.5 cannot be compared directly, but Ebbinghaus' value for retention after 24 hours is about 35% (savings)—about the same percent (recall) occurs in Underwood's curve for the case in which five lists were learned previously. Underwood concluded that much of the marked forgetting shown by Ebbinghaus was probably due to proactive inhibition from the many lists he learned in his experiments. Retention without proactive inhibition is much better than 35%, being about 75% for the recall of a single list after 24 hours. Thus, proactive interference or inhibition accounts for much of our forgetting in real life.
thus by-passing the stage of response integration. And the decreased emphasis on the multtrial procedures of list learning indicated a diminished concern with the acquisition, retention, and transfer of arbitrary pairings of items as seen in the serial and paired-associate methods.

It is customary to refer to this set of changes as reflecting the study of memory, rather than of verbal learning. Certain of these changes are not compatible with a simple associative view; at least, they could not have arisen easily from that viewpoint. The new (or renewed) emphases include those on organizational and coding processes in memory, on multicomponent conceptions of memory, and on the role of pre-existing knowledge in the construction of memory products. In addition, there has been revived interest in recognition memory, and a model of forgetting that interprets failures of retention as due to lack of access to available information in memory has been elaborated.

A. Organizational and Coding Processes in Memory

Miller (1956) pointed out that estimates of the human memory span are roughly constant, at about seven items, for materials as diverse as digits, letters, and words. This observation suggests that human memory capacity is limited, a suggestion not corresponding well to the idea that human memory has an enormous, if not unlimited, capacity for storage. Furthermore, there are many occasions when we seem to take in more than seven items of information at the same time.

Miller saw here the problem of how we overcome the limitation on our memory capacity. Miller’s solution suggested that we recode information into “chunks.” An example (not one used by Miller) will clarify this idea. Suppose that we have two 40-item lists of words. In one list the words are unrelated to one another, but in the other there are 10 words from each of four mutually exclusive categories—for example, animals, occupations, articles of clothing, items of furniture. The order of the words in each list is randomized, and the words of a list are presented one at a time to a subject who is instructed to recall the words in any order. This is the free recall procedure and was reintroduced by Bousfield (1953; see also Tulving, 1968, pp. 4–5). The method had been known early as the method of retained members but was dropped because it could not easily be analyzed in terms of stimuli and responses.

Recall of the list containing the words from categories is superior to that from the other list (Underwood, 1964b, pp. 63–64). In the recall of the former list, there will be sequences or clusters of words from the same category. These clusters occur to an extent greater than can be expected by chance. Miller’s analysis suggests that the person hearing the list containing categorized words can identify and remember the category names. There are, of course, fewer of these than there are list words, so that their number is compatible with the
FIG. 8.6. Correct recalls for CCC trigrams presented once, as a function of retention interval. The recalls occurred with latencies below 2.83 sec. (After Peterson & Peterson, 1959, p. 195, fig. 3.)

whether short-term memory follows the decay principle rather than the interference principle, and whether on other grounds as well short-term memory is different from long-term memory. These issues are discussed later. First, attention is directed to the proposal of a third system.

When an array of letters or digits is presented very briefly, there is reason to believe that there is awareness of more of the array than can be reported (Woodworth, 1938, p. 695). Sperling (1960) tested this idea by presenting arrays of letters visually for 50 milliseconds. He asked for one of two kinds of reports of what had been seen. One was a report of everything (whole report). In the other the subject was cued to report only one row of letters (partial report); however, which row to report was not indicated until the exposure was over. Figure 8.7 shows the results of these procedures when the cue for partial report was given at different times after the presentation. The data from the report of a row were multiplied by the number of rows, on the principle that, because the subject did not know for which row a report would be asked and because the row to be reported was selected at random, the number of letters available would be the same for any row. Sperling's data

FIG. 8.7. Number of letters correctly reported following a 50 msec. display of 12 letters after delays of the signal to report of 0, .15, .30, .50, and 1.0 sec. The solid bar at the right is for whole report. (Based on Sperling, 1960, p. 11, fig. 8.)
another). If the information remains long enough in STS, it is copied into long-term store (LTS). LTS is presumed to have an unlimited capacity, from which forgetting is more apparent than real. That is, our failure to remember may be due not to loss of information from memory but rather to an inability to retrieve the information that is still present there.

Although there has been wide acceptance of the sensory register and of long-term store (LTS), the short-term store (STS) has been a source of controversy. One area of dispute has concerned the causes of forgetting from STS. Questions here have been whether different processes underlie forgetting from STS and LTS (Melton, 1963) and whether the kind of coding in STS differs from that in LTS. Other problems include the duration of STS and what its capacity is.

The early work on STS suggested that the traces of items decay with time. This interpretation, however, was not sustained in an experiment by Waugh and Norman (1965), who found that it is the number of items, rather than the elapsed time that follows a to-be-remembered item, that is associated with forgetting. Waugh and Norman favored a displacement model. As formulated by Atkinson and Shiffrin (1968), STS is conceived as having only so many “slots” or spaces. When these slots are full, the entrance of another item in STS causes the displacement of one of the items already there. An objection to both decay and displacement theories is afforded by the finding that forgetting from STS is affected by the similarity of the to-be-remembered item to items that precede or follow it. Keppel and Underwood (1962), in a Peterson situation, compared retention of trigrams over retention intervals of 3 or 18 sec. when each interval was the first one tested. They found no forgetting for either interval when no previous tests had been made, but found substantial forgetting when the critical test had been preceded by other tests. This finding supports the role of proactive inhibition (PI) in forgetting from STS; but, as Wickens, Born, and Allen (1963) have shown, this PI occurs when the preceding items and the one tested are similar. Wickens et al. observed increasing PI over four trials when the materials were from the same class (e.g., letters) but found no PI on the fourth trial when a new kind of item (e.g., digits) was introduced. They named the recovery on the fourth trial “release from PI.” Loess (1964) has shown that the build up of PI occurs over only a few trials.

Another source of forgetting of the to-be-remembered unit is rehearsal-preventing activity. Retention is poorer when the retention interval is filled with a difficult task than when the interpolated task is easy (Dillon & Reid, 1969). Presumably, the difficult task prevents rehearsal. Reitman (1974) had her subjects remember a set of five words over a 15-sec. interval, during which they performed either a tone- or a syllable-detecting task. For those people who did not rehearse during the detection task, there was some forgetting; it was less, however, after tone detection than after syllable detection.
FIG. 8.9. Free recall of unrelated words as a function of serial position at presentation. The labels on each curve refer to the list length (10, 15, 20, 30, 40) and exposure duration per word (1 or 2 sec.). (After Murdock, 1962, p. 483, fig. 1.)

but do not affect the recency portion. As a matter of fact, the terminal sections of the curves (except for the shortest list) can be superimposed almost exactly. Figure 8.10 shows serial position curves for a list in which recall was either immediate or occurred after a filled interval of 10 or 30 sec. (Glanzer & Cunitz, 1966). The delay affects the recency effect but does not affect the other parts of the curve. Glanzer (1972) has shown that the primacy and intermediate portions of the curves, however, react to variables that do not affect the recency section. Among these variables are rate of presentation, meaningfulness of the items, a secondary task, chronological age, and mental ability. Craik (1970) had his subject recall each of a series of lists immediately after the presentation of the list. Then he asked for a final free recall of all the

