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# Improvement in Recall Over Time Without Repeated Testing: Spontaneous Recovery Revisited

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Four experiments investigated spontaneous recovery, or memory improvement over time without repeated testing. Although this phenomenon was previously studied within the verbal learning tradition, evidence for its existence was inconclusive. Experiments 1a–3 demonstrated the effect, showing that spontaneous recovery can be produced reliably across different types of study materials. One key is assessing spontaneous recovery in a within-subjects, rather than a between-subjects, design to permit a more sensitive test of the phenomenon. The proposed explanation for the effect invokes the process of retrieval inhibition as the cause of retroactive interference and the subsequent dissipation of inhibition as the cause of spontaneous recovery.



One of the most pervasive findings about memory is that it gets worse over time. Since the classic work of Ebbinghaus (1885/1964), the notion that people forget over time has gone relatively unchallenged; indeed, it has been confirmed in hundreds of experiments. The purpose of this article is to show evidence that retention can, under some circumstances, actually improve over time. One line of experiments has demonstrated such improvement. This research was begun by Ballard (1913) and was revived by Erdelyi and Becker (1974). When subjects take repeated tests for the same information, with short delays between the tests, improvement (or hypermnesia) will often occur (see Payne, 1987, for a review). Although the finding of hypermnesia is a valid example of memory improvement over time, it is necessarily restricted to a within-subjects design. Roediger and Payne (1982) demonstrated that this memory improvement occurs only when the same group of subjects is tested repeatedly; therefore, the presence of multiple identical memory tests, rather than the passage of time, is the driving force behind hypermnesia.

Are there situations in which memory improves without repeated testing? In other words, can subjects tested after a longer retention interval show higher performance than subjects tested on the same information following a shorter retention interval? This question defines the phenomenon of spontaneous recovery. Evidence for spontaneous recovery was originally observed in the animal conditioning literature, in which a previously learned response increased in strength with the passage of time (Pavlov, 1927). In his important demonstration, a classically conditioned response (salivation to a metronome) was extinguished through a lack of reinforcement (the withholding of meat powder that had previously been paired with the metronome). After a 23-min delay, the metronome produced a substantially larger response, as the salivation reflex regained strength over time (Pavlov, 1927, pp. 48–49, 58–59).

Evidence for this phenomenon was later demonstrated in the verbal learning tradition (Underwood, 1948b). For humans, a typical paradigm involved participants learning two consecutive lists of paired associates, which shared the same stimulus term and had different response terms (i.e., A–B, A–C lists). Participants learned the pairs via a procedure known as the *anticipation method.* They were presented with each stimulus term (or A term) individually and instructed to give an oral response to anticipate its associate. After the participant responded, the response term (B) was shown to the observers. This process continued for several trials until participants reached a predetermined criterion (e.g., 75% correct). At the end of A–B learning, participants began learning an A–C list. This originally led participants to respond with the appropriate B term that had been previously associated with A; this response was not reinforced, however, because the C term was then presented as the appropriate response. The A–B associations were gradually extinguished, through the lack of reinforcement. Immediately after learning A–C, participants given a cued-recall test generally showed poorer memory for the B terms, compared with control participants who did not receive the A–C list. This retroactive interference was said to have been caused by the unlearning of the A–B association as A–C was learned (Melton & Irwin, 1940), and the unlearning was believed to occur in a similar fashion as the process of extinction of conditioned responses.

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Underwood (1948a, 1948b) later proposed another process, suggesting that, like extinguished conditioned responses, the extinguished A–B associations should spontaneously recover over time. Underwood (1948b) had participants learn an A–B list, followed by an A–C list, then gave them a cued-recall test after 1 min, 5 hr, 1 day, or 2 days. The test was known as *modified free recall* (MFR), because participants were presented with the stimulus, or A, term and instructed to report the first of the two responses, B or C, that came to mind. Results showed that B responses increased slightly, yet reliably, from 1 min to 1 day, whereas C responses showed a substantial decrease over that interval. Also, although the C terms were much more likely as responses than the B terms on the immediate test, as the retention interval increased, this disparity decreased until B responses and C responses were reported at roughly similar levels after 2 days. Underwood concluded that, in the case of the first list (A–B), there was some process that was working in opposition to the normal forgetting process. He likened the process to the spontaneous recovery of conditioned responses. The basic findings were replicated by Briggs (1954; Briggs, Thompson, & Brogden, 1955).

