CHAPTER

3

VARIETIES OF GOAL-DIRECTED FORGETTING

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If asked, most of us would probably say that our biggest memory problem is forgetting things we want to remember. Frequently, however, forgetting is exactly what we need to do to function efficiently. For example, to avoid disabling emotions or dysfunctional personal relationships, we may want to forget past events in our lives that are painful or embarrassing. Another motivation to forget is the need to contend with a changing world: We need to remember our *current* phone number, not the one we had a few years back; how the operating system on *this* computer works, not the one on our old machine, and so forth. Also, when we search our memories for desired information such as someone's name, we continually–in a kind of "online" fashion–need to "forget" or inhibit closely related, but incorrect, information.

Our goal in the present chapter is to examine several varieties of what might be termed *goal-directed forgetting*–that is, situations where forgetting serves some implicit or explicit personal need. Specifically, we summarize the evidence that a particular mechanism–retrieval inhibition–is common to these several situations, and we speculate on some broader implications of retrieval inhibition as a forgetting mechanism. We exclude from our analysis those situations where we are instructed to ignore or disregard information that is confidential, not permissible in a courtroom, and so forth, because such instructions to "forget" are not necessarily consistent with our personal goals and needs (excellent analyses of the "disregard" literature are provided by Johnson, 1994, and in the chapters by Golding, Ellis, Hauselt, & Sego; Golding & Long; Isbell, Smith, & Wyer; Kassin & Studebaker; Schul & Burnstein; and Thompson & Fuqua in the present volume).

Cues to Forget: Implicit and Explicit

Implicit Cues. In both real-world situations and analogous research paradigms, cues to forget, although clear, are typically implicit. As we park our car in the morning, for example, we do not tend to instruct ourselves to forget the event of having parked our car in a different spot the preceding morning, nor do there tend to be signs posted that instruct us to do so. Similarly, in the various paradigms that incorporate an intrinsic updating requirement, such as the Brown–Peterson short-term-memory paradigm and the A–B, A–D list-learning paradigm of interference research, the cue to forget, although clear, is implicit. As each successive to-be-remembered set of items is presented in the Brown–Peterson paradigm, for example, the structure of the task itself makes it clear to subjects that the items from the preceding trial should now be forgotten, that continuing to remember them is a potential source of errors.

In other research paradigms, such as the retrieval-induced-forgetting paradigm (Anderson, Bjork, & Bjork, 1994), there is also an implied cue to forget, but the cue, as defined by the task itself, is more subtle and differs qualitatively from the implied cue in updating paradigms such as the Brown–Peterson or A–B, A–D paradigms. In the retrieval-induced-forgetting paradigm, a study phase is followed by a retrieval–practice phase, during which subjects are cued to retrieve some of the studied items multiple times and then, after a delay, are asked to recall all the items from the study phase. Typically, the to-be-remembered items are category-exemplar pairs where multiple exemplars are paired with each of a small number of category labels during the study phase. During the retrieval–practice phase, when subjects are cued via a category name and a letter stem to retrieve the particular studied exemplar that fits that combined cue, there is an implied cue to suppress or inhibit other exemplars that were paired with that category during the study phase. The need to suppress or inhibit serves an immediate rather than a long-term need, however, because during the retrieval–practice phase, it remains the subject's goal to remember as many items from the study phase as possible. In contrast, from the standpoint of a subject in a Brown–Peterson or an A–B, A–D experiment, items or associations that were to be learned, but that now are out of date, are history; inhibiting or suppressing those items is consistent with the long-term interests of the subject, as defined by the experimental task.

Explicit Cues. In other real-world and laboratory situations, the cue to forget can be more direct. For example, we have probably all been told something like: "Forget what I just said. I was reading the wrong number.

Here's the correct one." Or, "Forget those directions. It's too hard to get there that way. Here's the way you should go instead." Similarly, a defining characteristic of the directed-forgetting research paradigm, at least with human subjects, is that the cue to forget is explicit. Subjects are instructed at the beginning of such studies that, on occasion, they may receive an instruction to forget some of the material previously presented to them for study, and, if so, their memory for that material will not be tested later. Or, subjects might be unexpectedly told that materials they had just been studying for a later memory test will not be tested after all (e.g., they might be told that incorrect materials had been presented by mistake), and they are then presented with the "correct" materials to study for a later memory test.

Inhibitory Processes in Goal-Directed Forgetting

In a great variety of real-world and laboratory settings, then, we are cued, implicitly or explicitly, to get rid of, set aside, suppress, or inhibit, either permanently or temporarily, something that resides in our memories. Although the nature of the cue to forget or inhibit and the details of the task-defined motivation to forget or inhibit may differ substantially across such settings, we think that three distinct but related bodies of research suggest that a common mechanism—retrieval inhibition—may be involved. By retrieval inhibition, we mean the loss of retrieval access to information that is, in fact, still stored in memory as can be demonstrated by indices other than recall measures, such as recognition tests, relearning, or certain indirect tests.

Terminology. Because the term inhibition is used in multiple ways in the literature, often simply as a description of empirical effects that are the opposite of facilitation, we need to clarify what we mean by *retrieval inhibition* as a "mechanism." Unless modified, as in *retrieval inhibition/blocking* or *retrieval inhibition/suppression* (see R. A. Bjork, 1989), we mean that term to refer, collectively, to the set of possible mechanisms that result in loss of retrieval *access* to inhibited items, without a commensurate loss, if any, in the *availability* of those items (Tulving & Pearlstone, 1966), as measured by tests such as recognition. For a discussion of the full range of possible mechanisms, we refer the reader to Anderson and Bjork (1994).

Following a convention that goes back to the interference theorists of another era, then, we reserve *some* theoretical meaning for the word *inhibition*, and we use *interference* or *impairment* as terms that are simply descriptive of empirical effects. It should be emphasized, however, that some of the mechanisms that result in retrieval inhibition in its general sense do not involve an inhibition in what R. A. Bjork (1989) referred to as its "strong sense," that is, as a suppression type of process that is directed at the to-be-inhibited information, resulting in a suppression or deactivation of that information's representation in memory.

Relevant Research Paradigms. The three bodies of research that are the focus of the present chapter span the last 60 or so years of research on human learning and memory. One, research on "unlearning" and "spontaneous recovery," dates back to the 1930s, when questions having to do with interference and forgetting began to dominate experimental research on memory; another, research on "starting over" in the intentional-forgetting tradition, dates back to the 1960s; and the third, research on "retrieval-induced forgetting," represents a relatively new approach to the study of forgetting. In the three sections that follow, we summarize the phenomena in each of these areas that seem to implicate retrieval inhibition as a forgetting mechanism. We then conclude with a discussion of some remaining issues and some speculations about the potential relevance of retrieval-inhibition mechanisms to the inhibition and recovery of memories in clinical contexts.

UNLEARNING AND SPONTANEOUS RECOVERY

Historical Background

Although experimental research on the causes of forgetting dates back to the turn of the century when Muller and Pilzecker (1900) first reported evidence of retroactive interference, we begin our discussion of such research from the time of McGeoch's classical work on the causes of forgetting. In a seminal and devastating critique of the two dominant theories of forgetting of the time—Muller and Pilzecker's (1900) perseveration–consolidation theory and Thorndike's (1914) law of disuse—McGeoch (1932, 1936, 1942) proposed instead that forgetting was a consequence of interference and competition rather than the loss of memory traces per se.

Briefly, McGeoch's framework assumed that memory is fundamentally associative and that retrieval is guided by cues to which items in memory are associated. Thus, when applied to the A–B, A–D interpolated-learning paradigm, where the learning of a first A–B list of paired associates is followed by the learning of a second A–D list (that is, new responses to the same stimuli), both the B and the D responses are assumed to become associated in memory to the same A cue. Although McGeoch asserted that the availability of the original A–B association was not reduced by the interpolated learning of the A–D association, he assumed that competition occurring between the B and D responses at the time of a recall test would result in reproductive inhibition, with a consequent impairment in recall performance. More specifically, he assumed that at the time of the recall test, whichever response was momentarily dominant would displace the other, or, that both might compete and block one another at an implicit level so that neither could be overtly reported.

McGeoch's proposal was the subject of intense empirical research and theoretical analysis over the next several decades, resulting in a wealth of empirical findings and the development of what has come to be called interference theory, considered by many to be the most significant and systematic theoretical formulation in the field of human learning and memory. The history of this endeavor is a fascinating one (for a summary, see R. A. Bjork, 1992) and we recommend to the interested reader the detailed and scholarly accounts by Postman (1971); Postman and Underwood (1973); Crowder (1976); and Anderson and Neely (1996).

The important point about McGeoch's original theory for present purposes is that what he meant by reproductive inhibition is one theoretical instantiation of retrieval inhibition. With respect to the role of retrieval inhibition in goal-directed forgetting, the subsequent work by Melton and Irwin (1940) and others on "unlearning," as summarized in the next section, is highly relevant.

The Evidence for "Unlearning" and Spontaneous Recovery

In a now classic study, Melton and Irwin (1940) tested McGeoch's assumption of response inhibition by manipulating the degree of interpolated learning of a second list before subjects were asked to relearn the first list, and then measuring the number of list-2 items that were intruded during list-1 relearning. They found that list-2 intrusions increased to a point and then decreased as a function of the degree of list-2 learning. Given that such intrusions might be considered a straightforward measure of response inhibition, Melton and Irwin argued that another factor must be involved in retroactive interference and proposed unlearning as that factor. More specifically, they suggested that the retroactive interference suffered by first-list items during their relearning resulted from the action of two factors. First, during the interpolated learning of list-2 items, the original B responses are subject to unlearning (analogous to response extinction in classical conditioning), with the extent of such unlearning an increasing function of the degree of list-2 learning. Second, those list-1 responses still remaining at the end of list-2 learning are then, as McGeoch proposed, subject to competition from the newly learned list-2 responses.

It is important for present purposes to emphasize that what was encouraged in Melton and Irwin's experiment, if only implicitly, was a type of goal-directed forgetting. From their subjects' standpoint, list 1 became only a nuisance, so to speak, once the learning of list 2 began. List 1 should thus be erased, set aside, suppressed, or otherwise inhibited during list-2 learning. What Melton and Irwin actually proposed, however, was "unlearning," which, in the stimulus–response tradition of the time, they interpreted as analogous to the experimental extinction of conditioned responses in animals. Also, in the spirit of the times, they phrased their theory without reference to the subjects' intent with respect to the first list. Rather, unlearning was presumed to be an automatic consequence of changes in associate strength that resulted from list-2 learning. An implication of Melton and Irwin's unlearning proposal, given the assumed similarities to experimental extinction, is that list-1 items should show spontaneous recovery over time, analogous to conditioned responses that have undergone extinction. In that sense, it is the access to the unlearned list that is inhibited, or, in our terms, unlearning results in retrieval inhibition.

