CHAPTER 11

Recency and Recovery in Human Memory

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As time passes following a series of to-be-remembered items or events, there is a shift from recency to primacy in the ease of access to the memory representations corresponding to those events or items. Such effects occur on many time scales, across species, and for a variety of to-be-remembered materials. In this chapter, I argue that this shift, with delay, from preferential access to newer memory representations to preferential access to older representations is adaptive; I also argue that such shifts reflect the interplay of certain fundamental storage and retrieval dynamics that characterize human memory.

A chapter on recency and recovery dynamics in human memory is especially appropriate for this volume because Robert Crowder played an early and critical role in the efforts to understand the theoretical implications of recency and primacy effects and changes in those effects over time. He contributed both directly, through his own research and writing—as I attempt to indicate at various points in this chapter—and indirectly, through his students, who have shaped the field of memory research across the past several decades.

Before I move on to an analysis of the shift from recency to primacy with delay, which is the primary focus of this chapter, I need to review the evidence that recency effects reflect retrieval processes in human memory that are backward looking and sensitive to the temporal distinctiveness of to-be-recalled items. Much of the evidence for that conclusion was triggered by the introduction of the continuous-distractor paradigm, which I discuss in the next section.

Continuous-Distractor Paradigm

By accident, William Whitten and I (Whitten & Bjork, 1972, 1977), in a series of experiments on tests as learning events, stumbled across long-term effects of recency

I thank Arthur Glenberg, Ian Neath, and Henry Roediger for insightful comments on this chapter.

in a paradigm we designed to eliminate any such effects. To eliminate both primacy and recency effects, we devised what later came to be called (among other names) the *continuous-distractor paradigm*. We presented pairs of words to be remembered, we instructed the participants to restrict their rehearsal and other mnemonic activities to one pair at a time, and we required the participants to carry out a distracting (rehearsal preventing) arithmetic task before and after each pair. We then delayed the final test of participants' free recall by an additional period of arithmetic activity.

According to then-prevailing views, this procedure should have largely or entirely nullified the rehearsal and short-term-memory dynamics responsible for primacy and recency effects in free recall. Eliminating cumulative rehearsal across the early pairs should have eliminated primacy effects, and the final period of distraction, which was designed to exceed the holding time of short-term memory by a considerable margin, should have eliminated recency effects.

In fact, however, as shown in Figure 11.1, Whitten and I obtained striking effects of recency that extended back in time far beyond the holding-time limits of short-term memory. Our initial experiment included—during the period of distraction following the presentation of a given pair—an embedded overt test on, or covert rehearsal opportunity for, that pair. We entertained the possibility that such test and rehearsal events, which were the actual focus of our first experiment, might have somehow contributed to the long-term recency effects we obtained. In subsequent experiments, however, we were able to show that such effects were also obtained when such test and rehearsal events were eliminated. We also found that such effects did not appear with recognition testing, which suggested that the observed effects reflected retrieval dynamics in the recall of episodic events.

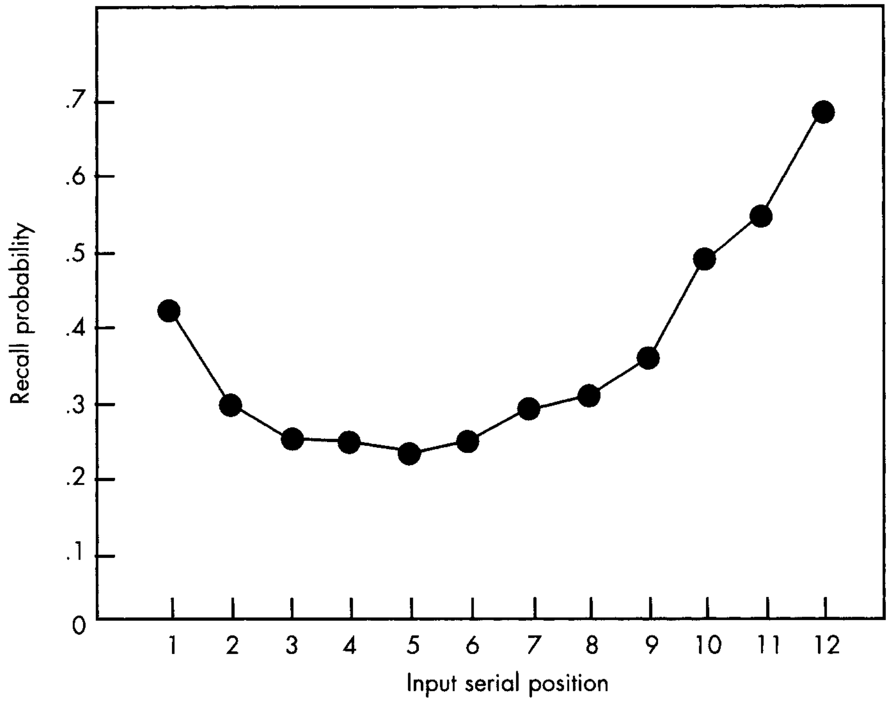
Whitten and I obtained these and other findings with variants of the continuous-distractor paradigm, which led the two of us and a number of other researchers, particularly Robert Crowder, to question not only the standard short-term-memory interpretation of recency effects in free recall but also—especially in Robert Crowder's view—the distinction between short-term and long-term memory. (We also obtained effects of primacy—as shown in Figure 11.1—which were later shown by Glenberg and his collaborators [e.g., Glenberg et al., 1980] to disappear if participants' opportunities and motivation to engage in cumulative rehearsal of successive word pairs were entirely eliminated.)

Recency-Sensitive Retrieval Processes

After initially being puzzled by the long-term recency effects we obtained and after a series of follow-up experiments, we (R. A. Bjork & Whitten, 1974) became convinced that the continuous-distractor paradigm reveals fundamental recency-sensitive retrieval processes—which, we argued, are "obscured by procedural characteristics of typical free-recall experiments" (p. 173). On the basis of our findings, we proposed

FIGURE 11.1

Recall probability as a function of input serial position. From "Recency-Sensitive Retrieval Processes in Long-Term Free Recall," by R. A. Bjork and W. B. Whitten, 1974, Cognitive Psychology, 6, p. 175. Copyright 1974 by Academic Press. Reprinted with permission.



that retrieval of the memory representations resulting from a well-ordered series of episodic events is a backward-looking process that results in preferential access to the most recent of those events.