One problem with the studies of Underwood (1948a, 1948b) and Briggs (1954; Briggs et al., 1955) is that they used the MFR technique in which only one response is given for each stimulus. Therefore, this procedure did not measure whether a response from the first list could be produced at the time of recall. Because only one response was required, spontaneous recovery following this procedure might reflect a change in response dominance over time rather than an increase in response accessibility. At the most immediate test, the C term is the most dominant response because the A–C list was the one learned most recently. As the delay between study and test lengthens, however, this dominance decreases. Therefore, both the B and C terms may be accessible on the immediate test, although only the C term is produced.

For an accurate measure of spontaneous recovery, there must be a method that eliminates this type of response competition. With this goal in mind, Barnes and Underwood (1959) developed a procedure called *modified modified free recall* (MMFR). In MMFR, subjects are asked to produce all of the responses that had been paired with a particular stimulus. In this procedure, any appropriate response that can be recalled by subjects is reported, thereby eliminating one sort of response competition. Any retroactive interference caused by a second list was assumed to have been caused by unlearning of the first-list associations during the learning of the second list.

The method of MMFR became the dominant means of assessing the levels of both interference and recovery. Although an absolute rise in first list, or A–B, recall over time has been reported on numerous occasions (Ceraso & Henderson, 1965; Forrester, 1970; Lehr & Duncan, 1970; Lehr, Frank, & Mattison, 1972; Postman, Stark, & Fraser, 1968; Postman, Stark, & Henschel, 1969; Shuell, 1968; Silverstein, 1967), in many other studies this increase was either small and nonsignificant (Ceraso & Henderson, 1966; Koppenaal, 1963; Slamecka, 1966) or nonexistent (Abra, 1967; Birnbaum, 1965; Houston, 1966).

In his review of the literature, Brown (1976) suggested that spontaneous recovery was both a meaningful and a reliable finding. Although the magnitude of recovery is often small, it had been discovered with several different testing procedures and over markedly different time courses. Absolute recovery was even obtained by Ceraso and Henderson (1965) and Silverstein (1967) over a 24-hr delay. Improvement over time was not evident, however, in similar studies conducted by Birnbaum (1965) and Houston (1966) after 1-day and 7-day intervals, respectively. Possible reasons for the disparity between these findings were considered in articles by Postman and his colleagues (Postman et al., 1968, 1969). They suggested that a rise in first-list recall is unlikely if there is a large degree of extraexperimental forgetting; amount of forgetting can be gauged by considering the performance of the control groups (groups that studied only the A–B list) over time. Even if recovery of first-list associations is occurring, it could be more than offset by the extraexperimental forgetting. In other words, even though the first-list associations are regaining strength over time, they may still be prone to some offsetting process causing forgetting. In order to find significantly better performance on a later test, the amount of recovery must exceed the amount of forgetting. In the experiments of Birnbaum (1965) and Houston (1966), there was substantial forgetting in the control conditions, which may have precluded absolute recovery in their experimental conditions. In those studies that demonstrated an absolute numerical recovery, recall of the control list dropped by less than 10% between the immediate and delayed tests. This realization of extraexperimental forgetting led Brown to adopt the index of relative recovery. Unlike absolute recovery, which implies an increase in first-list recall over time, relative recovery occurs when there is no change or a decrease in first-list recall, but the decrease is less than that shown in control conditions. This interaction suggests that a recovery process is operating in opposition to normal forgetting. On this measure, Brown (1976) discovered that a large majority of the relevant experiments (47 out of 53, or 89%) had demonstrated relative recovery (but not always absolute recovery).