Early attempts to demonstrate spontaneous recovery produced mixed results, creating some doubt as to its actual occurrence. In an analysis of these discrepant results, however, Postman, Stark, and Fraser (1968) were able to characterize the conditions under which spontaneous recovery should be detectable if, in fact, it does occur, and were then able convincingly to demonstrate absolute increases in the recall of first-list B responses under such conditions; namely, when there is little extraexperimental forgetting of materials, as measured by the performance of a control group that learns only one list. (See also, Wheeler, 1995, for recent research demonstrating spontaneous recovery.) Additionally, in the Postman et al. studies, evidence was obtained for systematic changes in recall order of first- and interpolated-list responses with time. Specifically, when recall of both B and D responses was required and the recall test immediately followed the period of interpolated learning, the interpolated D responses were likely to be recalled first; with delay of the test, however, order of recall changed to favor first-list B responses.

The Response-Set Suppression Hypothesis

The response-set suppression hypothesis was proposed by Postman et al. (1968) to explain both retroactive interference effects and the conditions under which items suffering retroactive interference would exhibit spontaneous recovery. In the context of the A–B, A–D list-learning paradigm, spontaneous recovery refers to an increase over time, following A–D learning, in subjects' ability to recall first-list responses.

The response-set suppression hypothesis accounts for both these effects as follows. When interpolated learning of the A–D list begins, covert or overt intrusions of the previously learned B responses are evoked, triggering the onset of a selector mechanism that suppresses the entire set of first-list responses. Such suppression facilitates second-list learning by allowing subjects to limit their responses to the currently correct set of D responses. At the end of interpolated learning, however, although the entire set of B responses is suppressed making B responses less accessible than D responses, which thus accounts for the observation of retroactive interference or the impaired recall of B responses, the specific A–B associations still remain intact. Furthermore, because the proposed suppression mechanism is assumed to be reversible and to diminish in effectiveness with the passage of time, B responses should become more accessible with time, resulting in the increased recall of B responses with test delay. That is, spontaneous recovery of first-list responses should occur.

Thus, as described by Postman and his colleagues, response-set suppression is clearly, in contrast to unlearning as characterized by Melton and Irwin (1940), a *goal-directed* inhibitory mechanism. The assumed suppression is directed at the to-be-inhibited items themselves—that is, the memory representation of the entire set of B responses—and the forgetting produced by that suppression serves the adaptive goal of facilitating second list or A–D learning by reducing the proactive interference attributable to the previously learned B responses. Again, response-set suppression is an example of retrieval inhibition, because, although the subject has lost retrieval access to the B responses, their representations continue to exist in memory as demonstrated by their spontaneous recovery under certain conditions and by other findings, such as the virtual disappearance of retroactive interference effects when a multiple-choice recognition test is given rather than a recall test (Postman & Stark, 1969).

INHIBITION IN DIRECTED FORGETTING

As the chapters in this volume so amply demonstrate, intentional forgetting can be studied using a wide variety of procedures and subject populations. For our purposes, however, one procedure is most relevant; namely, the so-called "list method" in which subjects, after trying to learn a set of items of some type, are then cued that those items are to be forgotten. Typically, then, the "true" to-be-remembered items are presented to replace the to-be-forgotten ones. The cue to forget is explicit rather than implicit, and there are other differences as well, but the list method of directed forgetting shares one strong similarity to procedures such as the Brown–Peterson and A–B, A–D paradigms: The need for a subject to update his or her memory creates a motivation to forget or inhibit the now out-of-date items. (For descriptions of alternative directed-forgetting methodologies in human memory research, see R. A. Bjork, 1972, or MacLeod in this volume.)

Basic Procedures

In a typical directed-forgetting experiment of the list-method variety, illustrated in Fig. 3.1, subjects are presented with a list of items to study for a later memory test, with the items presented one at a time. At some point, usually halfway through the list, the presentation of items is interrupted with a cue either to forget the preceding items (middle list of Fig. 3.1) or to keep on remembering the preceding items (left list of Fig. 3.1). In addition to these two types of lists, a control list or condition (right side of Fig. 3.1)

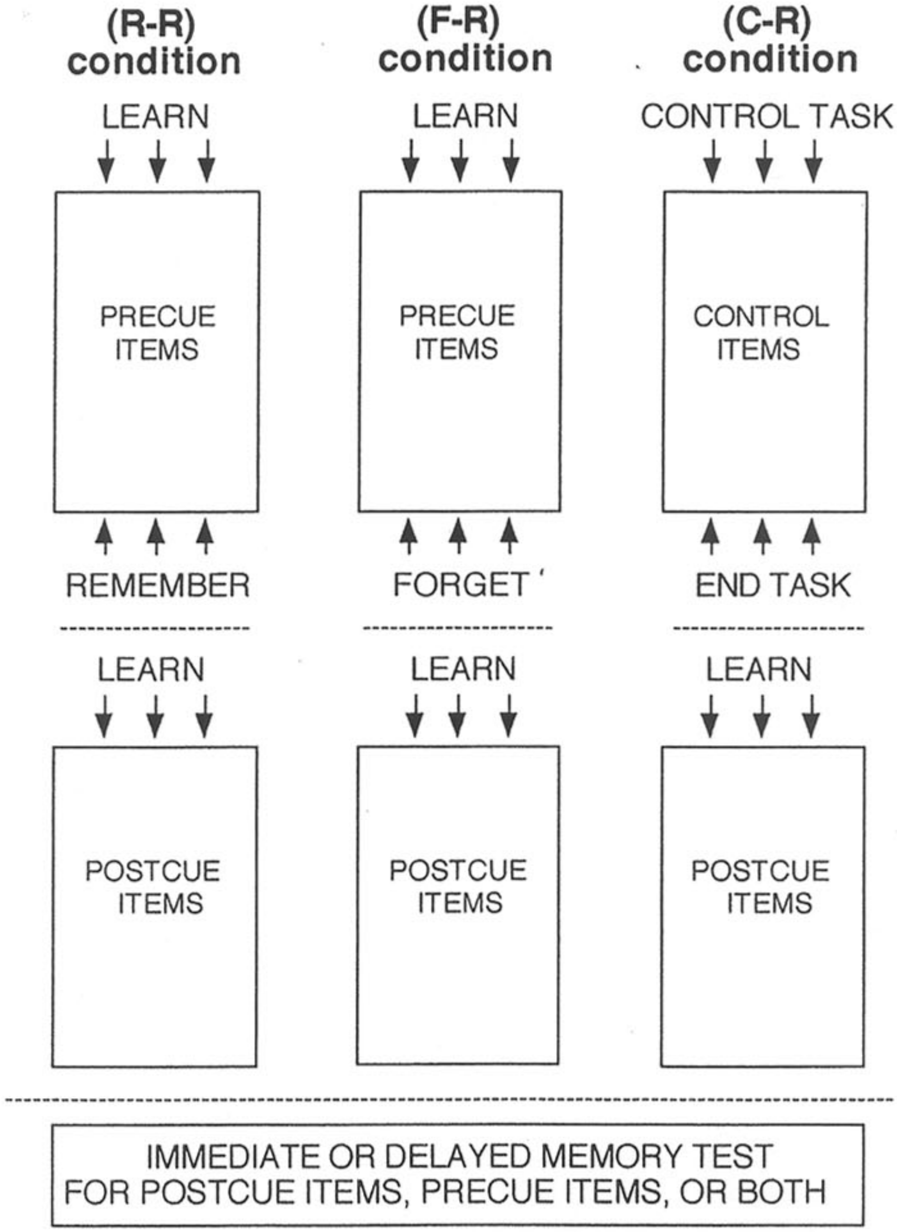

FIG. 3.1. Types of lists or conditions typically employed in the list-method paradigm of directed-forgetting research.

is also sometimes employed. In such a list, the precue items are replaced by a control task of some kind. For example, subjects might be asked to judge the similarity of pairs of shapes, with each pair presented at the same rate as the precue items in the other types of lists. Such a control condition permits a baseline measure of the recall of postcue items when there are no to-be-remembered or to-be-forgotten precue items. In the remainder of the present chapter, we refer to these three types of lists as forget–remember (F–R), remember–remember (R–R), and control–remember (C–R) lists or conditions.

The list method of directed forgetting can be used in either a within- or between-subjects design. When used in a within-subjects design, subjects are informed prior to the presentation of any lists that if a forget cue occurs, they will not be tested for their memory of the preceding items, only for their memory of the items to follow the forget cue; whereas, if a remember cue occurs, they need to keep remembering the preceding items for a later memory test. As long as these instructions are not violated, each of the different types of lists (R–R, F–R, and C–R) can be presented to the same subject multiple times. It needs to be emphasized, however, that in such designs, although subjects are informed at the beginning of the experiment that a cue to forget or a cue to remember can occur on any list, there is no way to anticipate which type of cue will occur during presentation of the precue items. Thus, until the cue occurs, subjects must process all presented items in the same way; namely, as items that they need to learn for a later memory test.

The effectiveness of the forget cue in this type of design is assessed by comparing the recall of postcue items in F–R lists to that of postcue items in R–R lists, and the forget cue is assumed to have been effective if proactive interference effects owing to precue items is significantly decreased in the F–R condition. Additionally, if a control condition was also employed, recall of postcue items from R–R and F–R lists can be compared to that of postcue items from C–R lists. Although subjects are not asked to recall forget items in experiments using this type of design, they are sometimes asked to try to recall any forget items that they can at the very end of the experiment when no further lists are to be presented. (An interesting exception to this rule is a study by Reitman, Malin, Bjork, and Higman, 1973, in which subjects were forewarned that they would occasionally be asked to try to recall forget items, but that they would be informed when they were being asked to do so, and that they should try not to let the possibility of such occasional tests influence what they typically did in response to a forget cue.)

When the list method of directed forgetting is used in a between-subjects design, the forget cue is usually introduced as a surprise. For example, in the F–R condition, presentation of the list may be stopped at the midpoint, at which time the experimenter explains that the preceding items were just for practice and can thus be forgotten, and that the subjects should now try to learn the real list, which is then presented. Or, in what is sometimes called the "whoops" procedure, presentation of items is stopped halfway through the list, at which time the experimenter explains that the preceding items had been presented by mistake, that the subject should thus try to forget those "incorrect" items and to learn the "correct" list of items that will now be presented. Then, following presentation of the next or second list, subjects are tested on the items they were instructed to forget as well as on those they were instructed to remember, and the effectiveness of the forget cue is assessed by comparing the recall of to-be-forgotten items to that of to-be-remembered items. Such misleading use of the forget instruction can, of course, only be used once for any given subject, explaining the need for the F–R versus the R–R condition to be manipulated as a between-subjects variable in these types of directed-forgetting studies.