FIG. 8.10. Serial position curves for free recall of a 15-item list after delays following presentation of 0, 10, or 30 sec. (After Glanzer & Cunitz, 1966, p. 358, fig. 2.)
instructed to learn the words or told that a recall of them would be requested. Thus the learning in these three groups was incidental—there was no intent to learn. Recall and clustering of the associated words did not differ between the groups instructed to learn and the group asked to rate pleasantness, and both of these groups recalled and clustered much more than did the groups that counted E's and estimated word length. It is a general finding (Postman, 1964) that intent to learn is unnecessary for learning if the materials to be learned or recalled are highly meaningful. In Hyde and Jenkins' case, intent to learn is also not important, given that the task (rating pleasantness) involves semantic processing; E-counting and estimating word length probably do not necessitate semantic processing but do permit a very superficial processing of the words. Craik and Tulving (1975) have extended these observations by showing that semantic processing leads to superior recall in intentional as well as incidental learning situations, and in recognition as well as recall. They also showed that there are variations in the effects of different semantic tasks. Processing was induced, for example, by showing a subject an incomplete sentence and asking whether a word to be presented next could complete the sentence appropriately. For example, one sentence was, "The man dropped the———", and the word was either "watch" or "cloud." Another, more complex sentence is of the type, "The old man hobbled across the room and picked up the valuable——— from the mahogany table." Again, "watch" is the appropriate choice. Recall was superior following more complex
the detection of ambiguity, the differentiation of complex sentences that have
the same apparent structure (e.g., John is easy to please vs. John is eager to
please), and the recursive insertion in sentences of other sentences through
embedding (e.g., The editor whom the writers that the newspapers hire like
lives in the country), offer insuperable difficulties for theories of language that
consider only the surface elements of sentences (Chomsky, 1957, 1959), as did
association theory. Bartlett’s stress on memory for meaning is similar to
Chomsky’s conception of the underlying structure of sentences.

This is not the place to discuss the details of Chomsky’s theory. Suffice it to
say that his theory of grammar stimulated a number of studies of memory for
sentences (see Fodor, Bever, & Garrett, 1974). But it soon became evident that
sustained memory for what we read or hear is, as Bartlett said, more for the
substance than for the grammatical characteristics of the input. Thus, Sachs
(1967) found that, in immediate memory, recognition for a sentence within a
passage is accurate, and word-order changes or changes from active to passive
voice are readily identified. With a delay before the memory test, however,
these three kinds of sentences no longer are differentiable, whereas a sentence
involving a change of meaning can still be rejected as not having been in the
passage. This finding is compatible with Chomsky’s idea that the underlying
structure of a sentence is apprehended and with Bartlett’s stress on meaning.
Subsequent research on memory for sentences and passages has been
concerned more with comprehension of meaning than with strictly
grammatical matters.

Evidence shows that, for comprehension and memory to occur, one must
know what a passage is about—that is, it must engage knowledge the subject
already has. For example, Bransford and Johnson (1972) developed a passage
that without a title was poorly comprehended and recalled, despite the fact
that the passage was grammatical and composed of common words. With a
title (in this case, “Washing Clothes”), however, comprehension and recall
improved markedly (see Dooling & Lachman, 1971). Perhaps the context
given by the title provides a guide to knowledge with which the input can be
integrated. In understanding an input, the subject makes inferences and
accepts presuppositions. An example of an inference is afforded by a series of
statements from a passage about a hypothetical people, the Ekawas. The
passage identifies the Ekawas as horsemen, the horsemen as nomads, and
then the nomads as plainspeople. If the inferences, “The Ekawas are nomads”
and “The horsemen are plainspeople,” are included in a recognition test, the
sentences are accepted as having been present in the passage (Brockway,
Chmielewski, & Cofer, 1974). Given the sentence “Debbie will return to
Europe,” one is likely, in a recognition test, to accept, as having been stated in
the passage, the presupposition “Debbie has been to Europe before.”

For both theoretical and practical reasons, there has been increasing
interest in describing comprehension of discourse; the practical reasons have
with comparisons of the models. The models differ. For example, some models represent knowledge as a network of concepts—that is, the semantic memory consists of nodes with pathways among the nodes (Quillian, 1968). Activation of a node may spread along certain of the paths (Collins & Loftus, 1975). One of the problems of such an arrangement is to account for the cases in which activation of a node does and does not spread to another node. An alternative model is couched in terms of features that items contain (Smith, Shoben, & Rips, 1974). For example, a given kind of bird would have values on such features or dimensions as size, color, commonness, and “goodness” as a bird (the difference, for example, between a robin and a chicken, both of which are birds; see Rosch, 1973). Items can be compared in terms of features and their values, and a similarity index computed.

Models of how people comprehend messages also are concerned with semantic memory. Among psychologists, Anderson and Bower (1973), Anderson (1976), Norman and Rumelhart (1975), and Kintsch (1974) have developed models, and students of artificial intelligence have also proposed models. These models are general ones, not limited to specific problems. They represent knowledge in an enduring memory, usually in propositional form, and represent word meanings. In general, as Lachman, Lachman, and Butterfield (1979) put it, they (the global models of comprehension) “suggest that a mature theory will contain an interface parser, a representational structure, control processes, and output synthesizing mechanisms.” This means that the system must know how to analyze the input it receives (interface parser), deal with it by directing it (control processes) to appropriate places in the enduring representational structure, further process it (control processes), and synthesize an output. For example, the input might consist of a question, the output of an answer, and the role of control processes would be to gain access to the appropriate part of the knowledge structure and carry out such operations there as are necessary to answer the question.

D. The Encoding Specificity Principle (ESP)

Earlier in the chapter, the point was made that free recall of a list of words from a small number of categories is superior to the recall of a list of unrelated words. Yet, recall of the categorized words is substantially less than complete. Tulving and Pearlstone (1966) suggested that recall would be improved if the category names were used as retrieval cues at the time of recall. One of their lists was composed of 48 words, four from each of 12 categories. At presentation time, the four members of a category were presented together, preceded by the category name, and the category name was used as a cue during recall. Cueing augmented recall in comparison to a noncueing condition. Most important, this augmentation was due to the appearance in
conditions that affect these performances differently and the conditions that produce comparable effects on them.

IV. AUTOMATIC EFFECTS OF REWARD AND REINFORCEMENT

Earlier in the chapter, it was observed that there is much evidence in verbal learning and memory situations that human subjects use strategies to perform the tasks set for them by experimenters (i.e., the subjects are not passive). Yet, there has also been a viewpoint that the influence of rewards in promoting human learning is automatic and that the acquisition of classical and operant conditioned reflexes occurs through automatic reinforcement. The major sources of these views are E. L. Thorndike and I. P. Pavlov (see Jenkins, Chapter 5, this volume).

After working with animals, Thorndike turned to the question of whether the laws of learning he had identified would hold in human learning. In his experiments with humans, reward was usually indicated by saying “right” after a response, punishment by saying “wrong.” Thorndike’s major results have been summarized (Postman, 1962) as follows:²

1. Sheer frequency of repetition produces only small amounts of learning.
2. Reward reliably strengthens stimulus–response connections and is the single most powerful determinant of learning.
3. Punishment does not weaken connections directly; whatever beneficial effects punishment does have must be attributed to the variability of behavior produced by annoyers, which in turn leads to the substitution and reinforcement of correct responses.
4. The action of after-effects upon connections is direct, automatic, and inevitable [p. 396].

The concept of reinforcement, as it has developed in this country, has much in common with Thorndike’s concept of reward; it, too, is often said to have its effects directly, automatically, and inevitably. Although there is little question that rewards and reinforcements contribute to learning, a central problem in the study of human learning is whether reward and reinforcement operate in an unconscious and automatic manner.