Related to the issue of extraexperimental forgetting is the degree of original learning of the target list. The anticipation method allowed experimenters to directly control the extent to which a list was learned. Participants studied and were tested for a list numerous times while concentrating on a single pair of associates at a time. The anticipation trials could continue until each participant had reached a predetermined level of learning (e.g., one perfect trial). As participants proceeded through the list, some responses were learned relatively quickly, and these responses were overlearned as the list was repeated. The act of overlearning makes these items more likely to be eventually spontaneously recovered. In Postman et al. (1969, Experiment 1), participants learned an A–B list of eight paired associates to a criterion of 5 of 8 correct via the anticipation method. In other words, after five of the eight B terms were correctly anticipated on a single trial list, the learning phase of A–B was terminated. This degree of learning did not lead to eventual spontaneous recovery, despite the fact that substantial retroactive interference was caused by learning A–C and A–D lists. In Experiment 3, Postman et al. performed an identical experiment, except that the first list was learned to a criterion of 5 of 8 and then four additional trials were given. Therefore, many of the individual paired associates were overlearned. Although this amount of learning resulted in approximately the same amount of retroactive interference as in the first experiment, this time spontaneous recovery was demonstrated: Participants recalled about 2.8 B terms on the immediate MMFR test and 4.2 on a similar test 16 min later (these numbers are estimated from their figure). Postman et al. concluded that, when associations are learned to a greater degree, recovery is more likely. When spontaneous recovery has been demonstrated in the past, the target list has usually been learned to one perfect trial. The lowest degree of learning reported that has led to absolute recovery is 8 of 12 (Lehr & Duncan, 1970). Therefore, thorough learning of the target list is probably one of the necessary conditions for recovery.

Two theories were proposed to account for spontaneous recovery. The first, the extinction–recovery hypothesis, assumes that first-list (A–B) associations suffer from unlearning during practice of the interpolated (A–C) list. In other words, on second-list learning, B terms become experimentally unlearned through the lack of reinforcement. Like an extinguished response, those associations will recover some or all of their strength with the passage of time (Underwood, 1948a, 1948b). This recovery process is the factor that runs in opposition to the usual process of forgetting. One implication of this view is that the unlearning and recovery processes operate independently on the individual A–B associations rather than uniformly on the entire set of associations. Note that the theory attempts to explain the recovery by analogy to conditioning phenomena, but both extinction and recovery require a theoretical explanation (e.g., Estes, 1955).

Postman et al. (1968, 1969) offered a different interpretation of spontaneous recovery, called *response-set suppression* (also sometimes known as response-set interference). Their explanation begins with the assumption that the driving force behind the process of unlearning is a mechanism that affects response selection during learning of the second list (from Underwood & Schulz, 1960). The mechanism suppresses the responses from prior lists while subjects are learning a subsequent list. There is also said to be some inertia inherent in the selection mechanism (Postman et al., 1969). On a recall test that occurs immediately after interpolated learning, a shift back to the first list is difficult because the selector mechanism favors the most recent list. The inertia operating on this mechanism is assumed to be of limited duration, and the direction of the mechanism is reversible. The theory is not concerned with explaining spontaneous recovery in the terms of either classical or operant conditioning.

This hypothesis differs from the unlearning–recovery hypothesis in several ways. First, it implies that retroactive interference does not result from a decrease in the strength of the associations between individual members of pairs. Unlearning theories assume that first-list responses are each gradually extinguished, because they are not reinforced during second-list learning. The Postman et al. (1968, 1969) response-set suppression explanation claims that the dominance of one entire set of responses leads to retroactive interference rather than changes in the individual associations. Associative unlearning theories also postulate a recovery process that works in direct opposition to forgetting. The suppression hypothesis implicates a decrease in response-set suppression over time, which operates through a change in the selector mechanism. Therefore, recovery reflects the dissipation of response interference, not the "rebuilding" or "relearning" of associations.

As an empirical test of unlearning–recovery hypotheses, Postman et al. (1969) compared the amounts of retroactive interference and spontaneous recovery resulting from two different types of interpolated learning. All participants learned a list of A–B pairs, and some participants were then presented with A–C pairs, whereas others got C–D pairs, which differed from A–B in both their stimulus and response terms. The unlearning hypothesis would predict greater unlearning and recovery for those groups learning A–C, because these groups are presumably losing, and eventually recovering, two kinds of associations (contextual and specific) rather than one (contextual), as in the C–D conditions (McGovern, 1964). Learning either type of interpolated list should have a general, depressing effect on first-list responses, and this phenomenon is called *contextual interference.* Subjects receiving the A–C list, however, suffered from the additional effect of specific interference, which was the specific stimulus–response interference created by the stimulus overlap between the A–B and A–C pairs. Neither relevant experiment (Postman et al., 1969, Experiments 1 and 3) was consistent with the unlearning–recovery hypothesis: Interference was roughly equivalent for the two conditions, and the C–D condition actually led to greater recovery in Experiment 1 (but see McGovern, 1964; Shulman & Martin, 1970). The authors concluded that spontaneous recovery resulted from a change in the dominance of one set of responses over the other rather than from a change in the strengths of individual associations.