Recency and the Ratio Rule

More specifically, we (R. A. Bjork & Whitten, 1974) proposed that

> recall following a series of ordered inputs to memory will exhibit long-term recency provided the inputs constitute a well-ordered series. Whether a series is well ordered in time is determined by two requirements: (a) Each input, whether a single item, two items, or a list of items, must be discrete in the sense that any encoding or rehearsal activities are focused on only the current item at any point in time; and (b) the actual temporal separation between adjacent inputs to memory must be at least a certain fraction of the retention interval from the presentation to the recall of those inputs. (p. 184)

The first of those requirements reflects a recognition that processes of interassociation and rehearsal during the study of a series of to-be-remembered items or events can reorder and smear the "input" positions of items or events. That is, the functional recency of a given event or item may not be determined by its nominal recency but, rather, by the point when it was last rehearsed or associated with some later event or item in the series.

The second requirement, and the kind of "Weber–Fechner reasoning" (R. A. Bjork & Whitten, 1974, p. 184) that lies behind it, is a key aspect of the proposal. The basic idea is that retrieval of a series of episodic events, as a kind of backward-looking search of memory, is sensitive to the temporal distinctiveness of the events in the series, but that such distinctiveness is determined by "the ratio of the temporal separation of successive to-be-remembered items (or sets of items) to the temporal delay from those items to the point of recall" (p. 189) rather than by the temporal separation of successive events per se. In other words, analogous to perceptual judgments of various types, whether representations in memory remain temporally distinct depends on their separation relative to the time that has elapsed prior to an effort to recall those events.

The ratio rule implies that recency effects that are present at one point in time disappear with a longer retention interval. In a test of that implication, we (R. A. Bjork & Whitten, 1974) presented four continuous-distractor lists, and we administered an end-of-experiment final free-recall test for all words from all lists—in addition to an end-of-list free-recall test after each list. On the final test, consistent with the ratio rule, within-list recency effects were no longer present, but there were between-list recency effects. That is, at the end of the experiment, the lists themselves constituted a well-ordered series but the word pairs within a list did not because, presumably, the interval separating successive pairs within a list was no longer substantial enough, relative to the increased retention interval, to make those pairs temporally distinct in memory.

It occurred to us (R. A. Bjork & Whitten, 1974) that the list-recency effects we obtained on the end-of-experiment test should also, according to the ratio rule, disappear at long enough retention intervals. When we contacted the participants the next day, unexpectedly from their standpoint, and asked them to free recall as many of the words from the studied lists as they could, the list-recency effects we had observed at the end of the experimental session were no longer in evidence. Our findings prompted us (R. A. Bjork & Whitten, 1974) to comment that "extended to its limit, the [ratio rule] implies that independent of time scale, recency effects that obtain at the conclusion of an ordered series of inputs to memory should disappear given that recall is delayed sufficiently" (p. 188).

Crowder's Elaboration of the Ratio-Rule Argument

Robert Crowder—in his 1976 textbook *Principles of Learning and Memory*, a masterwork of elegant writing and scholarship that became the basic text for graduate courses in human memory for the next 10–15 years—provided an especially clear and compelling characterization of the temporal-distinctiveness (ratio-rule) model William Whitten and I proposed. He also pointed out, in detail, the important implications of such temporal-distinctiveness mechanisms, not only for the understanding of recency effects but also for the distinction (or the lack thereof) between short-term and long-term memory and for the dynamics of proactive and retroactive interference. Because his analysis was so clear and provocative, and because his text, in addition to being the standard graduate text in human memory, also served as an indispensable resource for memory researchers, his arguments had a large impact on the field, triggering additional empirical and theoretical research on the role of temporal distinctiveness.

Crowder (1976) summarized his argument with the following passage; his telephone-pole analogy, which I italicized, captures the ratio-rule idea in a particularly concrete and compelling way.

> It is now time to examine in detail the alternative recency mechanism proposed by Bjork & Whitten. . . . There are several steps to the argument. First, they note that there is no long-term (or short-term, for that matter) effect of recency when testing occurs by recognition rather than recall for their experimental conditions. . . . This finding permits the conclusion that the source of recency is located at the retrieval stage rather than at acquisition or during storage. The second part of the argument is a loose assumption that, somehow at retrieval, the subject looks back toward his memories for the recent past much as, when we are moving through space, we can look back over the most recent objects we have passed. The temporal-spatial parallel is too convenient to resist following further: *The items in a memory list, being presented at a constant rate, pass by with the same regularity as do telephone poles when one is on a moving train. The crucial assumption is that just as each telephone pole in the receding distance becomes less and less distinctive from its neighbors, likewise each item in the memory list becomes less distinctive from the other list items as the presentation episode recedes into the past.*
>
> The third assumption of the alternative theory of recency has to do with how discriminability of equally spaced events is related to the passage of time. . . . Although two events that occur 2 sec apart do not ever change their objective separation, we seem to perceive them in a way that later, say a full hour later, these two events are perceived subjectively to have occurred at the same time. One possibility for an index of discriminability is an application of Weber's law stating that the necessary change in stimulus energy for a change in perceived intensity is a constant fraction of the baseline intensity. . . . This would hold that the amount of time by which two adjacent memories would need to be separated in order to be discriminable would be a constant fraction of the distance back, in time, of the younger memory. . . . *In terms of our telephone poles receding in space, the further one is from the two poles, the more widely spaced they must be in order to look separate.*
>
> These assumptions permit a theory of recency that holds up under every situation where recency is found, unlike the possibilities we have considered. (pp. 461–462, emphasis added)