Many experiments in Thorndike’s tradition have been devoted to this problem (Postman, 1962), but much evidence has also come from studies of operant conditioning with human subjects. In this work, reinforcement is often given by the experimenter in the form of a verbal response, such as

²For a biography of Thorndike, see Jončich (1968).
contingency, but there was no change for unaware subjects or for the controls, who were not reinforced at all. In part B of the figure, the occurrence of human nouns is plotted for the period before and the period after awareness occurred. There is a large rise in the curve as awareness of the contingency dawns. Similar findings for classical conditioning have been reported, and some reviewers (Brewer, 1974) believe that there is no good evidence for either classical or operant conditioning in humans without awareness.

Estes (1972) has offered an informational interpretation of reinforcement as an alternative to the view that reinforcement automatically strengthens stimulus–response connections. This interpretation holds that the learner mainly acquires information about the relationship between a response and a reward (or a punishment). If that information suggests that the relationship will reoccur, then responses will be facilitated by anticipation of future rewards and diminished by the anticipation of future punishments.

In practical applications of conditioning procedures, the question of awareness is often by-passed (see Mahoney, 1974). Applications have appeared in the clinical procedures known as behavior modification and as biofeedback and in educational techniques such as programmed learning.

One clinical technique is desensitization (Wolpe, 1958), in which a person is asked first to set up a hierarchy of situations that arouse anxiety. Then the individual is asked to imagine these situations, starting with the least anxiety-arousing ones, in the therapeutic situation. No aversive consequences occur there, so that the individual may become less fearful—that is, become desensitized to the situations when they occur in real life. Other procedures in behavior modification involve withholding reinforcement for undesirable behaviors and giving reinforcements for successive approximations to the actions that are desired. Thus, one might withhold attention from a child undergoing a temper tantrum while rewarding actions that are not consistent with the tantrum. Biofeedback procedures are designed to bring some symptoms under the individual’s control. Thus, the investigator might arrange that a person’s blood pressure be taken continuously and that the measurements be displayed to the person visually. Reinforcement would be given when the blood pressure falls (or rises) from some set level. Successful results of training sessions designed along these lines have been reported for several measures of autonomic nervous system function, such as blood pressure, heart rate, and skin temperature.

Programmed learning involves preparing a lesson that introduces the material to be learned in small steps; at each one the individual is likely to perform correctly, thus being reinforced. Failure is seldom experienced, and each person progresses at a rate that he or she determines. Programmed learning is widely used. While its results are often no better than those achieved by more conventional procedures, there may be savings in terms of teacher time, reduction of failure rates, and flexibility in arrangements for
called the period of no progress a plateau, and Fig. 8.13 shows one subject's learning curves for receiving disconnected letters, receiving disconnected words, and for receiving connected discourse. The last curve shows a clear plateau from about the 17th through the 24th week of practice. Plateaus have been found by other investigators with other tasks (see Woodworth, 1938, pp. 165–170), but they do not occur in the majority of records. In his survey of the literature and in the studies he conducted, Keller (1958), himself a former telegrapher, could find no convincing evidence for plateaus in learning curves. The plateau, then, may not be worthy of much further comment, except that Bryan and Harter offered an intriguing hypothesis for its occurrence. They proposed that receiving connected discourse cannot proceed beyond a given level until lower order letter and word receiving habits are well organized. These lower level skills were thought to lie at the base of higher order skills necessary for efficient receiving. This hypothesis has aroused continued interest over the years.

B. Knowledge of Results (KR)

During the learning of a task, one can tell a subject how good the performance on a trial was, either qualitatively (e.g., “right”) or quantitatively (e.g., a numerical score), or no information can be provided at all. A number of studies (see Hardesty & Bevan, 1964; Trowbridge & Cason, 1932) clearly indicate that acquisition is aided by KR and that quantitative KR is better
Cognitive accounts propose ways of understanding such motor behaviors. For example, Adams’ (1971) closed-loop theory of motor learning uses such intervening variables as perceptual and memory traces to explain the rapid execution of motor sequences. However, he stresses the role of kinesthetic feedback, and, as just indicated, there is little time for such feedback to be effective. An alternative postulates that the innervation of the muscles resulting from a motor command is monitored and compared with an image of the intended effect (see Festinger & Canon, 1965; Keele, 1968). Another idea proposes a motor program that, once under way, runs its course but is subject to feedback from outcomes (Fitts, 1964). Schmidt (1976) has suggested that motor programs are guided by a “schema” of the response specifications necessary for the movement to achieve the desired outcomes. Although not fully developed, Schmidt’s notion resembles the schema concept introduced earlier in connection with constructive views of memory.

VI. THE SHAPE OF THE FUTURE

Prediction as to the future course of the study of human learning and memory must, of course, be uncertain. Based on the history of the last century, however, it is possible to suggest a few directions that research on memory is likely to follow.

Stated negatively, one can say that the reliance on classical association theory and on list learning procedures will be largely abandoned. The problems of classical association theory probably cannot be surmounted in light of the productive character of human memory and language and in view of the strategies employed by the active human subject. A cognitive cast to the study of human memory seems inevitable in the decades to come.

The distinction between episodic and semantic memory demarks two general kinds of memory functions, and the distinction is likely to be reflected in research. Episodic memory holds wide interest to everyone, because it is our failure to remember dates, names, and other pieces of concrete information that underlies our concerns about our memories. Studies of attention and of coding processes will probably continue, with the focus on levels, depth, or spread of processing, rather than on the compartmental models. It seems likely that forgetting will increasingly be construed as a failure of retrieval, although much forgetting may be due to inadequate initial learning. Decay and interference will likely continue as plausible causes of forgetting, although their roles will be seen as less powerful in light of the significance of retrieval failures. An important prospect for the future is afforded by the possibility that a technology of retrieval cueing might be developed—that is, it may be possible on the basis of research to design procedures for the encoding of retrieval cues at the time of initial input of


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material. Such a technology, it can be hoped, would have a broader range of applicability than the presently available mnemonic techniques.

Semantic memory looms as a major but difficult topic in the study of human memory. Its concerns will be with the representation of knowledge—facts, principles, rules—in the human mind. In addition, research must deal with the operations that are performed on knowledge in order to answer questions, make inferences, and, in general, to think.

The century has witnessed innumerable investigations, but the problems studied were derived from a conception of human memory that no longer seems tenable. The explosive increase in memory research in the last 20 years has accompanied the appearance of techniques and problems not often apparent in the earlier work. The momentum of the vigintennium will no doubt continue under the banners of episodic and semantic memory.

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than qualitative KR. However, withdrawal of KR may or may not result in a reduction of performance on subsequent trials. If a large number of trials precede omission of KR, then the reduction does not appear (Adams, 1976, p. 210). One can give KR immediately after the response or delay it. Delay of KR does not affect performance on many tasks (Adams, 1967, pp. 488-489). An interpretation of KR as the withdrawal of reinforcement and thus as paralleling the extinction operation in conditioning is not supported by the varying effects of delay and withdrawal of KR. An alternative interpretation of KR is provided later in this section.

C. Retention of Motor Responses

It is commonly believed that motor responses and skills are retained better and for longer periods of time than verbal responses. A number of attempts to compare retention of verbal and motor responses have been made, but such comparisons encounter so many methodological problems that no compelling conclusions can be drawn.

