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A PROCESS VIEW OF SHORT-TERM RETENTION

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In this chapter we question the notion that the phenomena of recent memory are best attributed to one short-term or primary memory mechanism. Instead, we want to suggest that the various characteristic features of short-term retention may be due to several different features of a general memory system. Other workers have also pointed out difficulties for the notion that all short-term effects in memory arise from a single mechanism or process; for example, Bjork and Whitten (1972) and Tzeng (1973) have demonstrated recency effects that are not wiped out by interpolated activity. More explicitly, Baddeley and Hitch (1974) have suggested that short-term memory effects illustrated by "span" techniques may be rather different from recency effects in free recall. They develop the view that span phenomena reflect the limitations of a central processor (working memory) while the recency effect may be attributable to a retrieval strategy which utilizes recency cues (cf. Tulving, 1968). Lockhart, Craik, and Jacoby (1975) put forward some suggestions on the workings of a general memory system, and it is in this framework that we will consider the phenomena of short-term retention.

As a starting point, take Tulving's (1972) distinction between semantic and episodic memory. Our interpretation of these terms is that semantic memory is that part of the system concerned with storing general knowledge about the world; common features from many past events are

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combined to provide general laws and rules. These rules, in turn, are used to guide and interpret subsequent patterns of stimulation. Thus, as well as being a storehouse of generalized knowledge, semantic memory is seen as the pattern-recognition system whose function is to interpret incoming stimuli and prescribe the best course of action on the basis of past experience. Episodic memory, on the other hand, is the system in which the records of specific events and episodes are stored. Thus, questions like *What is the capital of France?* address semantic memory whereas *What did you eat for lunch yesterday?* is a question for episodic memory. Although Tulving points up the possible independence of these two systems, we would like to stress their very close *interdependence*—indeed it seems likely that the semantic–episodic distinction actually refers to aspects of one system rather than two distinct systems, but for the moment the heuristic and conceptual advantages of regarding them as separate, outweigh arguments for a unitary system. Since, in this chapter, the perceptual and interpretive aspects of semantic memory are stressed rather than the mnemonic aspects, the more neutral term "cognitive structures" will be used to refer to this part of the system.

If the notion of cognitive structures is extended to involve all levels of perceptual analysis and not just higher-level cognitive activities, then the levels of processing ideas suggested by Craik and Lockhart (1972) can be incorporated into this part of the system. It was argued that incoming stimuli are subjected to a series of analyses, starting with "shallow" sensory analyses and proceeding to "deeper" analyses of a more complex, abstract, and semantic nature. These ideas were modified somewhat by Lockhart, Craik, and Jacoby (1975). The general notion of depth of processing was still retained, but the original idea that processing involves a necessary and inevitable series of stages was largely abandoned. We still believe that some *domains* of processing to use Sutherland's (1972) term, must necessarily precede others (e.g., some sensory processing must precede semantic analysis) but further processing within a domain may be better characterized as a lateral "spread" of encoding rather than as a hierarchically organized series of levels. In any event, when a stimulus enters the system, a series of analyses is performed, and it is proposed that the products of these analyses both form the basis for conscious perception of the stimulus, and also constitute the memory trace of the stimulus in episodic memory.

In this system, the ease of carrying out a particular analysis is determined both by the "depth" of that analysis and by the compatibility of the stimulus with the analyzing structures. Thus, both shallow sensory analyses and deeper analyses that have received much practice, will be carried out easily. Such analyses require little conscious attention to be carried out effectively.

On the other hand, unfamiliar stimuli requiring deep semantic analysis cannot be processed "automatically" and do require conscious attention. Thus, the processes of attention are seen as regulating the analyses performed on the input—processing will be apparently "preattentive" or "automatic" when little processing is required (e.g., detection of a tone) and when the stimulus is more complex but is highly familiar (e.g., the evocation of a word's name and some aspects of its meaning by its printed form). The more complex and unfamiliar the processing, the more attention must be devoted to the processes of analysis.