Finally, we need to mention that there is another basic type of directed-forgetting paradigm, labeled *item-by-item cuing* by Bjork (1972), in which the presentation of each individual item is accompanied, either simultaneously or after a delay, by a cue to forget or to remember that item (see, e.g., Muther, 1965; Woodward & Bjork, 1971). Although there are many similarities between the effects obtained with these two paradigms, and originally it was thought that the processes initiated by the cue to forget were the same in both, there is accumulating evidence that this is not the case. That is, there are compelling reasons to believe that the impaired recall of to-be-forgotten items observed in these two paradigms arises as a consequence of somewhat different processes; in particular, that item-by-item cuing induces differential encoding and rehearsal of to-be-remembered and to-be-forgotten items, which creates a problem of separating the consequences of those differential processes from the consequences of retrieval inhibition (if any) per se.

Given our present focus, then, we limit our analysis to effects obtained with the list method, but we encourage the interested reader to see articles by MacLeod (1975, 1989), Paller (1990), and Basden, Basden, and Gargano (1993) and the chapters by MacLeod, Basden and Basden, and Hauselt in the present volume for results obtained with item-by-item cuing and for discussions of the differences between these two methods. We also encourage the interested reader to see the important work of Hasher, Zacks, and their colleagues, carried out using several variants of item-by-item cuing, on how the pattern of those results changes with aging (e.g., Hartman & Hasher, 1991; Zacks & Hasher, 1994; Zacks, Radvansky, & Hasher, 1996).

Basic Phenomena

Directed-forgetting effects obtained across many studies employing list-method procedures can be summarized in terms of three basic and robust findings. First, postcue to-be-remembered items are recalled better in F–R lists than in R–R lists. That is, the recall of to-be-remembered items appears to suffer less from proactive interference effects owing to precue items in F–R lists than in R–R lists. Second, recall of postcue items in F–R lists is often not different from that of postcue items in C–R lists in which no items are presented in the first half of the list. That is, the recall of postcue items in F–R lists often shows no evidence of suffering from any proactive interference effects owing to the presentation of precue items. In terms of the subjects' ability to recall the postcue to-be-remembered items, it is as though the preceding to-be-forgotten items had never been presented. Third, if subjects are unexpectedly asked to recall items that they were instructed to forget, their ability to recall such to-be-forgotten material is impaired compared to their ability to recall equivalent material that they were instructed to remember.

The reader is referred to R. A. Bjork (1972, 1989), Johnson (1994), and the chapter by MacLeod in the present volume for a review of the studies from which we have extrapolated this basic pattern of directed-forgetting results.

Evidence for Retrieval Inhibition in Directed Forgetting

The first suggestion that retrieval inhibition played a primary role in the production of the pattern of directed-forgetting results just described was reported by Geiselman, Bjork, and Fishman (1983). Until this time, the predominant theoretical account of directed-forgetting effects, proposed by R. A. Bjork (1970, 1972) during the early years of research on directed forgetting, attributed such effects to processes that had nothing to do with inhibition or suppression[1] or even forgetting. Instead, Bjork's model explained such effects in terms of two positive actions taken by subjects in response to a forget cue, namely, focusing all of their postcue rehearsal and other mnemonic activities on the to-be-remembered items and somehow segregating or differentiating in memory the to-be-remembered items from the earlier to-be-forgotten items.

In the Geiselman et al. (1983) study, subjects were presented with a list of two different types of items: intentional items they were asked to learn for a later memory test and incidental items they were asked to judge on a pleasantness scale rather than learn. These two types of items were presented auditorily and in strict alternation throughout the list, with each word being preceded by the appropriate cue, for example, the subject would hear "learn" hand, "judge" rake, "learn" bell, and so forth. Then, midway through the list, subjects either received an instruction that the to-be-learned words presented thus far were practice and should be forgotten

[1]Research by Roediger and Crowder (1972), Weiner (1968), and Weiner and Reed (1969) represent notable exceptions to this early reluctance to assume that inhibitory or suppression-like processes played a role in the production of directed-forgetting effects.

(i.e., the F–R condition), or subjects were instructed that the to-be-learned words presented thus far were the first half of the list and should be remembered (i.e., the R–R condition). Following presentation of the second half of the list, however, subjects in either condition were given a free-recall test and asked to recall all of the words that they could remember from the experiment; that is, judge words as well as learn words, and first-half list words as well as second-half list words.

Subjects' recall of the learn words showed the typical directed-forgetting result: lowered recall of precue to-be-forgotten words and enhanced recall of postcue to-be-remembered words. The important and surprising results, however, and the results leading to the postulation of a role for retrieval inhibition in producing directed-forgetting effects, were those obtained for the judge items. Namely, subjects' recall of these words showed the same directed-forgetting pattern as that obtained for the learn words. Although the results obtained for the learn words could continue to be explained in terms of the old assumptions of differential rehearsal and grouping of the second-half list words following the forget cue, the effects of the forget cue on the judge words could not be explained in those terms. Subjects were not trying to learn or rehearse the judge items. Nor was the forget cue directed at the judge words. Nonetheless, simply by being intertwined with the learn words, or being part of the same episode as the learn words, it appeared that the judge words had also been inhibited or rendered inaccessible by the forget cue. By being in the same place as the learn words, the judge words had, so to speak, suffered the same fate as the learn words.

Alternative explanations of these results, such as subjects becoming confused about what were learn words and what were judge words or that the impaired recall of to-be-forgotten words arose from output interference owing to to-be-remembered words tending to be output first on the recall test, were ruled out by additional analyses and experiments performed by Geiselman et al. (1983). For example, in additional studies, subjects were able to sort the words they recalled into judge and learn categories with high accuracy and, even when learn and judge words were drawn from different categories, the same pattern of results obtained. Similarly, controlling for output order during recall did not change the basic pattern of results.

Thus, on the basis of these findings as well as other considerations that we elaborate in a later section, the explanation of directed-forgetting effects obtained with the list method that we and others have come to prefer includes the additional mechanism of retrieval inhibition. More specifically, we believe that when subjects are told to forget preceding information and are then presented with new information to learn, a process is initiated that inhibits the subsequent retrieval of the to-be-forgotten information. Because such to-be-forgotten items are not retrievable, they do not interfere with the recall of to-be-remembered information. Furthermore, whereas this updating process inhibits the retrieval of the to-be-forgotten information, it leaves its strength in memory—as indicated by other measures—unaffected.

Evidence for this last assumption comes from the following findings: (a) When measured by a recognition test, memory for to-be-forgotten items is unimpaired as compared to that for to-be-remembered items (e.g., Block, 1971; Elmes, Adams, & Roediger, 1970; Geiselman et al., 1983; Gross, Barresi, & Smith, 1970); (b) in a relearning paradigm, to-be-forgotten items are relearned as readily as to-be-remembered items (e.g., Geiselman & Bagheri, 1985;[2] Reed, 1970); and (c) the proactive interference of precue items that is eliminated by the forget instruction can, under certain circumstances, be reinstated at full strength. Evidence for this last effect, obtained in a series of studies conducted by E. L. Bjork, R. A. Bjork, and various collaborators, is described in a later section.

Necessary Conditions for Retrieval Inhibition in Directed Forgetting

Although considerable evidence suggests that people can intentionally forget previously learned items in such a way that their retrieval access to them is inhibited, there also appear to be limitations to this ability. One limitation concerns the timing of the forget instruction. A forget instruction seems to be most effective if given immediately after the to-be-forgotten items have been presented for study. If the cue to forget is delayed until after additional study material has been presented, there is both less forgetting of the to-be-forgotten information and little or no reduction in the proactive interference owing to such items on the recall of the later studied items (e.g., R. A. Bjork, 1970; Epstein, Massaro, & Wilder, 1972; Roediger & Tulving, 1979).

Another constraint on the effectiveness of the forget cue appears to be that new learning needs to occur after the forget instruction is given in order to produce retrieval inhibition. Evidence for this possible necessary condition comes from an experiment by Gelfand and R. A. Bjork (1985; described in R. A. Bjork, 1989). In the critical aspect of this experiment for the present issues, an initial study list of nouns was followed by instructions either to forget or to remember the preceding items, after which (a) some subjects did nothing while the experimenter fumbled around killing time; (b) some subjects received a list of adjectives for which they had to perform a rating task; and (c) some subjects received a second study list of nouns to learn. Then, after each type of activity, all subjects—that is, both those given the

[2]Although we cite the Geiselman and Bagheri (1985) study here, the relevance of these findings for assumptions regarding retrieval inhibition is somewhat questionable as they were obtained using the item-by-item cuing procedure as opposed to the list method of directed forgetting.

forget instruction and those given the remember instruction—were tested for their recall of the first study list of nouns.

Consistent with the results of previous studies, Gelfand and Bjork found that recall for to-be-forgotten items was impaired for subjects given a second list of nouns to learn following the forget instruction. However, instructing people to forget the first study list of nouns did not impair later recall of such to-be-forgotten items when this instruction was followed by either the unfilled interval or the adjective-rating task. On the basis of this pattern of results, it would seem that the instruction to forget, in and of itself, is not sufficient to inhibit retrieval of the to-be-forgotten items; rather, a resetting of the learning process initiated by the presentation of a new list of to-be-remembered items is necessary for inhibition of the prior to-be-forgotten items to occur.

Nature of the Retrieval Inhibition Involved in Directed Forgetting

We turn now to a discussion of a series of studies dating back to 1973 in which E. L. Bjork, R. A. Bjork, and various collaborators (e.g., E. L. Bjork, Bjork, & Glenberg, 1973; E. L. Bjork, Bjork, & White, 1984) tried to characterize more fully the underlying processes involved in directed-forgetting effects by investigating the conditions under which the proactive interference owing to to-be-forgotten items is or is not reinstated. Or, expressed in terms of the theoretical processes presently under consideration, these studies tried to characterize more fully the nature of the retrieval inhibition involved in directed-forgetting effects by investigating the conditions under which such inhibition is or is not released.

The basic procedure used in this series of studies was to present the three list types described in Fig. 3.1 and then to measure subjects' ability to recall postcue to-be-remembered items by a free-recall test that was either immediate or delayed by different types of interpolated activities. Across the various studies conducted, the different types of interpolated tasks included solving arithmetic problems, a forced-choice recognition test, and a yes/no recognition test. When the interpolated task was a forced-choice recognition test, subjects were shown pairs of words and asked to judge which word had been presented in the postcue part of the list; thus, for all list types, the correct choice was always a to-be-remembered item. On a subset of the pairs, however, the distractor item was a word that had appeared in the precue part of the list; thus, for F–R lists, such pairs contained a to-be-forgotten item as a distractor. When the interpolated task was a yes/no recognition test, subjects were shown individual words and asked to indicate whether each had been presented in the postcue part of the list; thus, again, for all list types, subjects were only required to recognize to-be-remembered words. On some yes/no recognition tests, all distractors were new items; however, on others, a subset of the distractors came from the precue part of the list; thus, for F–R lists, these were to-be-forgotten items.