However, well-learned continuous motor responses are very well retained. After two years, Fleishman and Parker (1962) found virtually no forgetting for a three-dimensional tracking task somewhat similar to the task of piloting an airplane. A number of other studies have also shown good retention for other continuous motor tasks (see Adams, 1967, p. 500). These tasks require a great deal of practice for initial acquisition, and the high degree of learning may be one reason for the excellent retention.

However, retention losses are commonly found for discrete motor responses (Adams, 1967, pp. 501-504). For example, Ammons, Farr, Block, Neumann, Dey, Marian, and Ammons (1958) found more than 50% loss after one month for a discrete task given little practice, and about 80% loss for the same task after 2 years. Retention loss was reduced if the original practice was more thorough; but even then, after 2 years, there was a retention loss of over 50%.

The generalization about the excellent retention of motor skills, then, must be limited to continuous tasks. Discrete motor responses may be retained no better than are verbal responses.

D. Execution of Rapid Serial Movements

The interests of students of skilled performance include explaining the learning and performance of very rapid sequences of movements. An example is the rapid sequence of finger movements made by a skilled pianist in playing a string of 16th notes presto. As Lashley (1951) observed, the interval between the stroke of one finger and the next is so short as to make unrealistic the idea that a following stroke depends on the movement stimuli arising from the preceding one, as S-R theory would propose.
learning. One does not, for example, have to have a teacher available in order to work through a programmed text or the program in a teaching machine.

V. MOTOR LEARNING, MEMORY AND SKILL

Irion (1966) divided the history of this topic into three periods. The first period, beginning in the nineteenth century, was concerned with the study of learning curves for various activities (e.g., telegraphy), as well as with distribution of practice, the whole-part problem, and retention. The second period, from about 1927 to 1945, involved tests of hypotheses advanced to account for the superiority of distributed over massed practice and included work on transfer (e.g., cross-education), on the predictive value of psychomotor and other tests in the skills area, on the factorial composition of motor tasks as affected by practice (see Woodrow, 1946), and on retention and interference theory. The third period was heavily influenced by Hull’s (1943) behavior theory, particularly its concepts of reactive inhibition and conditioned inhibition, and reflected the interest in skilled performance among military psychologists during and after World War II. Following the war, there was substantial financial support from the military services for research on skills, and this research was highly sophisticated in experimental design and statistical analysis. Approximately three-quarters of the research published on skills to the time of Irion’s review was carried out in the third period. Since the third period, there has been further change in work on skills. This change is reflected in the material mentioned in the last portion of this section.

Skill involves performance in tasks like swimming, golf, target-shooting, and tennis in the sports area, and like operating a lathe or flying an airplane among occupations. Much of our knowledge about skills, however, has come from laboratory studies of continuous tasks like tracking and of discrete response tasks. Tracking involves an attempt on the part of the subject to follow a moving target. Discrete response tasks require the subject to learn, for example, which one of a set of switches to throw in response to specific visual patterns.

In the remainder of this section, a few topics that illustrate work in the motor skills learning area are described very briefly. The coverage is exhaustive neither of the area itself nor of any topic covered.

A. Learning Curves

In their study of learning Morse code, Bryan and Harter (1899) found that, for receiving messages, learning curves showed an initial improvement, followed by a period of no progress and then further improvement. They
"good," "right," or "mnmhmm." The reinforcement is contingent on the subject's giving a response, such as a plural noun, or a particular pronoun that is a member of a response class. After a period of no reinforcement that establishes the base-line frequency with which the to be reinforced response class occurs, reinforcements are administered. After the reinforcement period, an extinction period in which reinforcement is discontinued is employed. It is commonly observed that the frequency with which the desired response class occurs increases above that of the baseline period during reinforcement but declines with extinction. At issue in experiments of this kind is whether the changes just described occur without or only with awareness on the part of the subject of the response-reinforcement contingency.

The resolution of this issue is dependent on the assessment of the subject's awareness. When awareness is carefully measured, results like those shown in Fig. 8.12 are obtained. In this experiment, subjects were reinforced for saying "human nouns"—words denoting a person or persons, such as Architect, Girl, or Protestants. As shown in part A of the figure, the occurrence of human nouns increased very substantially for subjects who were aware of the

![Graph](image-url)

**Fig. 8.12.** (A) Human noun responses given by subjects aware and unaware of the reinforcement contingency and by control subjects who were not reinforced. (B) Occurrence of human noun responses before and after verbalization of the reinforcement contingency. (After Spielberger & DeNike, 1966, p. 315, fig. 2.)
recall of items from more categories than occurred in noncued recall. The number of items recalled per category did not differ in the cueing and noncueing conditions. Tulving and Osler (1968) further showed that if a cue is present at input, it is much more effective as a retrieval cue at recall than if it was not presented at input. Of the 24 words presented, 15 were recalled when the cue was present at both input and output, as compared to between eight and nine words if the cue was omitted at either input or output. These and other data led Tulving and Thomson (1973) to propose "the encoding specificity principle." This principle suggests that recall is facilitated if a cue present at input is also present at recall; apparent forgetting of material may be due not to the loss of information from memory but to the fact that no cue was encoded with the information at input or that the cue is not available at output. These ideas about inadequate or absent retrieval cues suggest an interpretation of forgetting that differs from the decay, displacement, and interference views summarized earlier in this chapter.

E. Recognition Memory

Earlier, mention was also made of the typical finding that recognition is a more sensitive index of what is remembered than recall. One hypothesis proposed to account for this difference is the generation-recognition hypothesis. The notion is that, in recall, items must be generated and that, from among the items generated one must also distinguish those that were actually presented from those that were not. Support for this idea comes from evidence that free recall is aided by associations among the words and by category membership of the words. Neither of these factors was thought to influence recognition (Kintsch, 1970).

More recent evidence has cast doubt on this hypothesis. First, there is the problem of comparing recall scores with recognition scores. Recognition scores are depressed by the number and similarity of the distractors in the recognition test, and the scores are also influenced by degree of learning (Bahrick & Bahrick, 1964; Murdock, 1963). It is not clear how to specify these variables so that the conditions of recognition are the same as those for recall.

A more serious objection comes from evidence that recognition scores are influenced by contextual factors, a finding not compatible with the generation-recognition hypothesis. For example, Tulving and Thomson (1973) presented a list of words to be remembered, and each word was accompanied by a contextual cue (another word). Despite arranging conditions that seemed to be specified by the generation-recognition hypothesis, the authors found that cued recall was superior to recognition performance.

Full understanding of the differences between recognition and recall performances remains to be achieved. Future research must analyze the
to do with the teaching of reading and other school subjects and with the problem of developing computers that can understand and produce messages. Theoretical reasons lie in questions as to the representation of knowledge in memory, gaining access to that knowledge, its utilization, and operations that may be performed in the course of gaining access to and employing knowledge. Considerable impetus to the study of these matters has come from computer science and artificial intelligence.

It is desirable to introduce here a distinction made by Tulving (1972) between episodic and semantic memory. Tulving was reacting to the differences in the study of memory in certain laboratory situations and in efforts to model the processing and use of knowledge. Tulving suggested that laboratory studies are related to our individual experiences of events and to our memories of those personal episodes. Thus, he referred to these memories as comprising episodic memory. The second class is more like knowledge, shorn of memory about where or when that knowledge was acquired. Word meanings and relationships, grammatical rules, mathematical manipulations, and the like would be included in this semantic memory. Tulving held that there would be important differences between these classes in the course of retention and their susceptibility to interference. The distinction between episodic and semantic memory is not a precise one, but it does serve to indicate that not all work with memory is concerned with the same levels of analysis.