The products of the analyzing operations carried out on a stimulus form the conscious percept evoked by the stimulus and they also provide one source of short-term memory phenomena. That is, the products of current operations are still in mind, still in conscious awareness—following James (1890), Waugh and Norman (1965) and others, we refer to this phenomenon as "primary memory." In this sense, an encoded item is still "in short-term memory" while we continue to pay attention to some aspects of the item. The notion that short-term memory has affinities with continued attention and awareness has also been suggested by Norman (1969), Atkinson and Shiffrin (1971) and by Anderson (1972). However, we also want to suggest that some phenomena of recent memory still occur after the item has been dropped from primary memory—specifically, that retrieval of recent events is particularly good for two or more reasons. Some speculations about these retrieval mechanisms are presented later. One further point about primary memory is that the type of coding, the nature of the material in mind, will depend on the nature of the features attended to. That is, rather than viewing primary memory as a structure in which items are placed, this type of memory is seen as the activation of some part of the perceptual analyzing system by the processes of conscious attention. These attentive processes are themselves neutral in character, but take on the attributes of the structures in which they are deployed. Finally, it is suggested that the contents of primary memory also form the latest addition to the episodic memory system—we are still aware of the current episode—but as soon as a further perceptual event occurs, the last event is pushed out of mind and "down the line" of episodic memory. This formulation removes the necessity for the notion of transfer to long-term memory; by the present view, perceptual encoding is sufficient to form the episodic memory trace—no further processes are necessary. Perhaps the best evidence that can be cited in support of the view that perceptual encoding is sufficient for trace formation is evidence from incidental learning experiments. Several studies have shown that performance under incidental conditions can be quite as good as performance in an intentional learning situation (Craik, 1973; Hyde & Jenkins, 1969, 1973).

Episodic memory is seen as a temporally ordered series of traces; our view is quite similar to Murdock's (1974) "conveyor-belt" model. Once an item has left primary memory (the proximal end of episodic memory) it must be retrieved and brought back into consciousness before some relevant decision can be made or some action performed. Jacoby (1974) postulated two mechanisms of retrieval from episodic memory. First, recent items can be retrieved by means of a search or scanning process in which the retrieval information is used to discriminate the target item from other items in recent memory. The search process proceeds backward from the present and becomes rapidly less efficient as increasingly more items intervene between presentation and test. Since the retrieval information is not used to provide access to the trace in any sense, but is used merely to select the target items from other items, the nature of the retrieval information (semantic, acoustic, etc.) has little effect on the forgetting rate—that is, the drop in effectiveness with increasing delay or a greater number of intervening items.

With very long delays between the presentation of an event and its attempted retrieval, it is quite implausible that the subject searches through all intervening items. In this second case, Jacoby suggested that the subject uses the retrieval information as a basis for reconstructing, as nearly as possible, the original perceptual encoding of the event. The reconstructive activities involve the cognitive structures, as did the initial encoding, and are guided and constrained both by the structure of semantic memory and by feedback from the episodic trace itself. This sounds rather mystical, but the basic idea is quite simple: when retrieval information is presented (either as a cue for recall, or the item itself for recognition) the system attempts to achieve a perceptual encoding of the type specified by the retrieval information. Formation of this percept is guided by processing rules in the cognitive structures, and also by feelings of partial recognition as the developing percept approximates the structure of the episodic trace. This type of retrieval is thus seen as "guided reconstruction" and in this case the nature of the retrieval information is highly important: deeper, semantic information is usually much more effective in the process of reconstruction, and such information will specify a particular episode more precisely. That is, shallower phonemic or structural features may be shared by many events, whereas deeper semantic patterns are generally more unique and distinctive.

Some evidence for these two retrieval strategies was also provided by Jacoby (1974). He presented each of two groups of subjects with a continuous list of 80 words. For one group, the list contained pairs of rhyming words at spacings of 0, 3, 6, and 12 intervening items, and the subject's task was simply to decide for each word whether a rhyming word had occurred previously in the list. The second group of subjects had a similar task on their 80-word list except they were looking for the presence of pairs of words from the same semantic category. The results of this part of the experiment are shown in the upper part of Fig. 1. The figure shows that in both cases detection of the paired word decreased somewhat as the spacing between words increased, but that there was no difference in the rate of decline between semantic and rhyme judgments. Jacoby suggested that subjects were using the scanning strategy to search for related words and that acoustic information was as effective for selection as semantic information. In an unexpected second phase of the experiment, subjects were given the first member of each pair of words and were asked to recall the second member. The results are also shown in Fig. 1 and it is seen that acoustic information is now much less effective than semantic information as an aid to retrieval. In this case, with a much longer delay between presentation and test, the scanning strategy is ineffective and the reconstructive strategy must be used. Now the richer encoding, and more powerful retrieval processes, associated with semantic information give rise to superior memory performance.