The recall performance obtained in these studies, which was based only on words that had *not* been re-presented in any of the interpolated tasks, can be summarized as follows. On the immediate recall test, the basic directed-forgetting pattern was obtained: Recall of postcue items from R–R lists was significantly poorer than that from F–R lists, which did not differ from that obtained in the C–R condition. When recall was delayed by the solving of arithmetic problems, performance levels were depressed, but the same basic directed-forgetting pattern was obtained as in the immediate recall condition. When, however, recall was delayed by either the forced-choice recognition test or the yes/no recognition test in which some of the distractors were precue items, a dramatically different pattern of results was obtained: Now, recall performance in the F–R condition decreased to the level of the R–R condition, with both being poorer than performance in the C–R condition. In contrast, when recall was delayed by a recognition test that did *not* re-present precue items as distractors, the basic directed-forgetting pattern of results (i.e., the pattern observed in the immediate recall condition) was again obtained.

Couched in the present theoretical terms, these results demonstrate that when a free-recall test is delayed by some dissimilar task, such as the solving of arithmetic problems, there is no spontaneous recovery of the proactive interference owing to to-be-forgotten items; that is, the retrieval inhibition imposed on such items is not released. When, however, the free-recall test is delayed by a recognition test of postcue to-be-remembered items on which only a small subset of the to-be-forgotten items appear as distractors, the retrieval inhibition of the entire set is apparently released, as evidenced by the drop in recall of postcue to-be-remembered items to the level of that obtained when subjects do not receive instructions to forget the precue list. It is not, however, the recognition test per se that releases the inhibition of the to-be-forgotten items. When the recognition test for postcue to-be-remembered items does not re-present any to-be-forgotten items as distractors, then the entire set remains inhibited, as evidenced by the lack of any proactive interference effects on the recall of the postcue to-be-remembered items.

Such a pattern of results raises questions of exactly what is inhibited as a consequence of instructions to forget and then released by certain tasks, such as a recognition task involving to-be-forgotten items as distractors. For example, does an instruction to forget cause inhibited overall access to the to-be-forgotten items in memory, or, rather, inhibited access to those items because they are part of an episode that is inhibited—namely, the learning of the list that subjects were instructed to forget? Additionally, would inhibited to-be-forgotten items, as indicated by recall measures and the absence of proactive interference effects, nonetheless continue to have indirect or unconscious effects on other types of performance?

To answer such questions, the same list types (R–R, F–R, and C–R) were again presented to participants and followed by a free-recall test of the postcue to-be-remembered words that was either immediate or delayed by an interpolated task (E. L. Bjork & Bjork, 1996, Experiment 2). In this study, however, the interpolated task was a word-fragment-completion task, which included a subset of precue and postcue items, and, thus, for F–R lists, some fragments were based on to-be-forgotten items. As in the earlier studies, on the immediate free-recall test (again, based only on the recall of words not re-presented on the intervening task), the basic directed-forgetting pattern was obtained. Given that it could thus be inferred that the to-be-forgotten items were inhibited, as evidenced by their lack of interference on the recall of the to-be-remembered items, two critical questions concerning the nature of this inhibition could be asked.

First was the question of whether access to the to-be-forgotten items to serve as appropriate completions on the word-fragment-completion task would also be inhibited. That is, would the completion rate for precue to-be-forgotten words be less than that for precue to-be-remembered words and, possibly, not different from the completion rate for the new, or unprimed, words? A positive answer to this question would imply that the effects of the inhibitory processes initiated by the forget cue were not limited to inhibiting conscious access to the precue list-learning episode, but that they also extended to the inhibition of specific item representations in semantic memory. The answer to this question was that the priming effect of the to-be-forgotten words was equal to that of the to-be-remembered words, indicating that indirect access to the to-be-forgotten items was either not inhibited by the directed-forgetting instructions or that possibly the original inhibition had been released during the word-fragment-completion task.

Thus, the second critical question to be asked was whether the intervening word-fragment-completion task had reinstated the proactive interference of the to-be-forgotten items on the recall of postcue to-be-remembered items. The answer was "no": The overall pattern of performance, although lower, remained the same as in the immediate recall condition; that is, the basic pattern of directed-forgetting results was obtained. Thus, despite no sign that the to-be-forgotten items were inhibited on the word-fragment-completion task (priming effects were just as strong for them as for the to-be-remembered words), that they were inhibited in some way was indicated by the lack of any proactive interference effects on the delayed recall test for the to-be-remembered items.

Considered together, the results obtained in this series of studies reveal several important characteristics concerning the nature of the inhibition involved in directed forgetting. Clearly, special conditions are necessary to release the inhibition imposed on items in response to the instruction to forget them, or to reinstate the proactive interference that would normally arise from such items. One such condition is that at least some subset of the to-be-forgotten items must be re-exposed to subjects. Mere exposure, however, is not sufficient. During this exposure, the forgotten material must be processed in a manner that accesses, or makes contact with, the initial learning episode. This necessary condition for release would seem to indicate that the inhibition involved in directed forgetting is not a general inhibition of the to-be-forgotten items as lexical entries. If that were the case, the to-be-forgotten items should have primed their completions less well than the to-be-remembered items primed their completions on the intervening word-fragment-completion task. Although the word-fragment-completion task does involve a type of retrieval in that only some letters of each word are presented, the type of retrieval involved is largely data driven. That is, it is not a task that directs or refers the subject back to the initial learning event or episode. On the other hand, the intervening recognition test is just such a task; indeed, when subjects encountered to-be-forgotten items in the context of this type of task, proactive interference owing to the forgotten items was reinstated.

In conclusion, the inhibition involved in the directed-forgetting situation appears to be a type of retrieval inhibition that impairs conscious access to original learning episodes that are the object of a forget instruction; that is, the episode in which the information was first learned and then intentionally forgotten. This inhibition does not, however, seem to inhibit the activation level of the to-be-forgotten information in semantic memory or to prevent it from having indirect or unconscious influences on behavior. Indeed, in some research in progress in which we are using a variant of Jacoby's famous-name task (e.g., Jacoby, Kelley, Brown, & Jasechko, 1989; Jacoby, Woloshyn, & Kelley, 1989) in a directed-forgetting design, we appear to be obtaining evidence that information subjects have intentionally forgotten can have greater indirect or unconscious influences on their judgments than information they have been instructed to remember (E. L. Bjork, Bjork, Stallings, & Kimball, 1996).

RETRIEVAL-INDUCED FORGETTING

The retrieval-practice paradigm (as instantiated in Anderson et al., 1994) was initially developed to assess the effects of increasing the retrieval strength of some items on the retrieval strength of other related items. This question was motivated, in part, to test predictions of what these effects should be according to the "new theory of disuse" proposed by R. A. Bjork and E. L. Bjork (1992). The relevant assumptions of the new theory of disuse are (a) that an item's representation in memory can be characterized by two types of "strengths," a storage strength and a retrieval strength; (b) that storage strength grows as a pure accumulation process and is unlimited in the sense that a given item's storage strength is not decreased by increases in the storage strength of other items; but (c) retrieval strength is assumed to be a limited resource—that is, if the retrieval strength of a given item associated with a cue of some type is increased via study or retrieval practice, the retrieval of other items associated with that cue is assumed to decrease. Anderson et al. obtained results consistent with those assumptions and inconsistent with spreading-activation theories, which predict that the benefits of practicing the retrieval of a given item should spread to other closely related items.

Beyond addressing that initial motivating question, the retrieval-practice paradigm has proven to be a rich source of other findings; in particular, findings that clarify the underlying mechanisms by which increasing the retrieval strength of one item decreases the retrieval strength of similar items. The results obtained by Anderson and Spellman (1995), which suggest that inhibitory mechanisms may play quite a general role in higher-order cognitive processes, have especially broad implications. How the logic of this paradigm has permitted the investigation of such questions and issues is explained in the next section.

The Basic Paradigm and Results

The logic of the retrieval-practice paradigm is most easily illustrated in the context of a simple semantic network, as shown in Fig. 3.2. Here, two category nodes are depicted, *Fruit* and *Drink*, each with two studied exemplars. In the context of this network, the basic questions addressed by the retrieval-practice paradigm concern the effects of giving retrieval practice to one exemplar, such as *Orange*, on the later recall of *Orange* itself, and on the later recall of other exemplars that are associated with the same category cue but that are not given specific retrieval practice, such as *Banana*. These effects can be assessed by comparing the later recall of *Orange* and *Banana* to the retrieval cue *Fruit* to the later recall of corresponding exemplars from an unpracticed category, depicted in Fig. 3.2 by the exemplars *Scotch* and *Gin* of the category *Drink*.

The basic procedure used in the retrieval-practice paradigm involves four phases: a study phase, a directed retrieval-practice phase, a distractor (retention interval) phase, and a final, surprise recall test. In the first phase, subjects are presented with a list of category-exemplar pairs, with the pairs being presented individually and in mixed order. After this study phase, subjects engage in directed retrieval practice on half of the items for half of the categories. Retrieval practice is directed by presenting a category

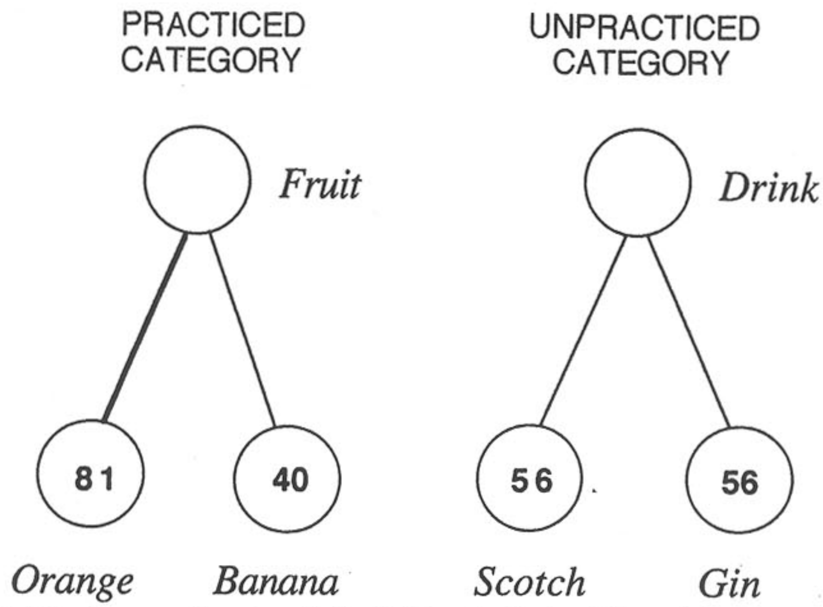

FIG. 3.2. A semantic network illustrating the logic of the retrieval-practice paradigm. The circles represent nodes for categories and exemplars, and the lines represent the associative links between them. Giving retrieval practice to *Fruit–Orange* (indicated by the heavier line connecting *Fruit* and *Orange*), but not to *Fruit–Banana* creates practiced and unpracticed exemplars from a practiced category, respectively. The unpracticed exemplars *Scotch* and *Gin* from the unpracticed category *Drink* serve as baseline controls. The numbers depicted inside the exemplar nodes illustrate a typical pattern of results obtained in this paradigm (e.g., Anderson et al., 1994, Experiment 1). The recall of *Orange*, a practiced exemplar, has been facilitated compared to the baseline of unpracticed controls (*Scotch* and *Gin*); whereas the recall of *Banana*, an unpracticed exemplar of a practiced category, has been impaired compared to the same baseline.

name, such as *Fruit*, together with a two-letter stem, such as "Or___" for the exemplar *Orange*, and subjects are instructed to retrieve the previously studied exemplar that fits the combined category-stem cue. To maximize the effectiveness of this retrieval practice, each pair is usually given three such retrieval-practice tests separated by expanding intervals filled with the retrieval practice of other items (Landauer & R. A. Bjork, 1978).