With the increasing emphasis on studying memory for meaningful connected materials, ways of describing the content of a passage have been developed. The descriptions are at an abstract level because the content must be portrayed in terms of meaning, not in terms of the words. A description of what the passage contains permits scoring of recalls in terms of how well they represent the passage. Kintsch (1974), for example, determines the hierarchical structure of propositions underlying passage content. He has shown that recalls are better for propositions high in the hierarchy than for subordinate propositions.

Under the heading of semantic memory, a number of investigators (see Lachman, Lachman, & Butterfield, 1979) have employed classification procedures that often take the form of sentence verification tasks. Speed of response is the measure used, and the person must employ pre-existing knowledge to answer the questions presented. For example, one might be asked to give the category name for a group of words like lion, goat, horse, or to say whether items come from the same category or not. Or one might have to respond true or false to sentences like “A goat is an animal,” “A canary is a horse,” “A canary has skin.”

Models concerning storage in memory of lexical and conceptual information have been developed from the data of these experiments. There are several models, and much of the research conducted has been concerned
sentences than following simple sentences, although both presumably involve semantic processing. Perhaps, as Craik and Tulving suggest, spread or elaboration of processing may be involved rather than levels.

A great deal remains to be learned in conjunction with levels or spread of processing, and research and theory of the future will likely be devoted to this topic. It is clear that the study of short-term memory has contributed much information to our understanding of memory processes. Likewise, the investigation of short-term memory has broken the hold that list learning procedures had for so many years on the study of verbal learning and memory. The explosion of research productivity since 1958 concerning memory is in no little part attributable to the techniques and problems that arose in connection with short-term memory.

C. Preexisting Knowledge and Constructive Processes in Memory

During the period dominated by work on verbal learning, there was study of the learning and retention of prose passages (see Welborn & English, 1937). Much of this work concerned learning curves, the retention of exact wording and of ideas, and comparisons with acquisition and retention of meaningless materials. Bartlett (1932), however, reported studies on the retention of stories (as well as the memory for visual figures; see Riley, 1962). He found memory to be inexact, so much so that he proposed that in recalling, we construct or reconstruct our "recalls," on the basis of the few details we do remember and in terms of a general impression, or schema, of the material studied. Our recalls, then, are markedly inaccurate, showing, in addition to omission of some of the original, such features as dropping details and amplifying others and altering the material to fit our preconceptions (see Cofer, 1977). To some extent, Bartlett's observations were influenced by the peculiarities of the Indian Ghost story he employed (Paul, 1959). The constructive theory has appealed to a number of investigators, because basically it posits that when one reads or hears a passage there is an attempt to find its meaning—that is, one tries to relate the material to the structure of knowledge that already exists.

The meaning or thought of a sentence or a passage can be expressed in various ways; and language users can understand and produce different ways of saying the same thing (i.e., paraphrases). To do so, they must comprehend or understand what is said in a manner not tied to particular wordings. It was linguistic theory, as developed by Chomsky (1957, 1965), that highlighted the importance of paraphrase in language and that suggested how the knowledge necessary to the understanding and production of paraphrases might be conceived. The fact of paraphrase, and other features of language use, such as
lists. Although the recency effect was pronounced in the immediate recall of each list, it disappeared in the final free recall, and recall from the last positions was actually poorer than it was from the middle positions (negative recency).

After the filled delays in the Glanzer–Cunitz experiment (Fig. 8.10), recall for the final positions in the list was not zero; rather, it was about the same as that for the mid-list positions. Thus, we can conclude that the recency effect contains two components: the part that resists the effect of the delay (presumably from LTS), and the part that is affected by delay (presumably from STS).

Estimates of the capacity of STS from free recall are that it contains from two to three words. Other estimates, however, are considerably larger—about seven items from work with memory span and as many as 20 words when words occur in sentences. These variable estimates, as well as the variable estimates of the duration of STS and the overlap of coding processes in STS and LTS, led Craik and Lockhart (1972) to suggest that compartmental models of memory be abandoned. Instead, they proposed a levels or depth of processing viewpoint.

Before elaborating this idea, mention must be made of rehearsal. It will be recalled that, in the Atkinson–Shiffrin (1968) model, material can be maintained in STS through rehearsal and is copied into LTS the longer it remains in STS. However, rehearsal turns out to be a nonunitary process. Mazuryk (1974) asked his subjects to rehearse the final four items of his lists in one of three ways: by rehearsing out loud, by rehearsing silently, or by thinking of associates to the items. His results are shown in Fig. 8.11 for final free recall. Performance in immediate recall is somewhat better for silent and overt rehearsal than for associating. However, performance in final free recall is superior for associating. The associational kind of rehearsal can be called elaborative rehearsal, and it seems to underlie transfer to LTS. Silent and overt rehearsal is called maintenance rehearsal; it provides that items will be maintained in immediate memory, but it does not lead to much transfer to permanent memory.

The differences between maintenance and elaborative rehearsal, as well as the other uncertainties mentioned earlier, led Craik and Lockhart (1972) to propose that the materials and the tasks set in experiments influence the depth or level at which the materials are processed. Superficial processing, such as recoding an input into acoustic-articulatory features, leads to rapid forgetting; deeper processing, such as is involved in elaborative rehearsal, leads to better retention.

A brief description of two kinds of experiments will clarify this distinction. Hyde and Jenkins (1969) asked their subjects to perform one of four tasks as a list of words was presented; one group was told to learn the words, one to rate the pleasantness of each word, the third to count the number of E’s in each word, and a fourth to estimate word length. The last three groups were not
Reitman’s results support the occurrence of both decay and interference in the Peterson situation. Because she used five-word sets, the number of items to be retained was smaller than the usual memory span, making the displacement theory inapplicable. Unfortunately, it is not possible to assess any role that PI may have had in her results. Interference is a clear factor in forgetting in the Peterson paradigm, but the evidence just reviewed does not rule out decay as a contributing process.

A second distinction made early in work on STS was that in STS the code or representation of material presented is acoustic-articulatory, whereas in LTS it is semantic. An example of the former is provided by Conrad’s (1964) study. He asked his subjects to recall in order each of several visually presented six-letter lists. He found that the errors made for a letter tended to be the same as those made in a task in which the same letters were presented auditorally in white noise for identification. Thus, for example, a B might be erroneously remembered or identified as a C. This finding suggests that the visually presented letters in the memory experiment were recoded into a speech form (hence, acoustic-articulatory) in STS. However, the limitation on coding in STS to speech-like representations can no longer be maintained. There is good evidence for encoding in visual terms (Shepard & Metzler, 1971), and materials encoded in the same modality (e.g., visual) interfere with one another (Brooks, 1968). Although there has been dispute about it, there is also evidence for semantic coding in STS (Shulman, 1971). Similarly, the tip-of-the-tongue phenomenon (Brown & McNeill, 1966) suggests acoustic-articulatory coding in LTS. These investigators asked subjects to provide the word for each of a set of definitions; when the subject could not do so but felt the word was on the tip of the tongue, the subject was asked for the word’s first letter, syllabic length, and other features. These features were often given correctly, indicating that there is nonsemantic knowledge in LTS.