Crowder saw R. A. Bjork and Whitten's (1974) findings, and the temporal-distinctive-ness model, as a challenge to concept of primary (short-term) memory;

that is, to the prevailing idea that there exists a primary-memory component of human memory that differs in fundamental ways from the long-term component of human memory. He pointed out that "to an extraordinary degree the concept of primary memory has been tied to the recency effect in free recall" (Crowder, 1976, p. 170), but that the temporal-distinctiveness model provided an account of "the original recency effect with conventional procedures, the removal of this effect by a distractor task after the last item and its restoration by the Bjork and Whitten manipulation" (pp. 172–173). The argument is that with conventional (immediate) free-recall procedures the last few list items, even without being separated by a distractor activity of some kind, are temporally distinct at the start of the recall process, but that they become indistinct if recall is delayed, even by 30 s or so, which accounts for the findings of Postman and Phillips (1965), Glanzer and Cunitz (1966), and other researchers, including R. A. Bjork and Whitten (1974). With the continuous-distractor procedure, recency effects survive such a delay because the greater temporal separation of successive list items keeps them temporally distinct for a longer period of time.

Crowder's basic argument, which he voiced more vigorously in subsequent publications, was that if a single mechanism could explain both short-term and long-term effects of recency there might not be a need for the concept of a separate short-term (primary) memory. In his subsequent analysis of another procedure used to study short-term-memory phenomena, the Brown–Peterson paradigm, he made similar arguments.

"Using an analogy with depth perception, and recalling the similar argument made in Chapter 6 to understand the data of Bjork and Whitten (1974)," Crowder (1976) continued,

> we see why performance deteriorates during the retention interval of any particular trial in the Brown–Peterson situation: When the stimulus has just been presented (that is, at an early retention interval) its own age in storage is just a tiny fraction of the ages of traces from other, previous items; there is a big differential in time between the correct item and potential interfering items, enhancing their temporal discriminability. However, after some time spent performing the distractor activity the various traces, correct and incorrect, have all receded toward the past and have become less distinct as they all recede into the distance. (p. 211)

After reviewing the body of research on the Brown–Peterson paradigm, and considering four other hypotheses that had been offered to explain the observed buildup of proactive interference across Brown–Peterson trials, Crowder (1976) concluded that the retrieval-discriminability hypothesis is consistent "with the evidence that we have used to reject, one by one, the other four hypotheses" (p. 213).

Generality of Long-Term Recency and the Ratio Rule

R. A. Bjork and Whitten (1974) speculated that their findings might reveal a fundamental law of sorts governing the retrieval of episodic events—independent of time scale and type of event. Robert Crowder not only endorsed that speculation but also pointed to even broader implications of the temporal-distinctiveness (ratio-rule) idea. It was other researchers, however, who gathered evidence that long-term recency was indeed general, provided certain conditions were met, and that the ratio rule, to a first approximation, accounted for the presence or absence of recency effects over a great range of temporal intervals. The following are some of those findings.

1. Alan Baddeley and his collaborators reported two naturalistic studies in which pronounced long-term recency effects were obtained over intervals of weeks and months. Baddeley and Hitch (1977) asked rugby players to recall the names of the teams they had played during the many weeks of the Rugby Union competition. They found a pronounced and long-term recency effect. Pinto and Baddeley (1991) examined participants' memory for parking locations. In one experiment, they surreptitiously recorded where their colleagues at the Applied Psychology Unit (APU) in Cambridge, England, had parked on arriving at the APU in the morning. They then tested each colleague's ability to remember where he or she had parked his or her car during the preceding 25 working days or so. In a second experiment, Pinto and Baddeley examined how well individuals who had visited the APU only once or twice (to serve as experimental participants) could remember—after delays that ranged from 2 to 6 weeks—where they had parked in the APU lot. As in the case of memory for rugby games, memory for parking locations exhibited recency effects extending back across days and weeks.
2. Rigorous and convincing support for the ratio rule was provided by Glenberg and his colleagues (Glenberg, Bradley, Kraus, & Renzaglia, 1983; Glenberg et al., 1980) and by Hitch, Rejman, and Turner (1980, reported by Baddeley, 1986). Both groups of researchers, using somewhat different procedures, covaried the interpresentation interval (IPI) between successive items in a list and the retention interval (RetI) from the last item to the test for recall of the list. In each case, the size of the recency effect obtained was fit well by a linear function of the log of the IPI:RetI ratio. Glenberg and his collaborators were able to show that the ratio rule not only gave a good account of the findings for IPIs of 4, 12, and 36 s and RetIs of 12, 36, and 72 s but also gave a good account for IPIs of 5 min., 20 min., 1 day, and 7 days, and RetIs of 40 min., 1 day, and 14 days. Pinto and Baddeley (1991), in their study of participants' memory for parking locations, also found support for the ratio rule. For those participants who parked twice in the APU parking lot, either 2 weeks and 4 weeks earlier or 4 weeks and 6 weeks earlier, the percentage of correct recall of given parking location was again fit well by a linear function of the log of ratio of the IPI (interparking, in this case) and RetI.