Another implication of the response-set suppression hypothesis is that, although there is substantial interference on the recall of A–B associations immediately after the interpolated lists are learned, the original associations have not been permanently unlearned but are only temporarily inaccessible. The hypothesis implies that the B responses are still available but cannot be produced. A test of this point was conducted by Postman et al. (1968, Experiment 4). All subjects learned a target A–B list, and half subsequently received A–C and A–D lists. In the retention test of interest here (an associative matching test), participants were given each stimulus term and a list of all response terms, and were asked to match them appropriately. There was a small amount of interference (about 1.5 items out of 12) and an even smaller amount of spontaneous recovery. This was consistent with the notion that A–B associations were not unlearned, but only temporarily suppressed or inaccessible for recall (also see Tulving & Psotka, 1971).

This response-set suppression hypothesis was the most elaborate attempt to explain spontaneous recovery within interference theory, and contrary evidence was produced by a few subsequent studies. Some of the more damaging findings were failures to replicate the work of Postman et al. (1969). Greater interference was demonstrated after an A–C than a C–D list, and absolute recovery was greater following A–C than C–D (Forrester, 1970; Shulman & Martin, 1970). The two paradigms (A–C and C–D) have also been compared in a mixed-list interpolation (Delprato, 1971; Weaver, Rose, & Campbell, 1971; Wichawut & Martin, 1971). In those experiments, one half of the pairs in the interpolated list (the A–C pairs) included a stimulus term from the first list paired with a new response, whereas the remainder (C–D pairs) shared neither a stimulus nor a response with the terms from the A–B list. On a subsequent MMFR test, there was greater retroactive interference for those A–B pairs that had suffered from the specific interference produced by A–C learning. This finding directly contradicted response-set suppression because it demonstrated that interference (or suppression) did not operate uniformly on the entire target list. Postman and Underwood (1973) acknowledged the problem and suggested the possibility of "differential suppression of subgroups of items" (p. 25) within a single list.

Unfortunately, the issue was never settled and few subsequent articles were published on the topic. Brown (1976) concluded that the response set interference theory was a viable alternative to the older unlearning–recovery interpretation but that it might be appropriate to consider the two interpretations as complementary rather than as directly opposed.

When the verbal learning tradition lost popularity in the early 1970s, interference theory also diminished in popularity. The type of paired-associates learning that was typical of spontaneous recovery research was not continued by the newer information-processing approach. As research in interference theory disappeared from the literature, investigations of spontaneous recovery also vanished. In more recent times, other researchers have investigated phenomena that bear at least tangentially to the notion of spontaneous recovery. As mentioned earlier, hypermnesia research (reviewed by Payne, 1987) involves memory improvement over time, albeit using repeated, identical memory tests to assess improvement. Also, some of the recent work by Robert Bjork and his colleagues (Bjork, 1989; Geiselman, Bjork, & Fishman, 1983; however, see Bjork, 1978) has emphasized the role of inhibitory processes that may be related to response suppression. Therefore, renewing the investigation of spontaneous recovery might lead to insights in the nature and function of human memory. The present experiments incorporated some elements of the traditional verbal learning paradigm but also expanded on them; although the procedures used here were conceptually derived from prior work on spontaneous recovery, they have been adapted to be compatible with a more contemporary approach to human memory. The primary purpose of this research was to demonstrate that the absolute recovery of information over time is a reliable phenomenon, at least under certain experimental conditions. Another goal was to attempt a tentative explanation of spontaneous recovery.