Jacoby points out that apparent discrepancies in past experiments can be resolved if the distinction between scanning and reconstruction is accepted. Although many studies have shown large benefits of semantic retrieval information over acoustic information (e.g., Craik, 1973; Hyde & Jenkins, 1969) other experiments have shown little or no difference

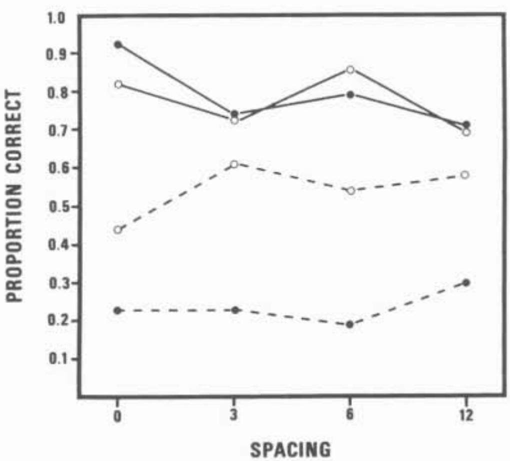

FIG. 1. Performance on a detection task (top two crves) and on a recall task (bottom two curves) for semantic and rhyme groups: open circles, semantic; closed circles, rhyme. (Data from Jacoby, 1974.)

between the two types of information (e.g., Bregman, 1968; Shulman, 1970). It is suggested that, whereas reconstructive activities dominated retrieval in the former set of studies, subjects tended to use a scanning strategy in the latter set, perhaps because of the generally shorter lags between presentation and test. Other studies that fit a backward search model are the reaction-time experiments by Murdock and Anderson (1973), although in this case, the lags can be quite long. Finally, it should be pointed out that Jacoby's distinction between two retrieval strategies bears many resemblances to Tulving's (1968) distinction between two types of retrieval cues in memory. The difference between the notions lies principally in the fact that Jacoby's retrieval strategies are not equated with any particular types of retrieval information—they are different modes of cue utilization—whereas Tulving's distinction is largely between two kinds of cue, temporal–phonemic on the one hand and semantic on the other.

To summarize, when a stimulus enters the system it is first processed more or less elaborately in the perceptual–cognitive system or "semantic memory." The subject is consciously aware of the products of these processing operations, and the resulting encoding simultaneously forms the latest addition to episodic memory. After further perceptual events have intervened, the original stimulus must be retrieved from episodic memory if it is to reenter consciousness. If the event was recent, it may be retrieved by means of a backward scanning process, otherwise the retrieval information is used to reconstruct the initial encoding.

It is suggested that the phenomena of recent memory may be tentatively attributed to three aspects of this general memory system. The first aspect is primary memory, described here as the products of current perceptual and cognitive operations. Items "in primary memory" are still in conscious awareness and are obviously more easily retrieved than items presented some time ago. It also seems likely that the characteristic of limited capacity is due to this part of the system (the notion of capacity is examined further later). The second source of recency is the backward scanning process. It is postulated that this retrieval strategy becomes rapidly less efficient as intervening events accumulate, thus giving rise to a further type of short-term forgetting. Finally, there may also be recency effects associated with the reconstructive retrieval strategy. Two possibilities are (*a*) that recently activated patterns of encoding in the cognitive structures can be relatively easily reactivated, provided little time has elapsed or few further events have intervened; and (*b*) that the reconstructive processes in the cognitive structures obtain more effective feedback and guidance from relatively recent episodes.

In the next section, some classic characteristics of short-term retention are described in terms of the present model. In the final section, some experiments are briefly reported and their compatibility with the present scheme examined.

CLASSIC FEATURES OF SHORT-TERM RETENTION

Four central issues for short-term memory research will be discussed and reinterpreted in the light of the ideas just outlined. These issues are capacity, coding, short-term forgetting, and the notion of transfer from short-term to long-term store.

Capacity

In the present scheme, primary memory reflects the activity of analyzing operations in the perceptual system. This activity may be thought of as one function of a limited-capacity processor that is deployed within the cognitive structures. The limited number of operations activated by the processor are then phenomenologically "in mind." By this view, memory span is simply the number of items for which activation can be maintained. The fact that span is affected by the nature of the material—sentence span is longer than digit span or word span—can be handled either by postulating that with deeper, more meaningful strings of items, the processor deals with superordinate descriptors of feature bundles (Miller's "chunks"); or by postulating that meaningful strings can more easily be maintained by the reconstructive processes in semantic memory, since they conform to learned rules and regulations.

Thus, the phenomenon of limited capacity is a function of the limited-capacity processor operating within the cognitive structures. The number of items held in this way will depend on the depth at which the processor is operating—more items can apparently be held at deeper levels, since the reconstructive processes can utilize learned rules.

A somewhat different way of looking at the phenomenon of limited capacity is that the limit is in terms of discriminability or resolving power rather than in terms of the number of items held. Thus, rather than the metaphor of a limited volume which can hold a fixed number of items, the alternative metaphor is a perceptual one, likening those items in consciousness to items in the visual field. Items in the center of the field are well perceived and discriminated from each other; items in the periphery are perceptually present but are not well discriminated, and items beyond peripheral vision are not present at all. A description of capacity effects in terms of discriminability has also been suggested by Kinsbourne and Wood (1975). The discriminability view has the attraction that Miller's (1956) observations on the similarities between memory span and absolute perceptual judgments may not be coincidental after all.