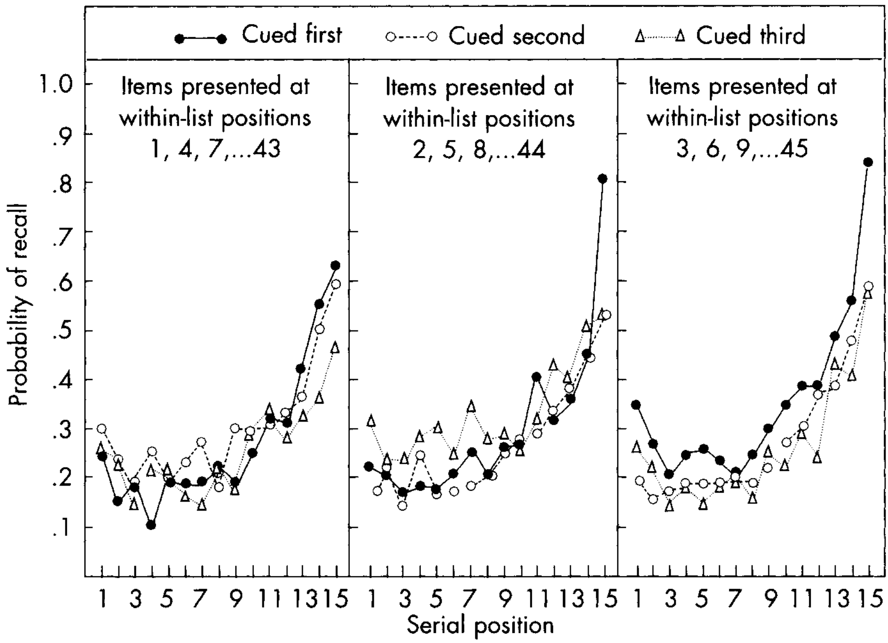
3. Watkins and Peynircioglu (1983) were able to demonstrate that participants' memories for interleaved events from three different categories exhibited pronounced recency across the events in each category. That is, they obtained three recency effects at the same time, each of which extended back in time far beyond the reach of short-term memory. The participants in Watkins and Peynircioglu's experiment were presented multiple lists, each of which consisted of the 15 members of a single category or the 45 members of three different categories. In the three-category case, the members of a first category were presented in list positions 1, 4, . . ., 43; the members of a second category in list positions 2, 5, . . ., 44; and the members of the third category in positions 3, 6, . . ., 45. After each single-category list, the category name was presented as a cue to participants to free recall the 15 members of that list. After each triple-category list, the names of the three categories were presented in succession as a cue to participants to free recall, in turn, as many members of each category as they could.

Watkins and Peynircioglu (1983) made the categories of to-be-remembered events distinct from each other, which they suggested is an essential part of their procedure, and they also structured the categories so that participants had to make some kind of active response when a member of a category was presented. Thus, in the "favorites" category, for example, the experimenter inquired as to a participant's favorite kind of pet, hobby, and so forth, which the participant then had to write down and remember. Other examples were the "drawings" category in which participants heard the name of an item, such as an umbrella or house, and had to quickly draw a simple sketch of that item, and the "sounds" category in which segments of sounds taken from sound-effect recordings, such as the sound of an owl, had to be identified and remembered. On average, the members of the to-be-remembered categories were presented about one every 10 seconds.

The results from the Watkins and Peynircioglu's (1983) three-category conditions are shown in Figure 11.2. As is apparent from the figure, there were pronounced recency effects across the 15 members of each category—effects that were comparable, in fact, to the recency effects obtained for the single-category lists. Because the members of the three categories were interleaved, the recency effects across the last 7 members or so of each category, as shown in Figure 11.2, actually extended back about 21 list positions from the end of a three-category list. Apparently, and consistent with ratio-rule arguments, the substantial interval between successive members of a given category—which was created by the presentations of one member from each of the other two categories—was sufficient to

FIGURE 11.2

Proportion category-cued free recall as a function of cuing order and within-category input serial position and for each set of presentation positions within the full list. From "Three Recency Effects at the Same Time," by M. J. Watkins and Z. F. Peynircioglu, 1983, Journal of Verbal Learning and Verbal Behavior, 22, p. 383. Copyright 1983 by Academic Press. Reprinted with permission.



make the last 7 members or so of each category temporally distinct at the time of recall.

4. Finally, Wright, Santiago, Sands, Kendrick, and Cook (1985) demonstrated that recency effects consistent with ratio-rule arguments could be obtained not only on many time scales and for many types of to-be-remembered materials but also across species. Using a memory-search paradigm that was adapted for pigeons, monkeys, and humans, Wright et al. found strikingly similar recency effects for all three species, which then disappeared if the memory probe following a given list was delayed.

Temporal Distinctiveness, Retention Functions, and the Passage of Time

One thrust of the ratio-rule analyses summarized above, and more broadly the role of temporal distinctiveness in determining level of recall, is that elapsed time per se plays little or no role in forgetting. Because forgetting functions, as typically measured and plotted, show an orderly decrease in performance with the passage of time, it is tempting to conclude that passage of time is the cause of forgetting. In Robert Crowder's (1976) words,

> intuitively, the most obvious aspect of forgetting is that we recall more and more poorly with the passage of time. It is quite natural in light of this intuition to suppose that memories fade because of the lapse of time since learning. Thorndike (1914) formalized this reasoning in his "law of disuse," which maintained that although use of habits leads to strengthening of them, the passage of time without practice, that is, disuse, weakened them. (p. 218)

Crowder went on, however, to point out that intuition and Thorndike's "law" are misguided, as McGeoch (1932), who "is generally credited with having buried the law of disuse, or decay theory, as the same idea is often called" (Crowder, 1976, p. 218), was the first to demonstrate. On the basis of both logic and empirical findings, McGeoch argued that the passage of time per se was unsatisfying and inadequate as a theoretical mechanism. He argued that rust, for example, is correlated with, but not caused by, the passage of time. McGeoch's most convincing arguments derived from evidence that degree of forgetting across a fixed retention interval could vary greatly, depending on what happened in that interval, and that under some conditions recall can increase with the passage of time.

The ratio-rule findings summarized above provide additional evidence that conditions exist where memory performance increases, rather than decreases, with retention interval. Increasing the activity and time between two successive to-be-remembered events—which, all other things being equal, also increases the retention interval to the first of those events—improves access to and, hence, recall of that event.

A compelling example of the importance of temporal distinctiveness and of the irrelevance of the passage of time was provided by Glenberg and Swanson (1986). They presented each of four pairs of to-be-remembered words auditorily. In a control condition, corresponding to the standard continuous-distractor procedure, there was a 4-s distraction period before each word pair and 10 s of distraction between the last pair and a free-recall test for the word pairs. In a second condition everything was the same, except for one crucial difference: 40 s of distraction rather than 4 s separated the first and second word pairs. In that condition, then, the retention interval for the first pair consisted of 58 s of distraction (plus the brief times necessary to present the second, third, and fourth pairs), whereas that same interval in the control condition included 22 s of distraction, nearly a three to one difference. The outcome, however, was superior recall of the first word pair in the condition with the much longer interval between the first and second word pairs (58% vs. 32%).