The retrieval-practice phase is followed by a distractor phase, typically lasting 20 minutes. A surprise recall test is then given for all category-exemplar pairs presented in the original study list. In this final test, subjects are presented with each category cue and asked to free recall any exemplars that they can remember from any part of the experiment. (A category-plus-stem cued-recall test has also been employed to control for output interference effects.) On the final test, recall of the three types of exemplars depicted in Fig. 3.2 are of interest: (a) exemplars given retrieval practice (e.g., *Orange*); (b) unpracticed exemplars from practiced categories (e.g., *Banana*); and (c) unpracticed exemplars from unpracticed categories (e.g., *Scotch* or *Gin*).

The results of a typical experiment using this paradigm (Anderson et al., 1994, Experiment 1) are also shown in Fig. 3.2, where the numbers inside the exemplar nodes represent the percentage of exemplars of that type correctly recalled on a final category-cued free-recall test. Practicing the retrieval of *Orange* to the category cue *Fruit*, compared to the baseline recall of unpracticed controls, facilitated its final recall (in this case, by 25 percentage points), consistent with many prior studies (for a sample, see Allen, Mahler, & Estes, 1969; R. A. Bjork, 1975; Landauer & Bjork, 1978; Whitten & Bjork, 1977). The recall of *Banana*, however, compared to the same baseline, was clearly impaired (in this case, by 16 percentage points).

Findings That Implicate Suppression

The impaired recall of unpracticed members of practiced categories, illustrated by the recall of *Banana* in Fig. 3.2, is what we have called *retrieval-induced forgetting*, and our conception of the mechanism producing such forgetting is as follows (see also Anderson et al., 1994). During the retrieval practice of *Orange*, *Banana* is activated causing interference. To retrieve *Orange* selectively in the presence of such competition, *Banana* must be inhibited or suppressed, which is then reflected in its impaired recall on the final recall test. According to this view, inhibitory processes facilitate momentary coherence in cognition and action, in that they serve to decouple competing representations from response-production mechanisms and prevent accidental, misdirected responding. This proposed function of inhibitory processes is compatible with the selection-for-action view of selective attention (see Allport, 1989), although the critical need for selection derives from competition among competing memory traces rather than from external percepts.

Given just the findings shown in Fig. 3.2, other explanations that do not appeal to inhibition in the strong sense, such as blocking (e.g., Blaxton & Neely, 1983; Roediger, 1974; Roediger & Neely, 1982; Rundus, 1973; Tulving & Hastie, 1972; Watkins, 1975) or response competition (e.g., McGeoch, 1942; Mensink & Raajimakers, 1988; Raajimakers & Shiffrin, 1981) owing to the strengthening of the practiced pairs, are consistent with the observed retrieval-induced forgetting. To test between these alternative explanations, we have conducted a number of studies using the following basic strategy. First, we construct a situation in which competitors would not be expected to interfere and thus be suppressed during the retrieval practice of other category-exemplar pairs. Then, we ask the question: Will the later recall of such competitors be nonetheless impaired, consistent with blocking or response-competition or strength-dependence explanations, or will their later recall *not* be impaired, consistent with the suppression hypothesis?

In one such study (Anderson et al., 1994, Experiment 3), we manipulated the taxonomic strength of the practiced and unpracticed exemplars. According to our suppression hypothesis, taxonomically strong, unpracticed exemplars should compete during the retrieval practice of other pairs and, thus, have to be suppressed. In contrast, taxonomically weak, unpracticed exemplars would be unlikely to compete during retrieval practice and, thus, should escape being inhibited. Most noninhibitory explanations, however, would have to predict that the recall of either type of exemplar would be impaired owing to the strengthening of the practiced pairs, and certain specific theories of that type predict that practice of weak exemplars should *cause* more retrieval-induced forgetting and/or that weak exemplars should *suffer* more retrieval-induced forgetting. What we found was that the recall of taxonomically strong exemplars (exemplars that should compete during retrieval practice of other exemplars) was impaired whether the practiced exemplars were taxonomically strong (e.g., *Orange*) or taxonomically weak (e.g., *Papaya*). In contrast, recall of taxonomically weak exemplars (exemplars that would be less likely to compete during retrieval practice of other exemplars) was not impaired and perhaps even facilitated, whether the practiced items were taxonomically strong or weak. This pattern of results was obtained even though large positive effects of retrieval practice were obtained for both strong and weak exemplars.

Additional support for the suppression hypothesis was obtained when we manipulated the type of retrieval practice given subjects (Anderson, Bjork, & Bjork, 1993, Experiment 2). In this experiment, all subjects studied the same list of category-exemplar pairs, but some subjects then engaged in a type of retrieval practice that we assumed to be competitive, whereas others engaged in a variation of retrieval practice that we assumed not to be competitive. To illustrate, subjects given competitive retrieval practice were cued, as before, with *Fruit–Or___*, whereas subjects given noncompetitive retrieval practice were cued with *Fr___–Orange* as a cue to recall "Fruit." Thus, in both cases, subjects engaged in retrieval practice of the critical category-exemplar associations and, in both cases, that association was very likely to be strengthened by these additional processing occasions. We assumed, however, that, in the former case, retrieving *Orange* would be subject to competition from other strong exemplars, such as *Banana*, which would then need to be suppressed during the retrieval-practice phase. In contrast, during the noncompetitive retrieval practice, there should be no such competition among exemplars.

The results obtained in this study were consistent with the suppression hypothesis. Both types of retrieval practice resulted in the strengthening of practiced category-exemplar pairs: Recall of *Orange* was facilitated by both the *Fruit–Or___* and *Fr___–Orange* types of practice; but it was only in the competitive retrieval-practice condition that the recall of unpracticed exemplars, such as *Banana*, was impaired. Again, these results provide strong support for the idea that retrieval-induced forgetting results from the need to select against potentially interfering competitors in order to achieve the goal of retrieving the target defined by the retrieval-practice cue.

Evidence of Cue-Independent Forgetting

Although the results just reviewed constitute strong support for the suppression hypothesis, the most compelling evidence that retrieval practice triggers *inhibition* in the strong sense of that term comes from research by Anderson and Spellman (1995). Using what they have called the *independent-probe technique*, they conducted an experiment using categories and exemplars related as illustrated in Fig. 3.3.

Thus, on the study list of category-exemplar pairs, there were categories, such as *Red* items and *Food* items, for which some exemplars studied under only one of the categories were also semantic members of the other category. Suppose now that *Red–Blood* is given retrieval practice. Both inhibitory and noninhibitory accounts would predict that retrieval practice of *Red–Blood* should impair the later recall of *Red–Cherry*. The crucial question that allows separation of these two types of accounts is what effect practicing *Red–Blood* should have on the later recall of *Food–Radish*. Only the suppres-

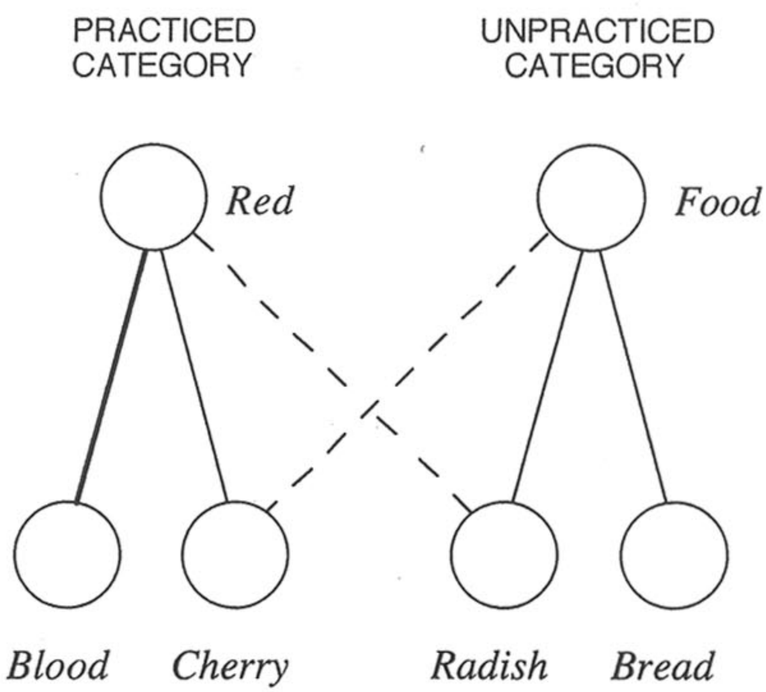

FIG. 3.3. Illustration of how related categories were constructed in Anderson and Spellman (1995, Experiment 1). *Blood* and *Cherry* are practiced and unpracticed exemplars, respectively, of a practiced category, and *Radish* and *Bread* are unpracticed exemplars from an unpracticed category. However, as illustrated by the dashed lines, *Radish*, although never studied as such in the experiment, is a semantic member of the *Red* category.

sion/inhibition account of retrieval-induced forgetting predicts that later recall of *Radish* to the retrieval cue *Food* might be impaired.

Such an impairment is predicted because *Radish's* implicit semantic link to the category cue *Red* should cause it to be activated and to compete during the retrieval practice of *Red–Blood*. That is, even though *Radish* was not paired with *Red* in the study list, it is a potential competitor when members of the *Red* category are retrieved during the retrieval-practice phase. If *Radish* does compete in this way, then to retrieve the desired target *Blood*, *Radish* will have to be inhibited, just like *Cherry*. Furthermore, if *Radish's* representation in memory is truly inhibited by being selected against during the retrieval practice of *Red–Blood*, then performance decrements arising from that inhibition should generalize to any cue used to test it.