Coding

Many short-term memory studies have been concerned with the coding issue—that is, with the nature of the short-term trace. Although much initial work pointed to an acoustic code for verbal items held in short-term memory (Baddeley, 1966; Conrad, 1964), later studies have postulated articulatory (Hintzman, 1967), visual (Kroll, Parks, Parkinson, Bieber, & Johnson, 1970), and semantic codes (Shulman, 1970).

In the present scheme, the coding issue is largely bypassed, since the nature of the code is a function of the type of operations currently active. Put another way, primary memory encoding depends on those features of the item which are being attended to or rehearsed. Whereas it seems likely that *any* salient feature may be used to hold the item, it is also reasonable that the name of a verbal item would provide a compact "handle" by which the word can be retained. The position suggested, then, is that while short-term encoding can involve any set of features which are activated or attended to, verbal items may usually be held in terms of their phonemic features.

Forgetting

Short-term forgetting is the function of several different processes. First, once a new perceptual event occurs, the previous event is no longer attended to and is dropped from conscious awareness or primary memory. This element of short-term forgetting has thus an all-or-none flavor—the item is either attended to or not attended to. It seems reasonable, however, to soften the description and suggest that when some new event occurs, some critical features of a few previous events can still be maintained—especially if the subject is trying to retain them, as in a memory test. If the subject's attention was totally diverted to some other event, however, the initial item would presumably be dropped from primary memory.

A second source of short-term forgetting is the drop in efficiency of the episodic scanning process as the event becomes less recent—empirical findings attributed to this source include the effect of spacing in Jacoby's (1974) data shown by the top two curves in Fig. 1; also the results of studies by Shulman (1970) and Bregman (1968). Further data relevant to this aspect of forgetting are presented in the following section. It is also tempting to include under this heading Murdock and Anderson's (1973) result of a linear increase in recognition latency with increasing lag, although this necessitates a backward scanning process which can operate effectively through at least 200 intervening items.

The third source of short-term forgetting is the declining effectiveness of the reconstructive processes as the event becomes remote. The sort of empirical findings which may be speculatively attributed to this source are the reports of relatively long-term recency by Bjork and Whitten (1972) and Tzeng (1973). Both studies found evidence that recent groups of items were better recalled than less recent items, even although an irrelevant task was interpolated between presentation and recall. Such recency effects are apparently relatively stable as opposed to the very fragile recency obtained in immediate free-recall tasks (Glanzer & Cunitz, 1966). Similar long-term recency effects have been found in cases where subjects are unexpectedly asked to recall all the words from a series of preceding lists. It is consistently found that words from recent *lists* are recalled better than words from early lists, although many further presentations and tests have intervened (Murdock, 1972).

In general, then, short-term forgetting is seen as multiply determined and not as the function of one store or process. It may be noted that decay plays little part in these suggested mechanisms—forgetting is generally seen as an active process involving displacement and interference, although the postulated drop in effectiveness of the reconstructive processes might be viewed as a type of autonomous decay.

Transfer to Long-Term Store

The notion of transfer from one store to the next was especially important in the models of Waugh and Norman (1965) and Atkinson and Shiffrin (1968). In the present scheme, the formation of a rich, elaborate, deep encoding in the perceptual–cognitive system is also the formation of a strong memory trace in episodic memory. Since the proximal end of episodic memory is conceptualized as the perceptual present, the trace does not need to be transferred to any other system, it is already in the episodic memory system. Thus, the notion of transfer becomes redundant.

Craik and Lockhart (1972) distinguished between two types of rehearsal: maintenance and elaborative rehearsal. The first involves reactivation of analyses that have already been carried out, whereas the second involves further, deeper processing. Although elaborative processing improves memory performance, it is best viewed as further cognitive activity rather than as transfer of the material to a different memory store.

SOME ILLUSTRATIVE EXPERIMENTS

Empirical evidence from three areas will now be reviewed briefly. The data come largely from recent experiments performed in Toronto and they illustrate the effects of diversion of attention, the effects of rehearsal, and the distinction between the two postulated modes of retrieval: scanning and reconstruction.