In the next section, I focus on another finding—the shift from recency to primacy with delay—that also illustrates, among other things, that recall performance for certain items can increase, not decrease, as they become less recent.

Shift From Recency to Primacy With Delay

On many time scales, for multiple types of events or materials, there is a shift from recency to primacy as the retention interval from the end of a list to a test of some kind increases. In the immediate free recall of a list of words, for example, recency effects are larger than primacy effects (e.g., Murdock, 1962), but that pattern is transient: On a test of final free recall, administered after several lists have been presented and tested (Craik, 1970) or not tested (R. A. Bjork, 1975), it is the early items in each list that are the best recalled and the final items in each list may even exhibit negative recency.

Such a shift occurs at the list level as well. As mentioned earlier, on an end-of-session test for all items from all lists studied during that session, the items in the recent lists are the best recalled, but that advantage is absent if recall is tested again at a 24-hour delay (R. A. Bjork & Whitten, 1974). In an experiment by Bower and Reitman (1972), in which participants learned each of five lists through a particular mnemonic method (the peg-word system), a pronounced list recency effect on an end-of-session test changed to a primacy effect across the five lists when recall was again tested after a week's delay.

A shift from recency to primacy—on a much shorter time scale—is also evident with probe (memory-search) procedures. If a list of items is presented one item at a time and then followed by a test item ("probe"), with the participant's task being to say whether the test item did or did not occur in the preceding list, there is recency at short probe delays, but primacy at longer delays (see, e.g., Knoedler, Hellwig, & Neath, 1999; Neath, 1993; and Wright et al., 1985). In fact, if the probe item matches the first item in the list, there is often an absolute increase in correct responding with delay of the probe. That is, as the retention interval increases, performance on the earliest list members increases and does not decrease.

In the learning of competing lists or habits, there is also a shift toward primacy with delay. Earlier learned habits or responses become relatively—and sometimes absolutely—more accessible with a delay, whereas later learned (competing) habits or responses become less accessible. Such a pattern is very general. It occurs in verbal-learning tasks, such as the classic A–B, A–D paired-associates list-learning paradigm, where the second to-be-learned list involves the same stimulus members as in the first list, but requires that a new response be learned to each stimulus (see Postman, 1971, for a thorough review of the spontaneous-recovery literature prior to that time; and see Wheeler, 1995, for a re-examination of recovery phenomena in verbal learning). In the clinical treatment of fears, where new, more adaptive, behaviors are learned to fearful stimuli, it is also common for there to be a gradual return of fear after treatment has concluded (see, e.g., Lang, Craske, & Bjork, 1999). There are motor skills examples as well: It is common knowledge among coaches and skilled athletes that earlier learned swings, styles, and techniques that have been replaced can often recover or reappear over time.

There are also, of course, compelling examples of such recovery in the animal-learning literature. Spontaneous recovery—in the form of a recovery, over time, of a learned response after the apparent complete extinction of that response—was first demonstrated in research on animals and dates back at least as far as the work of Pavlov (1927). Counterconditioning procedures in research on animals, which can be viewed as analogous to the A–B, A–D verbal learning paradigm, can also yield a recovery of first-learned response with time. The results of an experiment by Bouton and Peck (1992), shown in Figure 11.3, provide a good example. In a first phase of Bouton and Peck's experiment, rats were exposed to a tone followed by shock until the tone reliably elicited shock-appropriate anticipatory behavior. In a second—counterconditioning—phase, the tone was paired with food until the tone elicited food-appropriate behavior reliably. There was then a test phase, either 1 day or 28 days after the tone–food conditioning. As is apparent from Figure 11.3, the tone tended to trigger food-appropriate behavior after a 1-day retention interval, but when the testing was delayed by 28 days, the tone elicited more shock-appropriate behavior than it did food-appropriate behavior. Again, with a delay there was a shift in access toward the earlier learned behavior.

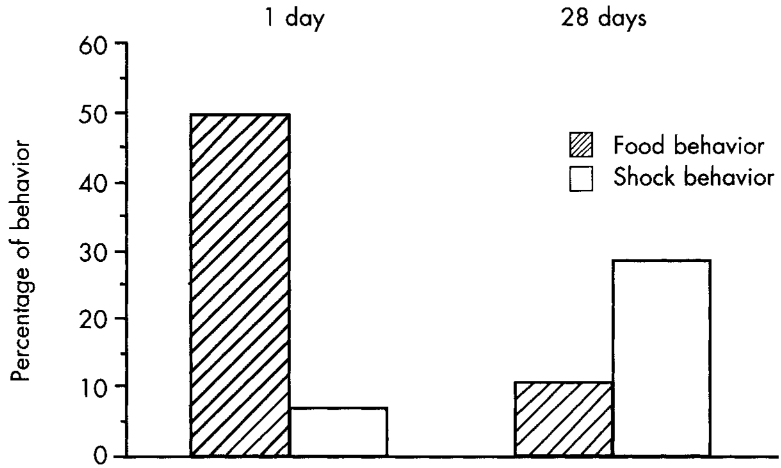
Regression as a Fundamental Property of Human Memory

The generality of such laboratory findings—across paradigms, time scales, and even species—coupled with observational and anecdotal parallels in everyday living has led me to argue elsewhere that a kind of regression process is a fundamental property of human memory (see, e.g., R. A. Bjork, 1978; and R. A. Bjork & Bjork, 1992). In the myriad instances where everyday living requires that one update procedural or declarative memory representations (by learning to operate a new car, e.g., or by learning a new tennis serve, a new married name of a friend, a new or updated computer program, or a new list in a memory experiment), one creates a competition among stored representations. At the end of the new learning, it is the more recent of those representations that is most accessible, but with the passage of time—and disuse of either representation—there is a loss of access to the more recent representation and an increase in access to the earlier representation. That is, over time, access to competing memory representations regresses toward the older of those representations.