The results obtained in this study replicated the basic pattern shown in Fig. 3.2; that is, facilitated later recall of practiced exemplars (e.g., *Blood* to *Red*) and impaired later recall of unpracticed exemplars from practiced categories (e.g., *Cherry* to *Red*). Additionally, the final recall of exemplars like *Radish* to the retrieval cue *Food* was also impaired significantly. The impaired recall of *Radish* was assessed by comparing performance on that item in the key experimental condition just described to the recall of that same item in a control condition where it was again presented as a *Food* but the category *Red* was neither studied nor practiced.

Anderson and Spellman's results provide strong support for an inhibitory account of retrieval-induced forgetting, because the mechanisms proposed by the noninhibitory accounts to explain within-category impairment (e.g., the impaired recall of *Cherry* to *Red*) are not applicable to the recall of items in response to a separate retrieval cue (e.g., *Radish* to *Food*). What is not so clear yet, however, is whether the inhibition observed is *retrieval* inhibition. Experiments on the recognition, relearning, or recovery of the inhibited exemplars, analogous to those in the directed-forgetting domain, have yet to be carried out. It is possible, at least in principle, that retrieved-induced forgetting does not simply impair the retrieval of the inhibited items, but also impairs some aspect of their episodic/semantic representation per se.

SIMILARITIES AND DIFFERENCES AMONG MECHANISMS

We have reviewed three research paradigms that involve what we describe as goal-directed forgetting, and we have indicated the evidence that leads us to think that the forgetting observed in each case is best explained in terms of inhibitory mechanisms. By doing so, we mean to assert that the forgetting observed in these situations reflects an impairment arising from a suppression-type process directed at the to-be-inhibited information for some adaptive purpose or goal. We do not, however, mean to assert that the processes by which such inhibition is invoked are necessarily the same, nor that the goal-directed nature of the forgetting is the same in each case. Indeed, we now turn to a discussion of issues concerning similarities and differences among the inhibitory mechanisms implicated in unlearning, directed forgetting, and retrieval-induced forgetting.

Does Intention Matter?

At a general level, the goal of the forgetting observed in all three paradigms is the same; namely, to avoid interference. One potentially significant difference, however, is the degree to which this goal is explicit. Of the three situations, the goal to forget seems most explicit in the directed-forgetting paradigm. In fact, in that paradigm, it may be the case that without an explicit intent on the part of the subject "to forget," inhibition of the to-be-forgotten items does not occur.

Such a possibility is suggested by the Gelfand and Bjork (1985) study described earlier. On the one hand, intent by itself did not seem to produce inhibition of the to-be-forgotten items; rather, new learning seemed necessary for the production of retrieval inhibition. On the other hand, new learning did not appear to be sufficient to produce inhibition. When subjects were given the list of adjectives to rate after being told to forget the previously studied list of items, one might have expected some inhibition of those items if new learning was a sufficient condition, because this type of adjective rating task produces good incidental learning. Thus, it may well be that both intent to update the system—that is, to forget some prior information—and the process of storing new information in memory—in particular, information that is looked upon as replacing the previously stored information—are necessary conditions for retrieval inhibition to occur.

Similarly, in the A–B, A–D paradigm, it is not clear the degree to which subjects' intentions play a role in causing the inhibitory mechanism of response-set suppression to be invoked during the interpolated learning of the A–D list. In fact, to our knowledge, there are no data that directly bear on this issue.[3] To the degree subjects realize that they need to replace the previously learned responses with the new set of responses, and that keep-

[3]A study by Postman and Gray (reported as a personal communication in R. A. Bjork, 1978) could be of relevance here. When, in an A–B, A–D paradigm, subjects were given explicit instructions not to give any thought to the first list during acquisition of the second list, second-list acquisition was both speeded up and there was little or no recovery of PI—that is, in our terms, little or no evidence of release from any inhibition imposed on the first-list items. In a more recent study by Wheeler (1995, Experiment 3), subjects were told that the A–B list had just been for practice and that they would not be tested on it. Whether such instructions contributed to inhibition of the A–B items, however, cannot be assessed as there was no comparable group given instructions to continue remembering the A–B list.

ing the old responses from intruding during the acquisition of the new responses will aid this process, one might speculate that subjects' intent could play a role, as in the directed-forgetting paradigm. Indeed, one could argue that although not explicitly instructed to forget the previously learned B responses and replace them with the D responses, there is nonetheless a very clear implicit cue to forget in this paradigm.

In contrast to these situations, however, it seems clear that in retrieval-induced forgetting, there is no explicit goal on the part of the subject to forget any of the materials presented in the previous study list. Rather, the goal during retrieval practice is selectively to retrieve the desired target exemplar when presented with its cue, a process that might be thought of as being analogous to selection for action or selective attention (see, Anderson et al., 1994, and, particularly, Anderson & Spellman, 1995, for a detailed discussion of the similarities between selective retrieval and selective attention). Nonetheless, the operations invoked to satisfy that goal result in the forgetting of similar or competing information, in particular the information that is selected against.

Recovery From Retrieval Inhibition

Our conjecture that there is an implicit instruction to forget in the A–B, A–D paradigm suggests that the processes involved in creating retrieval inhibition in that situation might be very similar to, if not the same as, those involved in the directed-forgetting paradigm. Certainly, the assumption that the suppression invoked in that paradigm applies to the entire set of first-list responses is similar to our assumption that the inhibition invoked in the directed-forgetting paradigm acts on the entire precue list-learning episode. On the other hand, whereas there does seem to be convincing evidence for spontaneous recovery of first-list B responses in the A–B, A–D paradigm, there is no such corresponding evidence in the directed-forgetting paradigm. Indeed, what direct evidence exists relevant to this issue, such as the results from the previously described studies in which recall was delayed by various intervening tasks or from studies reported by Gilliland, Basden, and Basden (1995, as cited in Basden & Basden in the present volume), indicates the opposite: Retrieval inhibition imposed by an instruction to forget does not diminish simply as a function of delay.

In coming to this inference, one might well wonder about the relevance of results obtained by Wheeler (1995) in his studies investigating spontaneous recovery. His subjects did show improved recall with delay for a target list that, after studying, they were told was just for practice and would not be tested. Indeed, Wheeler concluded from these results that effects due to retrieval inhibition dissipate over time or with delay from the interpolated learning of additional lists. A problem with this conclusion, however, is that none of his experiments incorporated what would be comparable to an R–R condition. Thus, we cannot really know whether the items in his target list were actually inhibited either in terms of subjects' ability to access or retrieve them or in terms of their not exhibiting proactive interference effects. That is, although when given a surprise test for the target list, subjects' ability to recall items from the list improved with time, we cannot really infer if this improvement was due to a release from retrieval inhibition or to other factors, such as a relative decrease with delay in the competitive dominance of items from the interference lists studied later. Clearly, this is an issue needing further research.

It also seems to be the case that the inhibition evoked in the retrieval-practice paradigm does not undergo spontaneous recovery. Moreover, based on preliminary results from our laboratory, it seems likely that different conditions may be necessary for the release of inhibition created by the retrieval-practice paradigm as compared to that created in the directed-forgetting paradigm.

Finally, we should point out that although the inhibition proposed by the response-set suppression hypothesis and that proposed to be invoked in the directed-forgetting situation seem more similar to one another than to that proposed to explain retrieval-induced forgetting, this is only true with respect to the response-set suppression hypothesis as formulated by Postman et al. (1968). If the possibility of stimulus-specific response suppression, as well as suppression of the entire set of list-1 responses, is assumed possible, as suggested by Postman and Underwood (1973) to account for results from studies using mixed-list interpolation, then the proposed inhibitory mechanism becomes more similar to that proposed by Anderson et al. (1994).

Shortly after the original proposal of response-set suppression, problematical results were reported from studies in which both A–D and C–D items were mixed together in the same interpolated lists (e.g., Delprato, 1971; Weaver, Rose, & Campbell, 1971; Wichawut & Martin, 1971). In these studies, half of the items in the interpolated list were C–D pairs for which neither the stimulus nor the response term had been on the A–B study list. The other half of the items, however, were A–D pairs. Thus, half the A–B pairs from the original study list had specific retroactive-interference pairs on the interpolated list whereas the other half did not. In such studies, recall on a subsequent MMFR test (i.e., a recall test in which subjects are free to give all responses associated to the same cue in any order, thus presumably eliminating response competition effects on recall) showed greater impairment for those A–B pairs with specific retroactive-interference pairs on the interpolated list than for those without such pairs. In essence, then, these results were inconsistent with the original notion of response-set suppression in which the mechanism of suppression was assumed to act on the entire set of first-list B responses.

In addressing the problem created by such findings for the response-set suppression hypothesis, Postman and Underwood (1973) proposed that "differential suppression of subgroups of items" (p. 25) within a list might be possible. Although they did not suggest a mechanism for such stimulus-specific response suppression, certainly one feasible mechanism would be that proposed by Anderson et al. (1994) to account for retrieval-induced forgetting. (A more detailed discussion and critical analysis of this suggested modification to the original response-set suppression hypothesis as a consequence of mixed-list interpolation findings can be found in Anderson & Neely, 1996; Brown, 1976; and Crowder, 1976.)

RELEVANCE TO INHIBITION AND RECOVERY OF TRAUMATIC MEMORIES: SOME SPECULATIONS

We end this chapter with some speculations concerning the possible relevance of the inhibitory processes that we have reviewed for an issue of considerable current concern: the forgetting and recovery of traumatic memories. We were asked to address this issue at a recent symposium of the Second International Conference on Memory (E. L. Bjork, Bjork, & Anderson, 1996). More specifically, in a symposium entitled "Inhibitory processes in memory: Clinical and experimental perspectives," we were asked what implications inhibitory processes identified in the laboratory might have for understanding clinical observations of the forgetting and recovery of traumatic memories.

Replacing Unpleasant Memories With Pleasant Ones

Here and elsewhere (e.g., R. A. Bjork, 1989; E. L. Bjork & Bjork, 1988; R. A. Bjork & Bjork, 1992), we have stressed the importance of forgetting in memory updating. The argument is that the type of retrieval inhibition demonstrated by directed-forgetting results plays an adaptive role in keeping readily accessible information that we need in our present situations by preventing information that is no longer needed (but still in memory) from interfering. It does not, therefore, seem too far fetched to assume that the same or similar processes could be involved in the replacing of unpleasant memories with more pleasant ones. Just as with the to-be-forgotten items in the present directed-forgetting research, such negative memories would still reside in memory, but one's access to them would be inhibited.