The Effects of Diversion of Attention

In a previous paper (Craik, 1973) it was predicted that total diversion of attention from an item should lead to complete short-term forgetting of the item. This prediction was based on the notion that primary memory was equivalent to conscious experience—once attention was removed from the item it had, by definition, left primary memory. However, there is now evidence that diversion of attention does not have such a dramatic all-or-none effect. In fact, both Reitman (1971) and Shiffrin (1973) have argued that diversion of attention by itself causes no short-term forgetting. In their studies, subjects held short lists of letters or words in memory over intervals of 15–40 sec. In one condition, subjects attempted to detect faint tonal signals during the retention interval, and the finding was that this signal-detection task (which presumably required the subject's attention) caused virtually no forgetting of the memory items. There was some forgetting however (about 35%) in a parallel study where subjects detected the syllable "toh" in a mixed series of "dohs" and "tohs" (Reitman, 1971). While Shiffrin (this volume) still stands by his statements that diversion of attention is not by itself sufficient to cause short-term forgetting, a further study by Reitman (1974) has shown that when all subjects who show signs of surreptitious rehearsal were excluded from the data analysis, the remaining subjects showed 34% memory loss in one experiment and 12% loss in the second. When the interpolated task was verbal, as opposed to tonal signal detection, there was a substantial further loss. Shiffrin explains Reitman's latest results in terms of intralist interference; it is not clear, however, why no evidence of such interference was found in Shiffrin's (1973) own experiments in which five verbal items also formed the memory load. An alternative explanation is that diversion of attention from items in consciousness or primary memory, causes some loss, but not total forgetting. The items still have an excellent chance of being retrieved from recent episodic memory. An interpolated task that involves similar events to the memory items will reduce the efficiency of retrieval and give rise to more forgetting.

Two further studies can be cited in support of the position that diversion of attention causes some forgetting, although not so much as when the interpolated task resembles the memory items. Watkins, Watkins, Craik, and Mazuryk (1973) found about 50% forgetting of verbal items when subjects performed very demanding nonverbal tracking or shadowing tasks during the retention interval. Again, however, forgetting was less than that usually found with a verbal interpolated task. Also, Anderson and Craik (1974) reported a free-recall study in which the recency effect for visually presented words, was reduced by a choice reaction-time task performed concurrently with list presentation.

All these findings may be subsumed under a simple description of forgetting from primary memory. Two main factors are implicated: the first is the degree to which the distractor task diverts attention from the memory items and thus prevents even minimal rehearsal; the second is the similarity between the distractor and memory tasks. Similarity may have its effect by reducing the discriminability of memory items from other recent events and thus reducing the effectiveness of the scanning process; similarity may also be detrimental to the reconstructive strategy in that reconstructed features are now shared by many recent episodic events and precise guidance of the reconstruction is less possible. An experiment by Deutsch (1970) nicely illustrates the negative effects of distractor similarity. She found that when tones formed the material to be remembered, a further series of interpolated tones caused more forgetting than an interpolated series of numbers.

The Effects of Rehearsal

In the models proposed by Waugh and Norman (1965) and Atkinson and Shiffrin (1968), rehearsal had a dual role in short-term retention. First, the items were maintained in the short-term store or rehearsal buffer and, second, this rehearsal activity also had the effect of transferring the material to long-term storage where it was laid down in a more permanent form. The results of several later experiments make it clear, however, that the maintenance function of rehearsal can be separated from its trace-strenghtening function. These studies show that further short-term rehearsal or longer residence of an item in short-term store, is not by itself sufficient to improve long-term retention.

In one such study, Jacoby (1973) presented five-word lists which different groups of subjects recalled either immediately, or following a 15-sec period of overt rehearsal. Following presentation and recall of several such lists, the subjects were given a final free-recall test in which they were asked to recall all previous words. Final recall performance was no better for the second group of subjects, despite the fact that they had rehearsed the words more often. Craik and Watkins (1973) reported a similar experiment in which the last four words of a 12-word list were recalled immediately after presentation or were given a 20-sec period of overt rehearsal. Again, it was found that final-recall performance for the last four words was not improved by the extra rehearsal period. Using a somewhat different paradigm, Woodward, Bjork, and Jongeward (1973) also conclude that prolonged residence in the short-term store does not necessarily lead to better long-term retention.

On the basis of these studies, it is concluded that "rehearsal" must be broken down into at least two component processes. To the extent that subjects merely maintain activity at one level of analysis—that is, repeat encoding operations already accomplished—rehearsal will maintain the items in mind but will not lead to improved memory performance. Alternatively, if the subject uses the rehearsal period to perform further, more elaborate analyses then better retention will result. This distinction between the maintenance and elaborative aspects of rehearsal (primary and secondary rehearsal) is also made by Bjork in this volume. However, secondary or elaborative rehearsal is not seen as "transferring" the item to a different storage system—more simply, elaborative rehearsal involves the formation of a richer, more unique encoding of the item. This richer trace facilitates the reconstructive processes and thus enhances long-term retention.