Training personnel in sports and military contexts tend to be aware, in a general way, of such regression. In military contexts, individuals who have been apparently well trained in new procedures and equipment are at risk over time of taking actions appropriate to the old procedures or equipment, particularly under stress. Elite athletes tend to be aware that a layoff can lead to the return of old habits—which, depending on the situation, can have desirable or undesirable consequences, such as when a recent slump in performance is attributable to recently acquired bad habits and techniques.

FIGURE 11.3

Percentage of food-appropriate or shock-appropriate behavior in response to a tone sounded 1 day or 28 days after tone–food training. The tone–food training was preceded by tone–shock training. From "Spontaneous Recovery in Cross-Motivational Transfer (Counterconditioning)," by M. E. Bouton and C. A. Peck, 1992,* Animal Learning and Behavior, 20, *p. 316. Copyright 1992 by the Psychonomic Society. Adapted with permission.



Such regression may also play a role in certain metacognitive assessments, such as estimates of how much a person or place has changed. As I emphasized elsewhere (R. A. Bjork, 1978),

> we are often surprised at how much a child had grown up, a friend has aged, or a town has changed since the last time one saw that child, friend, or town. Children do grow up, of course, friends do age, and towns do change, but a subjective judgment of such changes based on the difference between a regressed memory representation and the current state of the child, friend, or town will overestimate the actual changes. (p. 250)

Memory Regression as a Theoretical Problem

Understanding the process dynamics of regression and recovery phenomena poses a formidable theoretical problem. It is absolute recovery of the earlier of two competing representations, however, not its relative recovery, that is difficult to explain. Recovery of the earlier of two competing representations—relative to the more recent of those representations—is understandable, given the negatively accelerated form of forgetting functions. Jost (1897) may have been the first to make this point (in the first of the two "laws" he proposed): "If two associations are now of equal strength but different ages, the older one will lose strength more slowly with the passage of time" (as translated by Woodworth & Schlossberg, 1954, p. 730). Miller and Stevenson (1936) may have been the first to point out that the negatively accelerated character of forgetting over time provided a natural account of why first-learned responses recover relative to competing second-learned responses.

Absolute recovery of the first of two representations—as time and events pass following the learning of a more recent and competing representation—is much more difficult to understand. Intuitively, as mentioned earlier, one does not expect one's access to memory representations to improve over time. Absolute recovery, however, also poses a puzzle for formal theories as well as for memory researchers' intuitions, especially given that—empirically—access to first-learned responses and information can recover to the point that it exceeds access to second-learned responses and information (see Wheeler, 1995, for a similar argument).

Without some added assumptions, for example, temporal-distinctiveness mechanisms—including the ratio rule, Glenberg's (1987) "search-set" elaboration and extension of distinctiveness, and the "dimensional distinctiveness" model of Neath and his collaborators (e.g., Knoedler et al., 1999; Neath, 1993; Neath & Crowder, 1990)—cannot explain why access to the first of two competing representations should increase with delay, exceeding, eventually, access to the second, more recent, of those representations. Such ideas provide a natural explanation for why the advantage of second-learned representation over the first-learned representation should dissipate with delay and disuse, but they do not provide a mechanism to explain why access to the first representation should increase with delay—to the point where it dominates access to the more recently learned representation. In the next section I present a new interpretation of absolute recovery and an empirical test of that interpretation.

Absolute Recovery: A Possible Explanation

As Postman, Stark, and Fraser (1968) emphasized in the case of learning successive lists of paired associates, especially when those lists bear an A–B, A–D relationship—and I emphasized more broadly (R. A. Bjork, 1989)—learning new responses requires inhibiting old responses. In the case of the A–B, A–D paradigm, once A–D learning begins, the task at hand is to give the appropriate D responses, which requires not giving the earlier B responses. To the extent that the B responses come to mind during the learning of the A–D list, they need to be inhibited or suppressed.

That basic fact, viewed in the context of the "new theory of disuse" that Elizabeth Bjork and I proposed (R. A. Bjork & Bjork, 1992), suggests an explanation for why first-learned responses may recover with time, even to the point that they may dominate competing second-learned responses. The basic idea is that the need to inhibit first-list responses during second-list learning results in decreasing the retrieval strength (current accessibility) of those responses but may increase, not decrease, the storage strength (learning) of those responses.

Retrieval and Storage Strengths of First-Learned and Second-Learned Responses

In the new theory of disuse, Elizabeth Bjork and I assumed (R. A. Bjork & Bjork, 1992) that memory representations are double indexed in memory—by their current "retrieval strength" (how accessible or active they are) and their "storage strength" (how well learned or interassociated with other memory representations they are). Storage strength is assumed to accumulate as a consequence of study or practice and, once accumulated, is permanent. Retrieval strength, however, which completely determines the probability of being able to access a given stored representation, is volatile. It is assumed to increase as a consequence of study or practice but to decrease as a consequence of study or practice of competing responses or behaviors. Our theory is a "new" theory of disuse because, in contrast to Thorndike's (1914) original law of disuse, it is access to learned representation (retrieval strength) that is lost over a period of disuse, not the representation per se (storage strength).

In distinguishing between storage strength and retrieval strength, the theory resurrects a distinction that was common among learning theorists of an earlier era. The distinction is essentially the same, for example, as Hull's (1943) distinction between habit strength and momentary excitatory potential or Estes's (1955) distinction between habit strength and response strength. The distinction also corresponds, in a general way, to the time-honored distinction between learning and performance, a distinction necessitated by a range of findings from research on both humans and animals: What one observes is performance; what one is often trying to infer is learning. Storage strength and retrieval strength also correspond, roughly, to Tulving's distinction between the availability and accessibility of memory representations (see, e.g., Tulving & Pearlstone, 1966).

What is new about the theory are the assumptions governing how the current storage and retrieval strengths of a representation influence (a) the increments in the storage strength of that representation that result from study or practice and (b) the increments and decrements, respectively, in the retrieval strength of that representation that result from study or practice of that representation or competing representations. The assumptions of special pertinence to an analysis of recovery phenomena are the following:

Assumption 1. Storage strength serves to enhance the gain and retard the loss of retrieval strength. That is, access to representations in memory, as indexed by retrieval strength, is lost more slowly with disuse—and regained more rapidly given study or practice—the higher that representation's current storage strength.