Furthermore, whereas such memories would not tend to recover spontaneously (that is, become accessible on their own), as implied by the lack of recovery of to-be-forgotten items when recall was delayed by the arithmetic task, they could continue to influence behavior in indirect ways, as implied by the finding that to-be-forgotten items continue to prime, although still inhibited in terms of retrieval access. One's access to such memories, however, could possibly be reinstated under certain conditions, such as encountering or being supplied with cues that formed part of, or were a subset of, the inhibited episodic event or memory.

With respect to this possible means of reinstatement, it is interesting to consider a possible connection between the results obtained in the previously described directed-forgetting studies involving some to-be-forgotten items as distractors and the results obtained by Myers and Brewin (1994) using the semi-structured interview technique to assess the recollections of subjects classified as repressors. Repressors are individuals who score low on a measure of trait anxiety but high on a measure of defensiveness, and who are believed to possess a repressive coping style in that they typically report fewer negative memories than nonrepressors. When interviewed using this technique, however, Myers and Brewin found repressors to report more memories of parental antipathy and indifference than did nonrepressors. Perhaps the direct questions or probes used in this interviewing technique functioned like the to-be-forgotten foils in the interpolated recognition tests of the directed-forgetting studies, resulting in a reinstatement of retrieval access to inhibited unpleasant memories for the repressors.

Implications of Retrieval-Induced Forgetting

Although both the paradigm and findings from the area of directed-forgetting research seem the most directly applicable to the possible forgetting and recovery of traumatic memories, it is also possible to imagine how the hypothesized process of retrieval-induced inhibition could be a mechanism for the forgetting of traumatic memories. To illustrate, it seems reasonable to us to assume that in most abusive situations, the individuals being abused would have both positive and negative memories associated with their abusers. Furthermore, it seems reasonable that there would be both external and internal pressures for victims of abuse to want to retrieve only the positive memories associated with the perpetrator of the abuse. If so, then whenever such victims think about their abusers, they would tend to engage in retrieval practice for the positive memories.

Under that assumption, as victims practice retrieving positive memories, those memories—like practiced exemplars—would become more and more likely to be retrieved in the future, whereas the negative memories—being selected against and thus inhibited again and again—would become less and less likely to be retrieved in the future. As long as victims continue to practice retrieving positive memories, access to unpracticed negative memories will remain inhibited. Moreover, as Anderson and Spellman's (1995) results indicate, this impaired recall of negative memories might well extend to other possible retrieval cues.

The question thus arises as to how negative memories would *ever* be recovered if their inhibition was occurring as a result of this type of retrieval practice. Because we have little data addressing the issue of how the inhibition created in the retrieval-practice paradigm might be released, this remains an open question.

Does Intent Matter?

Finally, the role of intent would seem relevant in relating laboratory-defined inhibitory mechanisms to clinical observations of the forgetting of traumatic memories. That is, it seems reasonable to assume that the intent to forget traumatic memories would be an important aspect of successfully doing so. As reviewed earlier, however, it is unclear the degree to which intent plays any role in the production of the retrieval inhibition observed in any of the paradigms we have considered.

Corresponding to the directed-forgetting paradigm, where intent to forget, as well as new learning, may be necessary for inhibition of to-be-forgotten items to occur, both intent and new learning could also be necessary for the inhibition of traumatic memories. That is, simply having the intent to forget might not be sufficient; it would need to be coupled with new learning. Similarly, although intent seems not to play a role in the inhibition of unpracticed exemplars in the retrieval-practice paradigm (where, instead, inhibition seems to occur as a by-product of competitors being selected against during selective retrieval of a desired target), one could speculate that intention to retrieve only positive memories helps to discriminate positive competitors for retrieval from negative ones and, thereby, indirectly promotes the inhibition of negative memories.

In conclusion, although such possible linkages between the goal-directed forgetting observed in the laboratories of experimental psychologists and the real-world repression/recovery phenomena of interest to clinicians remain tenuous and highly speculative, they do suggest that there may be more common ground in clinical and experimental approaches to inhibitory processes than might have been thought some years ago.

CONCLUDING COMMENTS

Toward the end of the last decade, in a chapter on "Retrieval inhibition as an adaptive mechanism in human memory," R. A. Bjork (1989) blamed the computer metaphor and an "unappealing association to poorly understood clinical phenomena, such as repression" for the fact that "inhibitory processes have played little or no role" in our theories of human memory (p. 310). He argued that inhibitory mechanisms, although well represented in theories of lower-order cognitive processes, such as sensation and attention, were underrepresented in theories of higher-order cognitive processes, such as memory and language. At the end of that chapter, however, he predicted that the role of inhibitory processes in memory would seem "incontestable in the near future," and that the emerging "brain metaphor . . . and neural/connectionist approaches to the simulation of cognitive processes" would "push us towards" recognizing the role of inhibition in higher-order cognitive processes (p. 328).

Looking back at those arguments from the perspective of the present chapter, several comments seem warranted. First, as far as recognizing the role of inhibitory processes in memory and cognition, the field would seem to have been "pushed" even farther and faster than that chapter anticipated. Over a relatively brief time, as evidenced by the present volume, other recent volumes on inhibitory processes in attention, memory, language, and other cognitive processes (see, e.g., Dagenbach & Carr, 1994a; Dempster & Brainerd, 1995), and the current empirical and theoretical literature more generally, the picture has changed markedly. Much current theorizing, whether behavioral or neurobiological, and whether stated verbally or in formal/quantitative terms, is characterized by a presumed interplay of excitatory and inhibitory processes.

It seems safe to say, however, that the increased emphasis on inhibitory mechanisms is more a product of hard data than it is of any change of metaphor or style of formal modeling. A variety of behavioral, neuropsychological, and neurobiological findings have provided compelling evidence for inhibitory processes of one type or another. In part, those findings have emerged from new paradigms in behavioral research, such as the retrieval-practice paradigm discussed here and the "negative priming" paradigm (see, e.g., Tipper, 1985), and new procedures in neuroscience.

Our second comment is that the specific assertion that *retrieval* inhibition/suppression is a unique and broadly useful mechanism for avoiding interference and competition in human memory may, in a sense, have been an understatement. We have argued here that the retrieval-inhibition processes that underlie retrieval-induced forgetting are similar, in a formal sense, to those that underlie the updating of memory. Anderson and Spellman (1995) argued that the inhibition/suppression processes that give rise to retrieval-induced forgetting are formally similar to the inhibition/suppression processes identified long ago in selective attention. And analogous inhibition/suppression mechanisms have been implicated in perceptual encoding (as in the "negative priming" paradigm), perceptual recognition (see, e.g., Dagenbach & Carr, 1994b), the control of working memory (e.g., Zacks & Hasher, 1994), and the disambiguation of meaning in the comprehension of text and speech (e.g., Eberhard, 1994; Gernsbacher & Faust, 1991; Simpson & Kang, 1994).

To perhaps now overstate the case, it may be that retrieval inhibition is *the* primary solution in the functional architecture of the human as an information-processing device to the problem of avoiding interference and competition at various levels of cognitive processing. In a broad range of motor and cognitive activities, *selecting* appears to involve *inhibiting*. The formal properties of selection/inhibition processes may have much in common across domains; Anderson and Spellman (1995, p. 94), for example, interpret the total pattern of retrieval-induced forgetting results as evidence that retrieval is best regarded as "conceptually focused selective attention." The common goal of such selection/inhibition mechanisms is to enhance the selection of task-relevant percepts, movements, and stored information by inhibiting competing percepts, movements, and information. The importance of selection/inhibition mechanisms is also underscored by the accumulating evidence that the efficiency of such mechanisms may play a significant role in developmental changes in cognitive abilities (e.g., Bjorklund & Harnishfeger, 1990; Dempster, 1992), deficits in information processing that accompany aging (e.g., Hasher, Stoltzfus, Zacks, & Rypma, 1991; Hasher & Zacks, 1988), and even, possibly, psychopathologies, such as schizophrenia (e.g., Beech, Powell, McWilliams, & Claridge, 1989).

Finally, a somewhat ironic comment seems called for with respect to the uniquely human and adaptive character of retrieval inhibition as an updating/selection mechanism. It is "uniquely human" because it differs so markedly from the overwriting/scanning mechanisms typical of nonliving information-processing devices, such as a computer. It is "adaptive" because it enhances updating/selection without erasing the representation of the inhibited information, should that information be needed later. As an adaptive solution to the updating/selection problems faced by humans as information processors, however, it is important to note that retrieval inhibition is the product of evolution and the living organism, not the product of the human intellect. Where the human intellect *has* played a role is in the design of the less flexible and less sophisticated updating/selection mechanisms characteristic of computers, tape recorders, and other inanimate information-processing devices.

REFERENCES

Allen, G. A., Mahler, W. A., & Estes, W. K. (1969). Effects of recall tests on long-term retention of paired associates. *Journal of Verbal Learning and Verbal Behavior, 8*, 463–470.

Allport, A. (1989). Visual attention. In M. I. Posner (Ed.), *Foundations of cognitive science* (pp. 631–682). Cambridge, MA: MIT Press.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (1993, November). *Strengthening is not enough: Evidence against the blocking theory of retrieval inhibition*. Paper presented at the Psychonomic Society, Washington, DC.

Anderson, M. C., & Bjork, R. A. (1994). Mechanisms of inhibition in long-term memory: A new taxonomy. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 265–325). San Diego, CA: Academic Press.

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 1063–1087.

Anderson, M. C., & Neely, J. H. (1996). Interference and inhibition in memory retrieval. In E. L. Bjork & R. A. Bjork (Eds.), *Handbook of perception and cognition: Vol. 10. Memory* (pp. 237–313). San Diego: Academic Press.

Anderson, M. C., & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102*, 68–100.

Basden, B. H., Basden, D. R., & Gargano, G. J. (1993). Directed forgetting in implicit and explicit memory tests: A comparison of methods. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 603–616.

Beech, A., Powell, T., McWilliams, J., & Claridge, G. (1989). Evidence for reduced "cognitive inhibition" in schizophrenia. *British Bulletin of Clinical Psychology, 28*, 109–116.

Bjork, E. L., & Bjork, R. A. (1988). On the adaptive aspects of retrieval failure in autobiographical memory. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory: Current research and issues: Vol. 1. Memory in everyday life* (pp. 283–288). London: Wiley.

Bjork, E. L., & Bjork, R. A. (1996). Continuing influences of to-be-forgotten information. *Consciousness and Cognition, 5*, 176–196.

Bjork, E. L., Bjork, R. A., & Anderson, M. R. (July, 1996). *Inhibition and suppression: Intentional and unintentional.* Paper presented at the International Conference on Memory, Abano Terme, Italy.