An experiment by Mazuryk (1974) illustrates the differences between primary and secondary rehearsal processes. Subjects were presented with 14-word lists for immediate free recall. The first ten words of each list were silently learned in all cases, but the last four words were studied in one of three ways: by silent learning, by overt rehearsal, or by generating verbal associates to each list word. The immediate free recall phase was followed by a final free recall for all lists. Figure 2 shows that the "associate" condition was somewhat detrimental to immediate recall, for the last four items, while Fig. 3 shows that association yielded *superior* recall of these items in the final test. This study illustrates a positive effect of primary, maintenance rehearsal—it is a more efficient method of holding verbal items for a short time, although subsequent long-term performance is poor. Presumably, in short-term retention, more items can be held in mind if only their shallow phonemic features are processed and attended to.

The Distinction between Scanning and Reconstruction

It was suggested earlier in this chapter that after an item is dropped from conscious awareness, it can still be retrieved efficiently for some short time. Furthermore, it was suggested that very recent events may often be retrieved by means of a backward scanning or search process that uses retrieval information to select the target item. For remote events, this retrieval process is inefficient and a second, reconstructive process is involved in such cases. It was postulated that the nature of the encoded trace (phonemic, semantic, etc.) had little effect on the scanning process, whereas such encoding differences had large effects on reconstruction. The empirical justification for these ideas comes from studies by Bregman (1968), Shulman (1970), and Jacoby's (1974) experiment described earlier.

One further study by the present authors will be reported in support of the distinction between scanning and reconstruction. The experiment was originally conceived as one study in a series exploring the effects of

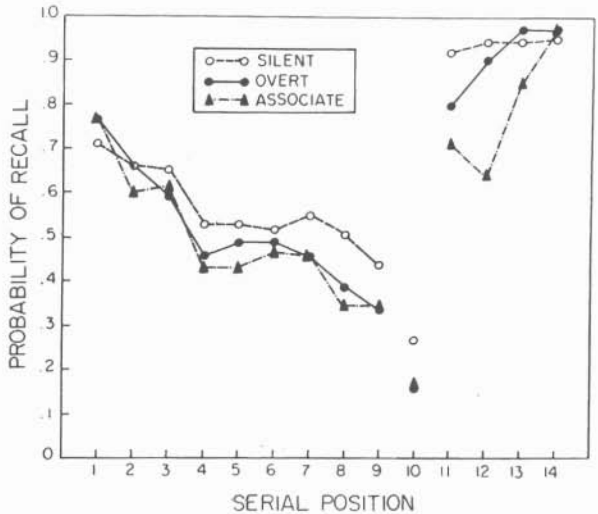

FIG. 2. Serial position curves for immediate free recall. (From Mazuryk, 1974.)

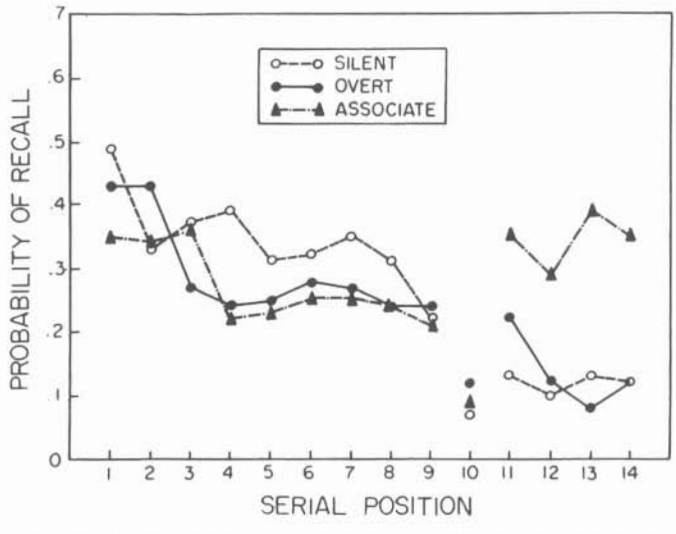

FIG. 3. Serial position curves for final free recall. (From Mazuryk, 1974.)