From prior research in this area, it is evident that, when spontaneous recovery has occurred, it was because of a reduction in retroactive interference over time; there was typically substantial retroactive interference immediately after interpolated learning, and the interference dissipated over time. Therefore, all of the experiments reported here included two different learning conditions, manipulated between participants: One group learned a target list followed by similar, interfering lists, whereas controls received only the target list. Participants in both conditions were then tested either immediately or following some short delay (always less than 1 hr). From Brown's (1976) review, it is evident that spontaneous recovery is more likely to occur across intervals of less than 1 hr. There are two potential effects of interest: the amount of interference resulting from interpolated lists and any recovery (whether absolute or relative) demonstrated in these interference conditions. Experiments 1a and 1b were conducted to replicate the general finding of spontaneous recovery and to establish a paradigm that could lead to further study.

## Experiments 1a and 1b

Two similar experiments were conducted concurrently to determine whether spontaneous recovery for a target list could occur. The experiments differed only in the length of the longest retention interval and are described together. The procedure differed from those commonly used in the verbal learning tradition in some respects. If spontaneous recovery is a reliable effect, then it should be obtainable in experiments that do not use the specific methods that were traditionally used to study interference theory. All participants studied a target list under intentional memory instructions. The list was composed of individual pictures rather than pairs of associates. Again, this was an attempt to demonstrate spontaneous recovery using materials other than those typical of verbal learning experiments.

After studying the target list, all subjects were given a false instruction, which led them to believe that their memory for the target list would not be tested. The rationale for this instruction stems from a potentially important feature of verbal learning experiments. Again, past experiments on this topic have generally used the anticipation method, in which subjects learned by overtly anticipating the response (or B) term when presented with each stimulus (or A) term. The appropriate response term was then displayed to participants, regardless of whether it had been correctly anticipated. After some predetermined criterion was reached, another list, often conforming to an A–C paradigm, was learned in a similar fashion. An important point about this procedure is that subjects were never informed about their subsequent memory (usually MMFR) test. Also, the anticipation method included "test" opportunities during each study trial, as participants were tested for each response term as the stimulus terms were individually presented. Therefore, during interpolated (A–C) learning, participants probably believed that they were through with the original A–B associations and had no reason to continue remembering them.

Therefore, to at least partially simulate this feature of verbal learning experiments (that participants did not need to continue remembering the target list), immediately after studying the target list, all participants were falsely informed that the list had only been for practice. Then participants in interference conditions studied two additional similar lists and received an immediate free-recall test for each list. Meanwhile, participants in control conditions performed a distractor task. All participants in the short delay conditions then received an unexpected free-recall test for the target list. The remaining participants, assigned to the long delay conditions, received the test following a longer retention interval. In Experiment 1a the interval was 16 min, whereas in Experiment 1b it was 36 min.

## Method

*Participants and design.* Both experiments were conducted with 120 University of Houston undergraduates who participated in return for partial credit in a lower division psychology course. In both experiments, the design was a 2 × 2, completely between subjects; therefore, there were 30 participants randomly assigned to each condition. Independent variables were study condition (interference or control) and retention interval (short or long delay). In Experiments 1a and 1b, the delayed retention intervals were 16 min and 36 min, respectively.

*Materials.* A target list of 12 pictures was constructed from Snodgrass and Vanderwart's (1980) series. In order of presentation, the target words were *foot, butterfly, purse, guitar, clown, wagon, fork, clock, telephone, apple, glasses,* and *sun.* Subjects in interference conditions viewed two additional lists of 12 pictures each, selected from the same source. The pictures in the second list were *fish, tennis racket, airplane, pipe, bicycle, clothespin, saw, lamp, snowman, candle, basket,* and *well.* The third list comprised *whistle, table, toothbrush, bread, comb, hammer, ear, pencil, kite, piano, scissors,* and *grapes.*

*Procedure.* Procedures for both Experiments 1a and 1b were identical except for the length of the retention interval; therefore, they are described together. Participants were tested in groups of 4–16. The experimenter told participants that the first part of the experiment had to do with memory and that they would be shown a list of pictures (List 1), which they should memorize. Participants viewed the slides from a slide projector at a rate of 5 s per slide, which included a 0.75-s interval between slides. The list was presented three consecutive times in the same order, with a 15-s break between presentations, during which the experimenter reminded participants that they should keep paying attention to the slides and try to memorize them as well as possible.