Assumption 2. The higher the current retrieval strength of a representation, the smaller the increments in both storage strength and retrieval strength that result from study or practice of that representation. Thus, somewhat surprisingly, the more accessible a representation, the smaller the increment in storage strength (learning) that results from additional study or practice of that representation. Put differently, conditions that result in forgetting (loss of retrieval strength) also create opportunities for additional learning (i.e., increments in storage strength).

As applied to a situation such as the A–B, A–D paradigm, where new learning updates or replaces old learning, the hypothesis is that the elicitation of first-list responses during second-list learning, and the need to suppress those responses, has differing consequence for the storage and retrieval strengths of those responses. More specifically, the active suppression of those responses is assumed to decrease their retrieval strength, but the elicitation process is assumed to increase the storage strength of those responses. As a consequence, by the end of second-list learning, first-list responses have lower retrieval strength than second-list responses but higher storage strength. The retrieval strength of second-list responses therefore is lost more rapidly than the retrieval strength of first-list responses, leading, perhaps, to a crossover in dominance as retention interval increases.

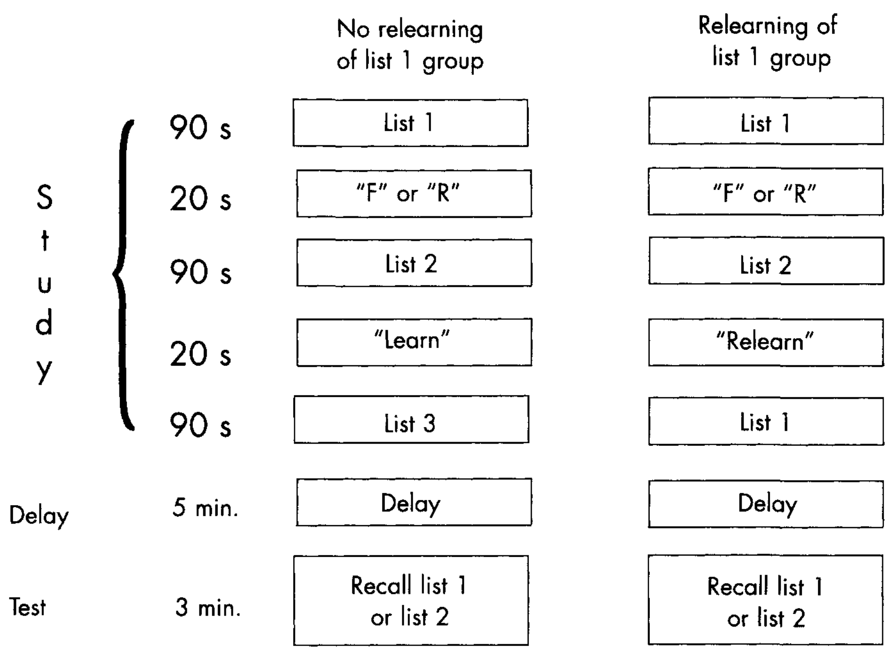
A Test of the Explanation

An experiment by Liu, Bjork, and Wickens (1999) was designed, in part, as a test of the foregoing conjecture. After being asked to study a first list of words, participants were then instructed to either forget or remember that list. In the forget-instruction condition, the participants were told that the first list had been presented for practice, that it should be forgotten, and that the upcoming list was the actual list to remember. In the remember-instruction condition, the participants were told that they should continue to remember the first list and that they should try to also remember the second, upcoming, list. In both conditions, a second list was then presented for study. Following the second list, half the participants in each group were asked to relearn list 1, which was then presented for study. The remaining participants in each group were presented a third list to learn. In all cases there was then a 5-min. filled retention interval after which the participants were asked to recall list 1 or list 2, but not both. The design and procedure are summarized in Figure 11.4.

Prior research on directed forgetting demonstrates that one consequence of an instruction to forget a first list is enhanced recall of the second (to-be-remembered list) list—compared with a corresponding remember-instruction condition. Recall of the first list, however, when participants are unexpectedly asked to recall that list, is impaired relative to a remember-cue condition. Liu et al. (1999) expected that same pattern of results for the condition in which recall of list 1 or list 2 was

FIGURE 11.4

Sequence of events in the relearning and no relearning conditions.* From Costs and Benefits of Directed Forgetting, *by X. Liu, R. A. Bjork, and T. W. Wickens, November 1999, paper presented at the meeting of the Psychonomic Society, Los Angeles, CA. Reprinted with permission.



delayed by the learning of a third list. That condition served as a control condition for the relearn-list-1 condition, which is the condition of primary interest.

In the condition where list 1 was relearned, the key consideration, from the perspective of the new theory of disuse, is the status of list 1 at the time of its relearning. Multiple findings from research on directed forgetting, such as unimpaired recognition of first-list to-be-forgotten items, support a conclusion that the encoding (storage strength) of first-list items is not affected by an instruction to forget those items (see, e.g., E. L. Bjork & Bjork, 1996; E. L. Bjork, Bjork, & Anderson, 1998). Instead, it is retrieval access to the first-list episode that is inhibited. At the time list 1 is relearned, then, its storage strength in the forget-instruction condition should be comparable to its storage strength in the remember-instruction condition, but its retrieval strength should be lower.