The duration of STS in the Peterson’s situation has been estimated (Melton, 1963) as 30 sec. Other estimates are considerably shorter—for example, 5 sec. according to Baddeley (1972). One reason for this discrepancy lies in a distinction between STS and short-term memory (STM). STS is a theoretical concept, whereas STM is a term applied to certain memory experiments. Performance in such experiments can reflect roles for both STS and LTS. An example is provided by the case of free recall of unrelated words. Figure 8.9 shows recall of words by practiced subjects as a function of the serial position of the words in the presentation order (Murdock, 1962). The lengths of the lists and exposure times for each word are shown in the figure. Noteworthy in these curves is their shape: All have high sections for words in the initial serial positions and even higher sections for the last few words in the list. These are called the primacy and recency portions of the curves, respectively. The middle portion in each curve is low. It is evident that length of list and exposure time affect the primacy and the middle portions of curves.
show that the amount of information available immediately after presentation, as shown in partial reports, is much greater than that contained in whole reports. Further, with partial reports the number of items reported declines over the 1-sec. interval shown in Fig. 8.7. Sperling's results, which have been replicated in both visual and auditory experiments (see Crowder, 1976), have been interpreted as showing that there is a rapidly decaying sensory memory from which information must be transferred to short-term memory. Other names for this memory are the "sensory register" and the "very short-term memory." Neisser (1967) has referred to the visual case as iconic memory and to the auditory form as echoic memory.

A general integration of the components of memory is shown in Fig. 8.8. Atkinson and Shiffrin (1968) proposed this arrangement, in which information enters the system at the sensory register. Some of the information there is transferred in recoded form to the short-term store (STS), where it can be maintained by rehearsal. Without rehearsal or the occurrence of other control processes, the information is lost from short-term store, either through decay or through displacement by new items that enter the system (Atkinson and Shiffrin have seemed to offer both alternatives at one time or

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**FIG. 8.8.** A model of the memory system. (After Atkinson & Shiffrin, 1968, p. 93, fig. 1.)
limited capacity. At recall, then, the person can decode the category names into the instances designated by the categories (see Cohen, 1963). Much experimental work now supports the importance of organization in memory (see Bower, 1972; Mandler, 1967; and Tulving, 1962, 1968).

B. Attention and Components of Memory

Miller’s observation that there is a limit on human capacity (unless supplemented by coding and organization) was consistent with the findings of research on communication during and after World War II. Broadbent (1958) summarized many experiments, the results of which also pointed to capacity limitations when information is received and processed. These experiments were concerned with multiple-channel listening tasks and with memory for short, and rapidly presented messages. In listening tasks, a person was asked to shadow a message presented to one ear and to ignore another message being presented simultaneously to the other ear. The major interest lay in what information the person obtained and retained from the message on the nonshadowed ear. If one’s capacity is limited and fully employed in shadowing one message, then there can be little or no processing of the unattended message. In fact, many experiments indicated that the person knows very little about the unattended message, confirming the idea of a limited capacity. Later work (see Kahne, 1973) has led to modifications of this view and to theories of attention. In this section, however, the concern is with memory.

Broadbent (1954) presented two strings of digits simultaneously, one string to one ear, a second to the other ear. When asked to report what they had heard, the subjects typically reported by ear, and performance for the ear reported second was inferior to that for the ear reported first. This evidence suggested to Broadbent that there is a brief, limited-capacity memory that is distinct from long-term memory, a conclusion similar to that reached by James, as indicated earlier.

Brown (1958) and Peterson and Peterson (1959) conducted further experiments on short-term memory. Their work led to an outpouring of research on this topic. The Peterson’s experiment involved presentation of a three-consonant trigram (i.e., a subspan list), followed by the presentation of a three-digit number. The subject spoke the trigram and then counted backward by threes or by fours from the three-digit number. The counting task was designed to prevent rehearsal of the trigram (distractor method). The subjects counted over intervals ranging from 3 to 18 seconds; at the end of the interval a cue was given for the recall of the trigram. Figure 8.6 shows amount recalled at each interval. Clearly, there was enormous forgetting over the 18-second interval. This degree of forgetting for a single item over such a short time surprised students of memory. Controversy arose (Melton, 1963) over
Forgetting has received a great deal of study, especially in the retroactive and proactive inhibition paradigms (Postman, 1961). The theoretical account outlined earlier, however, is no longer tenable (Postman, Stark, & Fraser, 1968). Rather it seems that instead of specific competition of responses, forgetting may be due to the inhibition of the entire first-list response set. The phenomena of interference are real enough, but it is possible that their explanation should now be sought outside the confines of interference theory (see, later, the discussion of the encoding specificity hypothesis).

III. MEMORY

In the 1950s, research turned away from an emphasis on verbal learning and toward studies of memory for materials commonly presented only once. This change came when investigators reintroduced (Tulving, 1968, pp. 4–5) the method of free recall, in which the recall of a list of words is requested in any order in which they occur to the subject, when the study of retention of lists shorter than the memory span was introduced, when memory for sentences became a way of investigating the validity for the language user of linguistic theories of grammar, and when the failure of the linguistic analysis pointed to the retention of meaning rather than of form as the major consequence of a person’s study of sentences and prose passages. These changes arose from a number of sources, as suggested later, and reflected a decline in the dominance of the Ebbinghaus tradition. The materials used in experiments became meaningful (words, sentences, paragraphs), rather than meaningless,
trace decay, but the other version, which is identified with Gestalt psychology, would predict systematic changes in recall, reflecting the altered trace. A third alternative suggests that the trace must perseverate in the nervous system for a time before it is firmly established. This neural perseveration and consolidation theory was proposed by Müller and Pilzecker (1900), and they tested it in experiments in which two tasks were learned in succession. Müller and Pilzecker expected that learning the second task would disrupt the perseveration and consolidation of the traces left by the first task and thus cause it to be forgotten. The results of their experiments confirmed their expectations.

The second class of explanation is the interference theory of forgetting. In this interpretation, interference and consequent forgetting of one task occur between one task and another one when the two tasks are similar; dissimilar activities do not interfere with each other. The intertask interference, where it occurs, causes forgetting. In one version of interference theory, forgetting is attributed to the fact that learning two responses to the same stimulus produces, when one response is equal to or greater in strength than the other, the inhibition of the response with equal or lesser associative strength. Thus, in a paired-associate situation, one initially learns pairs that can be designated as A–B, with A standing for the stimulus and B for the response. A second
Woodrow (1927) examined transfer due to training in methods of learning. He tested his subjects beforehand with several memory tasks and repeated them after the experimental treatment had been completed. There were three conditions: (1) no training or practice; (2) practice in memorizing—over 4 weeks the subjects spent 8 hours memorizing nonsense syllables and poetry; (3) training in memorizing—the subjects spent 8 hours being instructed in methods of memorizing (and also practicing memorizing with these methods). The methods included whole learning, use of self-testing, using grouping and rhythm, attending to meaning and representing it by symbols and images, being alert and concentrating, having confidence, and using associations (with nonsense syllables). The practice group showed no more gain than the no-practice group on the memory tests, but in the memory training group there was substantial improvement. It appears, then, that training in techniques of memorizing can transfer. Training in the use of mnemonic aids has a history going back to ancient Greece (see Yates, 1966) and has several contemporary counterparts. None of these systems trains the memory “faculty” as such but provides the individuals with techniques that, like those taught by Woodrow, have applicability to a number of memory tasks. Two such methods are the method of locations and the peg-word method. In the first, one learns in order a number of objects as, say, they appear during a walk on campus. When these locations are well established in memory, one can then take a list of words or a list of errands to be undertaken and project a vivid image of each word or of each errand on one of the locations. In remembering the list, one repeats the walk through campus mentally, retrieving the words or the names of the errands from the images projected on each location. In the peg-word method, one learns a jingle, like “one is a bun, two is a shoe, three is a tree,” and so forth. Again, with a list of things to be remembered, one creates an image of the to-be-remembered object in interaction with a peg-word. For example, if the first object on a list is toothpaste, the image might be of a bun with teeth being brushed with a toothbrush. Remembering the numbers will evoke the peg-words, and they in turn evoke the images projected on them. These methods and others (see Cermak, 1975) can be very effective. Their applicability, however, seems to be greatest for such memory tasks as remembering words and dates in order.