different encoding operations on subsequent memory performance and was designed to look at the effects of lag between encoding and recognition. Encoding was manipulated by asking subjects different types of questions about subsequently presented target words. "Shallow" encoding was induced by asking *Is the word in capital letters?* A deeper level was induced by asking *Does the word rhyme with* ________? and a semantic encoding was encouraged by asking *Is the word a member of the following category?* A long series of words was presented, each was preceded by an encoding question to which the subject answered yes or no. Also within the one long series, interspersed with the encoding questions, were recognition tests for words presented earlier in the series. Half of the recognition words were "new" distractor items; the old items were presented at lags of 0, 1, 3, 6, 12, and 24, where "lag" refers ro the number of intervening encoding and recognition trials. On the basis of previous studies in the series it was expected that the deeper semantic questions would lead to better recognition, but Fig. 4 shows that no such effect was found—recognition performance declines with lag, but there is no difference between the encoding questions or whether they necessitated a yes or no response. After 10 subjects had been tested in the experiment, it was decided to see whether the expected "levels" differences would reemerge in a final free-recall test, given subsequent to the long encoding and recognition series. The idea was that final recall performance must depend on reconstruction, since the events had occurred some time previously, and semantic encoding should benefit the reconstructive process. Thus, Fig. 4 shows the results for 20 subjects on the initial recognition test and final recall performance for the last 10 subjects. In the recall phase, the typical "levels of processing" result reappears (Craik, 1973) even although there is no trace of such differences in the recognition phase. This extremely interesting result should be treated with some caution, as attempts to replicate the finding have yielded inconsistent and noisy data—it is possible that subjects in the experiment reported here treated the study rather casually or became

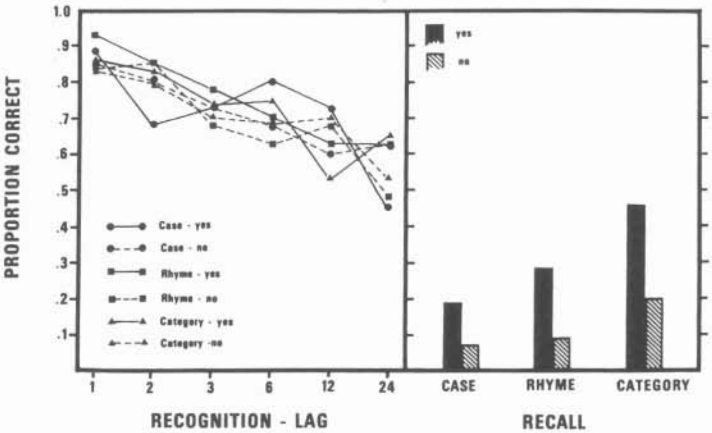

FIG. 4. Initial recognition (left panel) and final free recall (right panel) in a "levels-of-processing" task.

bored by the rather tedious procedure. In any event, under these conditions, subjects show no differences between semantic, phonemic, and structural encoding during one phase of the experiment, but such differences do appear in a later phase. The data provide persuasive evidence for the existence of two retrieval processes in recent memory, the first of which (scanning) uses retrieval information to select the target item, whereas the second process uses the retrieval information as the basis for reconstruction of the original event. Deeper level, semantic encodings are beneficial to the second process but not to the first.

CONCLUSIONS

Summary of the Ideas Put Forward

The main point made in the paper is that short-term memory should no longer be thought of as a single mechanism or process, but rather that there are a number of characteristic effects associated with short-term retention and these effects may be due to several different underlying processes. Baddeley and Hitch (1974) have also suggested that more than one process gives rise to short-term memory effects; our views have obvious affinities with their suggestion.

We have tried to document the position that three main processes underlie the phenomena of recent memory: a limited capacity central processor; retrieval by means of a backward serial scan, and a second method of retrieval in which the item's initial encoding is reconstructed. Our view of the central processor resembles the notion described by Broadbent (1958) and developed by Moray (1967) and Posner and Warren (1972)—processing is deployed within the existing cognitive structures, where it emergizes a limited number of perceptual or cognitive operations. Products of the active operations are phenomenologically "in mind" and are immediately translatable into overt responses. The precise representation of an item in the processor depends on the amount of analysis or "depth of encoding" the stimulus has been subjected to. The items or elements activated by the processor may be grouped and manipulated in novel ways—in this sense the items are described as being "in primary memory" and the processor may be viewed as a heuristic problem-solving device. The formation of a percept or "conscious construction" (Posner & Warren, 1972) in the cognitive structures is also seen, by the present view, as forming the latest addition to episodic memory.

Once conscious attention has been removed from an item, it must be retrieved from episodic memory before it can be matched with a further stimulus or given as an overt response. It is suggested that recent items can be retrieved by means of a serial search process which proceeds back into episodic memory and which uses retrieval information to select the desired item. The efficiency of the search process is impaired for remote items and for items embedded in very similar events. In the second method of retrieval, an encoding of the original item is reconstructed in the cognitive structures. Reconstruction is guided by the retrieval information provided by the environment, by habitual routines in the cognitive structures, and by feedback from the episodic trace itself. In this sense the reconstructive processes resemble a servomechanism. Further constructive efforts are guided by the memory trace so that the new encoding "homes in" on an approximate reconstruction of the original event. Recent events are easier to reconstruct than remote events since the operations underlying their representations are still primed in the cognitive structures and feedback from the episodic trace is more precise. To these two suggestions, a third may be added (Shiffrin, this volume); recent episodes will share the same contextual features as those currently energized by the processor, thus reconstruction of recent events is further aided.