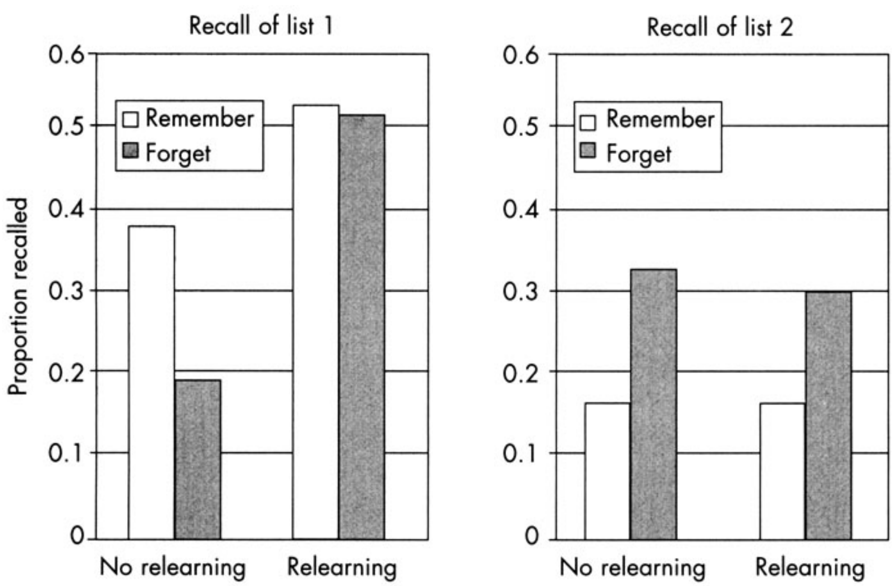
As a consequence of that pattern—that is, equal storage strength but lower retrieval strength—the new theory of disuse predicts that the relearning of list 1 should be more effective in the forget-instruction condition than in the remember-instruction condition. Such a prediction follows because increments in both storage strength and retrieval strength are assumed to be larger the lower the current retrieval strength (see Assumption 2). After relearning, then, list 1 in the forget-instruction condition should possess higher storage strength than list 1 in the remember-instruction condition and its disadvantage in retrieval strength should be narrowed. Given that combination, there should then be a slower rate of loss of retrieval strength across the final retention interval because storage strength acts to retard the loss of retrieval strength (see Assumption 1).

It follows from such reasoning that the final recall of list 1 in the forget condition should exhibit enhanced recovery versus the final recall of list 1 in the remember condition. It also follows that list 2 should retain its advantage in the forget-list-1 condition because that advantage results from more efficient encoding of list-2 items. Overall, such arguments lead to the counterintuitive prediction that total recall in the relearning condition, summed across list 1 and list 2, should be better when participants had earlier been instructed to forget list 1.

The results of Liu et al.'s (1999) experiment are shown in Figure 11.5. As predicted, list 1 shows enhanced recovery in the relearning condition, to the point

FIGURE 11.5

Percentage of free recall of words from list 1 or list 2 as a function of whether participants had been instructed to remember or forget list 2 and whether list 1 was or was not relearned after the presentation of list 2. Data from Liu et al. (1999).



that it is recalled as well in the forget condition as in the remember condition, and list 2 retains its advantage in the forget-instruction condition. In contrast, in the control condition, in which there was no relearning of list 1, recall of lists 1 and 2 exhibits the standard pattern: enhanced recall of list 2 and impaired recall of list 1.

Concluding Comments

The results obtained by Liu et al. (1999) provide preliminary support for the proposition that recovery phenomena reflect an interplay of encoding (storage) strength and current accessibility (retrieval strength), the latter of which is volatile and subject to competitive dynamics. Whether that view holds up under more direct and rigorous testing remains to be seen.

If the shift from recency to primacy with delay—that is, memory regression—is as fundamental a property of human memory as I argue, then one might ask What, if anything, might be useful or adaptive about such a shift? My own conjecture is that the recency and recovery dynamics I sketched in this chapter result, statistically, in enhanced access to the skills and knowledge one tends to need. In general, such dynamics result in information and procedures from the recent past being the most accessible in the near future. On a statistical basis, given the characteristics of everyday work and living, that tends to be the information one most needs. If there is a long period of disuse, however, the statistics seem different. The fact that there has not been a need for recent information and procedures may signal changes that mean that older, typically better learned, information and procedures are once again relevant. Were one to spend a year in England, for example, it would be useful if—in driving a car—recent (England-appropriate) information and procedures were more accessible than less recent (U.S.-appropriate) information and procedures. But what might a period of disuse of England-appropriate procedures tend to mean? Probably that the less recent U.S.-appropriate procedures and habits are once more what are needed, meaning that a regression to less recently learned procedures and habits would definitely be adaptive.

As an evolutionary argument, the preceding driving-in-England example may be less than convincing. It is not difficult, however, to think of other examples that might have evolutionary significance. Suppose, for example, that a location long used for hunting or foraging were to become dangerous, owing to the presence of a predator, a contaminated food supply, or another reason. On the short term, it would clearly be adaptive to avoid that area, that is, to have access to relevant memories that encourage avoiding that area, but it may well be nonadaptive to avoid that region permanently. After a period of disuse, a recovery of access to memories and habits that would once again encourage hunting or foraging in that area is likely to be adaptive.

Viewed more broadly, my conjecture as to what might be useful or adaptive about a shift from recency to primacy with delay is consistent with Anderson's argument that human cognitive processes may have evolved to be a solution, perhaps optimal, to the information-processing demands posed by the environment (Anderson, 1990; Anderson & Milson, 1989). One aspect of Anderson's (1990) argument, based in part on the similarities in use statistics for library borrowings and file accessing, is that "there [may be] 'universals' in information retrieval that may transcend device and generalize to human memory" (p. 49).

Pursing the library analogy, consider the likely future-use statistics for a book that has been borrowed *n* times, all in the last couple months, versus another book that has been borrowed *n* times, but with the borrowings distributed across the past year. Anderson did not report the exact statistics of interest, but it seems clear that in the near future, it is the first of those books that is the more likely to be needed (i.e., signed out). Suppose, though, that there is a period of disuse for both books—that is, that neither book is signed out for a month or so. It then seems likely that the second book, the one with the longer history of use, is the more likely to be needed (borrowed).

Whether such statistics-of-use arguments can withstand scrutiny and additional empirical analyses remains to be seen. What is clear at this point is what Robert Crowder was probably the first to see—that temporal distinctiveness and changes in such distinctiveness with time play a critical role in the retrieval and interference dynamics that characterize human memory.

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