The early research on transfer was oriented toward school learning and memory training. After about 1930, however, transfer research turned to the problem of similarity between tasks or task elements as the basis for transfer. As the analysis of similarity relations developed, it pointed to the paired-associate method as the method of choice for transfer studies, because given two lists of paired associates, one could study specific transfer effects between them in terms of similarity relations between the stimuli of the pairs or between the responses, or between both, and so on. The vast literature on specific transfer has been summarized by McGeoch and Irion (1952) and
It will be remembered that Müller and Schumann (1894) investigated grouping through the use of rhythm. They also compared the strength of the association between the members of the trochee with the strength developed between the second element of the trochee and the element that followed the trochee. This element had been as frequently contiguous with the second element as the latter had been with the first element. Yet the association within the trochee was much stronger than that between the second element of the trochee and the one that followed it. A somewhat similar observation was reported by Thorndike (1932). His subjects listened to a long list of word-number pairs. Thorndike tested for recall of numbers that occurred in the pairs by presenting the word and asking for the number. He also tested for the word that followed the number in the preceding pair. Again, contiguity and frequency were the same for the two cases, but retention of the number of a pair was much better than for the word following the number. Thorndike suggested that the pair members "belong" together, and this factor of belonging was seen as clearly necessary for the effects of contiguity and frequency to be apparent.

Neither the directional nor the incremental account of the formation of associations has received consistent support from research. Asch and Ebenholtz (1962) offered data suggesting that the strength of associations is symmetrical. Rock (1957) and Estes (1960) argued for instantaneous rather than gradual formation of associations. The investigation of these proposals has disclosed many methodological complexities and difficulties (Battig, 1968; Postman, 1963). They are mentioned here only to make the point that the simple associative model has not received total acceptance.

The S-R model of Ebbinghaus, then, has been rejected or found incomplete by most current investigators. There is too much evidence for activity on the part of the learner, and the simple principles of contiguity and repetition fail to account in detail for what is learned.

4. Transfer of Training. Transfer refers to the influence that learning one task has on the learning of another task; the effects can be facilitative (positive transfer), disruptive (negative transfer), or zero (no determinate transfer). For example, learning French may aid the learning of Spanish. Learning the alphabet in the forward order has disruptive effects on learning it backward. Learning to swim would have no detectable effects on either learning Spanish or learning to recite the alphabet in backward order.

Practically speaking, transfer is a very important topic because if it occurs, then what we study and learn is not specific to the original learning situation. Thus, when we study to read, we learn more than how to read the particular materials used in our instruction. Ideally, we can, instead, read anything. Similarly, arithmetic skills, learned in class, can be applied widely. A major
can be seen, the effects of distribution are dramatic. Hintzman (1974) has summarized evidence that, in a variety of verbal learning tasks, performance increases as the time between repetitions of an item increases up to 15 sec. In free recall, even longer intervals facilitate retention of the repeated items (Melton, 1970).

Theoretical understanding of this spacing effect has not been achieved, although a number of hypotheses have been advanced (Hintzman, 1974). Clearly, spacing of repetitions of the same material, at least within limits, has effects that are large enough to have practical importance in augmenting memory for events.

Groupings of material and recitation during practice, then, join low similarity, meaningfulness, and imagery/concreteness of materials in facilitating rote learning of lists presented in serial and paired-associate formats. Spaced repetitions of items facilitate learning in several tasks. These findings show large effects on learning, and the methods involved can probably be adapted to practical learning situations.

3. Processes in List Learning. The associative approach to list learning rested on a number of assumptions. One was that the learner is essentially passive, forming associations between the stimulus, as presented by the experimenter, and the response. The typical experimental procedures provided that the stimulus and response would be contiguous in space and time, reflecting the law of contiguity, and that they would co-occur a number of times. Many investigators conceived the formation of associations as gradual, not instantaneous, with each repetition of the pair adding an increment to the strength of the association. The association was believed to be directional—that is, the association is such that the stimulus can elicit the response, but not conversely. The idea that associations are formed gradually, of course, reflects the law of frequency as a factor in determining strength of
A factor that relates importantly to ease of learning is the degree of similarity among the items in a list. In the paired associate and serial tasks, learning becomes more difficult as interitem similarity increases. This is probably due to the difficulty of discriminating among highly similar items. Thus, if we construct six syllables from only three consonants and one vowel, we will have the very similar syllables, PON, NOP, ROP, POR, NOR, RON. Even greater similarity can be obtained by using consonant “syllables” (Witmer, 1935), such as XLN, LNX, NXL, XNL, LXN, and NLX, that employ only three consonants. Try to imagine learning this list in serial order or learning each of these syllables as a response to a different letter—for example, B, C, D, P, T, V—all of which have the same vowel sound. Letter duplication in words is also a source of difficulty in paired-associate learning of lists. Nelson (1972) finds that the greatest source of difficulty occurs when initial letters are identical and next when the last letters are the same. Apparently, the semantic properties of the words are not sufficient to overcome this kind of similarity.

2. What Are Economical Ways of Learning Lists? Meumann (1913) indicated the importance of techniques that foster quick learning: “The increased demands of the present age require children to master a much greater body of knowledge than was deemed necessary in former generations. This condition has given rise to the problem as to the best means of avoiding overburdening the pupil ... it can be solved only by devising improvements in methods of learning and in methods of teaching which shall be psychologically sound [p. vi].” He believed that the results of studies like those of Ebbinghaus would contribute to the solution.

Four techniques have been thought to facilitate learning: the use of rhythm and grouping; recitation during practice; learning the material as a whole or by dividing it into parts; learning by massed or by distributed practice.

At first thought, one might think that the best techniques would be those that lead to good retention. However, it turns out that retention is governed largely by how well the material was learned in the first place. The more practice on a task the better is the retention (Krueger, 1929). Factors such as meaningfulness and imagery speed up the rate of acquisition. When the degree of learning attained with highly meaningful and less meaningful materials is equated, retention of these contrasting materials is the same. Similarly, the common view that retention differs for fast and slow learners is wrong; fast learners acquire more than slow learners and hence their retention is superior (Underwood, 1954, 1964a). Rate of acquisition is thus a better measure than retention for judging whether one method of learning is better than another.

Müller and Schumann’s (1894) subjects imposed a rhythm on their reading of a list of nonsense syllables; without these rhythms learning was retarded.
commitment to association of elements, to repetition, to list learning, and to the description of functional relationships between experimental conditions and obtained results.

B. Verbal Learning After Ebbinghaus

A large literature follows the Ebbinghaus tradition, and no adequate summary can be attempted here (but see Kauser, 1974; McGeoch & Irion, 1952). Verbal learning is usually identified with the rote learning of lists of words or nonsense syllables. The major problems studied in this paradigm, as I see it, were as follows: How is the acquisition of lists affected by features of the learning methods and the materials used? What are economical ways of learning lists? What processes underlie list learning and what is their status? What governs transfer of learning from one task to another? How may forgetting be explained?

In list learning, a list of items or pairs is presented one item at a time to a subject, who has been instructed to learn the list. A presentation of the entire list constitutes a trial. Trials are continued until some criterion of mastery is attained. This criterion might be that performance is perfect on one or on two successive trials, or is at some lower level, such as mastery of three-fourths of the list. After the criterion has been reached, a retention interval, a condition of no further practice, often ensues followed by a test of what was learned earlier.