Many traditional ways of speaking about short-term memory are at least partly invalidated if the present set of views is accepted. To talk of an item being "*in* short-term store" has relevance only to those items activated by the processor, not to items retrieved from episodic memory. Similarly (as Baddeley and Hitch point out) "capacity" notions are relevant only to operations involving the central processor, and not to the retrieval processes. Finally, neither coding nor forgetting can be attributed to a single structure or mechanism—both are multiply determined. On the other hand, we do not believe that the system is totally flexible and that behavior merely reflects the subject's current strategy. Further explorations must document the limitations imposed by mental structures and assess the freedom of mental operations to work within these limitations.

Comparisons with the Chapters by Bjork and Shiffrin

Although the viewpoint of the present paper is somewhat different to that adopted by either Bjork or Shiffrin, there is a substantial degree of overlap in the basic concepts. First, there is general agreement that perceptual analysis proceeds from shallow sensory analyses to deeper cognitive analyses and that short-term storage essentially involves continuing processing, or activity of operations in the permanent cognitive structures (long-term or "semantic" memory). The energizing of operations is carried out by a limited-capacity central processor which is also involved in the processes of attention, rehearsal, and retrieval (Bjork). In his paper, Shiffrin is less general about activation of long-term structures or processes, but the basic notion seems the same. All three papers agree that the active contents of the short-term store include processes induced by the present environment and also processes contributed by the organism from past learning. There is agreement that short-term storage is an active process.

Although this contribution provided no evidence on the mechanism of attention, we feel reluctant to endorse the rather automatic view of encoding put forward by both Bjork and Shiffrin. Both papers espouse a "late selection" view of attention (Deutsch & Deutsch, 1963; Norman, 1969) in which all inputs are fully analyzed but only a few are then selected for conscious awareness. It is not clear what "fully analyzed" means here. Does it imply that stories, images, and past associations are all evoked and in some sense present in the system when a series of unrelated words is presented at a rate of two words per second? That seems very unlikely. We prefer a view based on Treisman's (1969) model of attention in which shallow sensory analyses are carried out relatively easily and require very little attention; deeper cognitive analyses—especially unfamiliar, novel analyses—progressively require attention for their successful completion. Thus, while simple or well-practiced analyses can be carried out as well when attention is deployed elsewhere, the apparent "automaticity" is only relative. Even here there may be no disagreement between the papers, at an empirical level at least, since Shiffrin allows that the subject has control over the later stages of encoding.

We are in full agreement with Bjork that the qualitative nature of short-term encoding will reflect the type of operations energized (or elements activated) by the central processor. Shiffrin's view does not seem radically different. There is a growing consensus also on the roles of rehearsal. Both Bjork's paper and this chapter explicitly distinguish between the maintenance aspects (primary rehearsal) and the elaborative aspects (secondary rehearsal) of the process. Shiffrin also distinguishes between *rehearsal* of shallow (e.g., phonemic) information and higher-order coding; it seems that he too is willing to attribute two rather different roles to rehearsal. At a more empirical level, we are all agreed that longer residence in short-term store does not necessarily strengthen the item's long-term representation. Shiffrin uses the term "transfer" to describe the formation of a long-term trace, but it is not the short-term items which are transferred; rather the notion of transfer refers to the formation of a new association between items already present in long-term store. By our view, the encoding operations carried out during the item's initial presentation are sufficient to establish the trace.

Bjork's paper deals largely with encoding and storage problems. Shiffrin tackles questions of forgetting and retrieval—it is perhaps here that agreement is least and that most future effort should be expended. Shiffrin's view is that short-term forgetting is a function of interference by similarity, this notion is also a part of our scheme, in that similarity reduces the effectiveness of the scanning retrieval process by reducing discriminability, and also reduces the effectiveness of the reconstructive process since the retrieval information provided by cues does not specify an episodic trace uniquely.

Thus, although there are differences in emphasis and description between the three papers, there is an impressive degree of agreement too.

CONCLUDING COMMENTS

Is the distinction between short- and long-term memory still a useful one? If STM and LTM are conceptualized as two distinct mechanisms we are inclined to answer "no." The answer is "yes" however, if the question is asking whether there is something qualitatively different about items retrieved recently after presentation. Furthermore, since the whole functioning of the perceptual–memory system in some sense revolves around those operations that are currently active—those items in conscious awareness—we believe that a fuller understanding of the phenomena of recent memory may provide the key to a fuller understanding of cognitive functioning more generally.

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