Bjork, E. L., Bjork, R. A., & Glenberg, A. (1973, November). *Reinstatement of interference owing to to-be-forgotten items.* Paper presented at the meeting of the Psychonomic Society, St. Louis, MO.

Bjork, E. L., Bjork, R. A., Stallings, L., & Kimball, D. R. (1996, November). *Enhanced false fame owing to instructions to forget.* Paper presented at the meeting of the Psychonomic Society, Chicago, IL.

Bjork, E. L., Bjork, R. A., & White, S. A. (1984, November). *On the induced recovery of proactive interference.* Paper presented at the meeting of the Psychonomic Society, San Antonio, TX.

Bjork, R. A. (1970). Positive forgetting: The noninterference of items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior, 9*, 255–268.

Bjork, R. A. (1972). Theoretical implications of directed forgetting. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory* (pp. 217–235). Washington, DC: Winston.

Bjork, R. A. (1975). Retrieval as a memory modifier. In R. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 123–144). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bjork, R. A. (1978). The updating of human memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 12., pp. 235–259). New York: Academic Press.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 309–330). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bjork, R. A. (1992). Interference and memory. In L. R. Squire (Ed.), *Encyclopedia of learning and memory* (pp. 283–288). New York: Macmillan.

Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In A. Healy, S. Kosslyn, & R. Shiffrin (Eds.), *From learning processes to cognitive processes: Essays in honor of William K. Estes* (Vol. 2, pp. 35–67). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bjorklund, D. F., & Harnishfeger, K. K. (1990). The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review, 10*, 48–71.

Blaxton, T. A., & Neely, J. H. (1983). Inhibition from semantically related primes: Evidence of a category-specific inhibition. *Memory & Cognition, 11*, 500–510.

Block, R. A. (1971). Effects of instructions to forget in short-term memory. *Journal of Experimental Psychology, 89*, 1–9.

Brown, A. A. (1976). Spontaneous recovery in human learning. *Psychological Bulletin, 83*, 321–328.

Crowder, R. G. (1976). *Principles of learning and memory.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Dagenbach, D., & Carr, T. H. (Eds.). (1994a). *Inhibitory processes in attention, memory, and language.* Orlando, FL: Academic Press.

Dagenbach, D., & Carr, T. H. (1994b). Inhibitory processes in perceptual recognition: Evidence for a center-surround attentional mechanism. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 327–357). Orlando, FL: Academic Press.

Delprato, R. G. (1971). Specific-pair interference on recall and associative matching retention tests. *American Journal of Psychology, 84*, 185–193.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review, 12*, 45–75.

Dempster, F. N., & Brainerd, C. J. (Eds.). (1995). *Interference and inhibition in cognition.* San Diego, CA: Academic Press.

Eberhard, K. M. (1994). Phonological inhibition in auditory word recognition. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 383–407). Orlando, FL: Academic Press.

Elmes, F. J., Adams, C., & Roediger, H. L. (1970). Cued forgetting in short-term memory: Response selection. *Journal of Experimental Psychology, 86*, 103–107.

Epstein, W., Massaro, D. W., & Wilder, L. (1972). Selective search in directed forgetting. *Journal of Experimental Psychology, 95*, 18–24.

Geiselman, R. E., & Bagheri, B. (1985). Repetition effects in directed forgetting: Evidence for retrieval inhibition. *Memory & Cognition, 13*, 51–62.

Geiselman, R. E., Bjork, R. A., & Fishman, D. (1983). Disrupted retrieval in directed forgetting: A link with posthypnotic amnesia. *Journal of Experimental Psychology: General, 112*, 58–72.

Gelfand, H., & Bjork, R. A. (1985, November). *On the locus of retrieval inhibition in directed forgetting.* Paper presented at the meeting of the Psychonomic Society, Boston, MA.

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 117*, 245–262.

Gross, A. E., Barresi, J., & Smith, E. E. (1970). Voluntary forgetting of a shared memory load. *Psychonomic Science, 20*, 73–75.

Hartman, M., & Hasher, L. (1991). Aging and suppression: Memory for previously relevant information. *Psychology and Aging, 6*, 587–594.

Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 163–169.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *The psychology of learning and motivation* (Vol. 22, pp. 193–225). New York: Academic Press.

Jacoby, L. L, Kelley, C., Brown, J., & Jasechko, J. (1989). Becoming famous overnight: Limits on the ability to avoid unconscious influences of the past. *Journal of Personality and Social Psychology, 56*, 326–338.

Jacoby, L. L., Woloshyn, V., & Kelley, C. (1989). Becoming famous without being recognized: Unconscious influences of memory produced by dividing attention. *Journal of Experimental Psychology: General, 118*, 115–125.

Johnson, H. M. (1994). Processes of successful intentional forgetting. *Psychological Bulletin, 116*, 274–292.

Landauer, T. K., & Bjork, R. A. (1978). Optimal rehearsal patterns and name learning. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory* (pp. 625–632). London: Academic Press.

MacLeod, C. M. (1975). Long-term recognition and recall following directed forgetting. *Journal of Experimental Psychology: Human Learning and Memory*, *104*, 271–279.

MacLeod, C. M. (1989). Directed forgetting affects both direct and indirect tests of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*, 13–21.

McGeoch, J. A. (1932). Forgetting and the law of disuse. *Psychological Review*, *39*, 352–370.

McGeoch, J. A. (1936). Studies in retroactive inhibition: VII. Retroactive inhibition as a function of the length and frequency of presentation of the interpolated lists. *Journal of Experimental Psychology*, *19*, 674–693.

McGeoch, J. A. (1942). *The psychology of human memory*. New York: Longman.

Melton, A. W., & Irwin, J. M. (1940). The influence of degree of interpolated learning on retroactive inhibition and the overt transfer of specific responses. *American Journal of Psychology*, *3*, 173–203.

Mensink, G. J. M., & Raajimakers, J. W. (1988). A model of interference and forgetting. *Psychological Review*, *95*, 434–455.

Muller, G. E., & Pilzecker, A. (1900). Experimentelle beitrage zur lehre von gedachtnis. *Zeitschrift fur Psychologie*, *1*, 1–300.

Muther, W. S. (1965). Erasure or partitioning in short-term memory. *Psychonomic Science*, *3*, 429–430.

Myers, L. B., & Brewin, C. R. (1994). Recall of early experience and the repressive copying style. *Journal of Abnormal Psychology*, *103*, 288–292.

Paller, K. A. (1990). Recall and stem-completion priming have different electrophysiological correlates and are modified differentially by directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*, 1021–1032.

Postman, L. (1971). Transfer, interference and forgetting. In J. W. Kling & L. A. Riggs (Eds.), *Woodworth and Schlosberg's experimental psychology* (3rd ed., pp. 1019–1132). New York: Holt, Rinehart & Winston.

Postman, L., & Stark, K. (1969). The role of response availability in transfer and interference. *Journal of Experimental Psychology*, *79*, 168–177.

Postman, L., Stark, K., & Fraser, J. (1968). Temporal changes in interference. *Journal of Verbal Learning and Behavior*, *7*, 672–694.

Postman, L., & Underwood, B. J. (1973). Critical issues in interference theory. *Memory & Cognition*, *1*, 19–40.

Raajimakers, J. W., & Shiffrin, R. M. (1981). Search of associative memory. *Psychological Review*, *88*, 93–134.

Reed, H. (1970). Studies of the interference processes in short-term memory. *Journal of Experimental Psychology*, *84*, 452–457.

Reitman, W., Malin, J. T., Bjork, R. A., & Higman, B. (1973). Strategy control and directed forgetting. *Journal of Verbal Learning and Verbal Behavior*, *12*, 140–149.

Roediger, H. L. (1974). Inhibiting effects of recall. *Memory & Cognition*, *2*, 261–269.

Roediger, H. L., & Crowder, R. G. (1972). Instructed forgetting: Rehearsal control or retrieval inhibition (repression)? *Cognitive Psychology*, *3*, 244–254.

Roediger, H. L., & Neely, J. H. (1982). Retrieval blocks in episodic and semantic memory. *Canadian Journal of Psychology*, *36*, 213–242.

Roediger, H. L., & Tulving, E. (1979). Exclusion of learned material from recall as a postretrieval operation. *Journal of Verbal Learning and Verbal Behavior*, *18*, 601–615.

Rundus, D. (1973). Negative effects of using list items as retrieval cues. *Journal of Verbal Learning and Verbal Behavior*, *12*, 43–50.

Simpson, G. B., & Kang, H. (1994). Inhibitory processes in the recognition of homograph meanings. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 369–381). Orlando, FL: Academic Press.

Thorndike, E. L. (1914). *The psychology of learning*. New York: Teachers College Press.

Tipper, S. P. (1985). The negative priming effect: Inhibitory effects of ignored primes. *Quarterly Journal of Experimental Psychology, 37A*, 571–590.

Tulving, E., & Hastie, R. (1972). Inhibition effects of intralist repetition in free recall. *Journal of Experimental Psychology, 92*, 297–304.

Tulving, E., & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. *Journal of Verbal Learning and Verbal Behavior, 5*, 381–391.

Watkins, M. J. (1975). Engrams as cuegrams and forgetting as cue-overload: A cueing approach to the structure of memory. In C. R. Puff (Ed.), *The structure of memory* (pp. 347–372). New York: Academic Press.

Weaver, G. E., Rose, R. G., & Campbell, N. R. (1971). Item-specific retroactive inhibition in mixed-list comparisons of the A-B, A-C, and A-B, D-C paradigms. *Journal of Verbal Learning and Verbal Behavior, 10*, 488–498.

Weiner, B. (1968). Motivated forgetting and the study of repression. *Journal of Personality, 36*, 213–234.

Weiner, B., & Reed, H. (1969). Effects of the instructional sets to remember and to forget on short-term retention: Studies of rehearsal control and retrieval inhibition (repression). *Journal of Experimental Psychology, 79*, 226–232.

Wheeler, M. A. (1995). Improvement in recall over time without repeated testing: Spontaneous recovery revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 173–184.

Whitten, W. B., & Bjork, R. A. (1977). Learning from tests: The effects of spacing. *Journal of Verbal Learning and Verbal Behavior, 16*, 465–478.

Wichawut, C., & Martin, E. (1971). Independence of A–B and A-C associations in retroaction. *Journal of Verbal Learning and Verbal Behavior, 10*, 316–321.

Woodward, A. E., Jr., & Bjork, R. A. (1971). Forgetting and remembering in free recall: Intentional and unintentional. *Journal of Experimental Psychology, 89*, 109–116.

Zacks, R. T., & Hasher, L. (1994). Directed ignoring: Inhibitory regulation of working memory. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 241–264). Orlando, FL: Academic Press.

Zacks, R. T., Radvansky, G. A., & Hasher, L. (1996). Studies of directed forgetting in older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*, 143–156.