1. Factors Affecting List Acquisition. Improvements upon Ebbinghaus’ procedures were made and involved more careful construction of nonsense syllables and of apparatus for presenting items one by one for controlled intervals of time (Müller & Schumann, 1894). For many years, variations on Ebbinghaus’ method for serial learning were used by students of verbal learning. Each item was conceived as serving as the stimulus for the next response, with that response being the stimulus for the next one. In other words, the serial list was considered after learning to consist of a chain of associations. As Postman (1968a, p. 153) has observed, employment of the method continued despite the fact that it is an unsatisfactory way in which to analyze associations between specific items.

The paired associate method, invented by Calkins (1894), eventually replaced the serial method because it permits associations to be developed between members of each pair. In it, the learner is instructed that a list of pairs of items will be presented; the task is to be able to give the second member of the pair when the first one is presented. The pairs are shown in different orders from trial to trial to minimize serial learning. Other methods, as well as variations on serial and paired associate methods, have been introduced. However, the central problem of association formation has dictated a
As a theory of forgetting, decay, mentioned as perhaps underlying loss from some of the parts of memory, refers simply to an erosion with time of the traces that experiences leave in the nervous system. Decay is thus a passive view of forgetting, arising from processes (e.g., metabolism) that take time to occur. A major contrary view denies decay and interprets forgetting as being due to the influence of interfering responses. In other words, we forget something not because it is necessarily lost forever but because some other memory or response blocks it from expression. Interference theory has taken several somewhat different forms, but in each of them it is opposed to decay theory. A relatively new theory, the encoding specificity principle, places the responsibility for forgetting on defective or inadequate retrieval processes. This view holds that many memories are available—still exist in storage—but that access to them is difficult or perhaps impossible. The way to assure good recall is to encode a cue with the to-be-remembered item at the time it occurs. Later, at recall, this cue will permit access to the desired item if the cue is present.

In this introduction a number of issues have been identified, along with some of their implications. Contrasts have been drawn between the association and the cognitive models. The unitary and compartmental models of memory have been identified. The issue of limited capacity and the question of whether forgetting is due to decay, interference, or inadequate retrieval have been introduced. These various issues, which are much more complex than a simple summary suggests, seem to the writer to be major theoretical divisions that have arisen in the progress of the century. Of course, there are many others, more specific in character, that have appeared. Some of these receive attention in the sections that follow.

II. THE ASSOCIATIONIST TRADITION:
VERBAL LEARNING

A. Ebbinghaus' Contribution

Ebbinghaus recognized the difficulty of holding constant the conditions for studying memory and saw problems in its measurement. He asked (1885): "By what possible means are we to measure numerically the mental processes which flit by so quickly and which on introspection are so hard to analyze [pp. 7–8]?" Further, he was aware that words, poems, sentences, and prose passages differ greatly from one another and that therefore none of these materials offers a simple, standard unit. Yet he wished to introduce to the study of memory the methods of natural science. To do so meant that he must surmount these difficulties. (For a more extensive account of Ebbinghaus' life and work, see Boring, 1950, pp. 386–392; Postman, 1968a; and Shakow, 1930.)
from a purely associative theory are seldom verified; that, as a result, additional, nonassociative processes must often be proposed; and that, in principle, associative mechanisms cannot account for the conceptual and productive capacities of the human mind as seen in perception, memory, thought, and language. The position contrary to association views the human organism as an active, thinking participant in matters of learning and memory, in contrast to the associationist's conception of an essentially passive organism that responds mainly in terms of associative strength.

Experimental inquiry under the associative model has been largely concerned with the formation of associations between discrete elements, a set of elements comprising a list to be learned. Factors that affect rate of acquisition, the retention or persistence of associations, and the conditions under which the learning of one association will help or hinder the learning of another one have been major emphases of inquiry. Some investigators have bypassed the state of acquisition by measuring natural-language word associations and employing interword associations in their experiments. These studies use the word-association test, a technique introduced by Sir Francis Galton (see Galton, 1879–1880).

The nonassociationists have stressed experiments with stories or other prose as their materials and have looked especially at changes over time in the retention of such materials, finding errors attributable to the subject's existing knowledge. Recent research has examined the process of comprehension of sentences and passages in terms of presuppositional and inferential factors involved in comprehension. The kinds of problems identified and the methods used in this perspective are clearly very different from those arising from the associationist model. Furthermore, the nonassociationistic models tend to eschew the naive realism of the associationists. The experimenter's stimuli, copies of which were thought by the associationists to be stored, are regarded by their opponents as subject to selective analysis and recoding by the learner; the representations in memory of these stimuli bear little or no resemblance to the original stimuli, because the representations are abstract rather than specific.

The associationist-nonassociationist (or cognitive) split runs through most of the century of research on human learning and memory, but it has been especially prominent in the last 20 years of the period. Another theme in these two decades is the notion that human memory is not a unitary thing but can be appropriately divided into components that have different characteristics and functions. The associationistic view had not divided memory into compartments and had considered it as a unitary matter. Ebbinghaus recognized that he could remember up to six or seven items after a single presentation, and Jacobs (1887) introduced the concept of the memory span—that is, the number of items a person can remember in order after a single presentation. But the memory span, which is illustrated by Ebbinghaus'
boxes. These laws, the Laws of Effect and Exercise, were also tested by Thorndike in investigations with humans, because he thought of them as very general laws, applicable across species and tasks. Thorndike's studies of human learning, however, used methods unlike the puzzle box (described later in this chapter). At the turn of the century, I. P. Pavlov, the Russian physiologist, introduced and extensively investigated the conditioned reflex in experiments with dogs. Principles of conditioning have provided a theoretical framework for some work with human verbal learning and motor learning, and conditioning has been studied in humans.

Experimental psychology in the United States, since the emergence of the functionalist and behavioristic schools late in the nineteenth and early in the twentieth centuries, has stressed learning processes. Further, it has viewed these processes as general ones, applicable across a wide range of species, including the human. Experimental psychologists have often assumed that complex phenomena, such as those seen in the human, are combinations of simpler processes and that understanding of the simple would yield the principles involved in the complex. Hence, in many studies, simple tasks were employed with humans; and principles applicable to the human, it was thought, would emerge from work with animals. These assumptions underlay much of the work of the century under review. They have foundations in the philosophy of associationism, and the next section of this chapter reviews some of the ideas of the associationist philosophers.

A. English Associationism

Throughout the study of learning and memory, an important issue has been whether the concept of association is adequate as a framework to guide research on human memory. What were the assumptions about the human mind and the processes of association made by the associationists? For most of them there were three primary assumptions: (1) the mind at birth is a blank tablet—its contents develop through the experience of the senses; (2) we sense the world as it is—that is, the associationists were naive realists; (3) our experiences are of simple ideas that can be combined into complex ideas. For example, James Mill said that one could have ideas of glass and wood, which, combined, would yield the more complex idea of a window. Such a view readily leads to attempts to decompose experience into its simple, fundamental elements, as given by sense experience, and to a concern with the process that combines simple ideas into complex ones or that underlies the succession of ideas. Association is the process, and the complex is seen as resulting from a combination of the simple by association.

All of these assumptions can be and have been questioned. However, the associationists went on to propose laws of association. In 1820, Thomas Brown (see Warren, 1921) listed twelve laws; he regarded three of them as primary and nine of them as secondary. The primary laws are contiguity,