After the third time through the list, the experimenter told all participants that List 1 was just a practice list and that their memory for the list would not be tested. Participants in control conditions were informed that they would have to learn a different list later in the experiment. As a distractor task, they were then given a sheet of arithmetic problems, and the problems were grouped together in pairs. They were instructed to solve the problems and then to circle the problem in each pair that had been the most difficult for them to solve. Participants in interference conditions were told that they were going to see another list, List 2, which would contain 12 different pictures. These participants were given sheets of paper and told that, immediately after watching the list, they would have 1 min to write down all of the names of the pictures from List 2 that they could remember. They were also warned that they should be sure not to report any of the items from List 1. Participants viewed the list one time, at a rate of 5 s per slide, with 0.75 s between slides. Immediately after the final slide, the experimenter told them to write down the names of the pictures from List 2 in any order. Again, it was stressed that nothing from List 1 should be written.

After List 2 recall, participants were told that they would see List 3, which again would contain 12 different pictures. The experimenter told subjects that, similar to List 2, after viewing List 3 they would have 1 min to write down the names of the pictures in List 3. List presentation and recall was performed in an identical way as for List 2.

At this juncture, one half of the participants were asked to leave the testing room and wait in another room. (This half had been randomly selected and informed before the experiment began that there would be a point in the experiment when they would be asked to leave the room for a few minutes.) These participants were warned not to talk about the experiment in any way while they were out of the room. The remaining participants were in the short delay conditions. They were told that they would take a free-recall test for the names of the pictures in List 1. In addition, participants in the interference conditions were reminded that List 1 was the list that they had seen three times and that it was the only list on which they had not yet been tested. They were also instructed to write down the names of pictures from List 1 only in any order. All participants were given 2 min to recall the picture names. The short delay test occurred 1 min 15 s after participants in interference conditions had completed their recall test for List 3 or 7 min 30 s after all participants had studied the target list. After the test, the experimenter collected the recall sheets and brought the rest of the participants back into the testing room.

Participants then worked on the arithmetic distractor task until it was time for the long delay test. All participants took this long delay test, regardless of whether they had taken the first test, and recall instructions were repeated for all participants. (Although all participants received a recall test at the long delay interval, the data reported are only for those participants who took their first test at this interval.) The long delay test began either 15 min or 35 min after the beginning of the short delay test in Experiments 1a and 1b, respectively. When the test was completed, the experimenter collected the test sheets; participants were then debriefed and thanked. During the debriefing, participants were told why it had been necessary to falsely inform them that their memory for List 1 would not be tested.

## Results

Means are graphed in Figure 1. From the figure, it is evident that Lists 2 and 3 produced retroactive interference for the target list. There was absolute recovery over time demonstrated by subjects in interference conditions, whereas participants in control conditions showed a small decrease in recall over time. Another finding was that there was no substantial difference between Experiments 1a and 1b; increasing the long delay retention interval from 16 to 36 min had virtually no effect on spontaneous recovery. To confirm this observation, the data from both experiments were originally analyzed in a single analysis of variance (ANOVA), which included experiment (1a or 1b) as a between-subjects variable. There was not a main effect of experiment on recall scores, and experiment did not interact with any other variable (all $Fs < 1$). Therefore, the data were collapsed across the two experiments for all subsequent analyses.

The data were analyzed using a 2 × 2 ANOVA, with study condition (interference or control) and retention interval (short or long delay) as between-subjects variables. The overall ANOVA showed a main effect of study condition, $F(1, 236) = 68.50, p < .001, MSE = 5.19$. There was no effect of retention interval ($F < 1$), and the two variables showed a significant interaction, $F(1, 236) = 3.94, p < .05, MSE = 5.19$.

To determine the source of the interaction, simple main effects of retention interval were conducted for each study condition. Within-condition variance from the overall analysis was used in the computation of simple main effects. There was a small but nonsignificant decrease for control conditions ($F < 1$), as retention dropped over time, from 10.6 items to 10.2 items. Participants in interference conditions demonstrated better retention after the longer interval (8.4 items to 7.5 items). The increase was significant, $F(1, 236) = 4.02, p < .05, MSE = 5.19$.

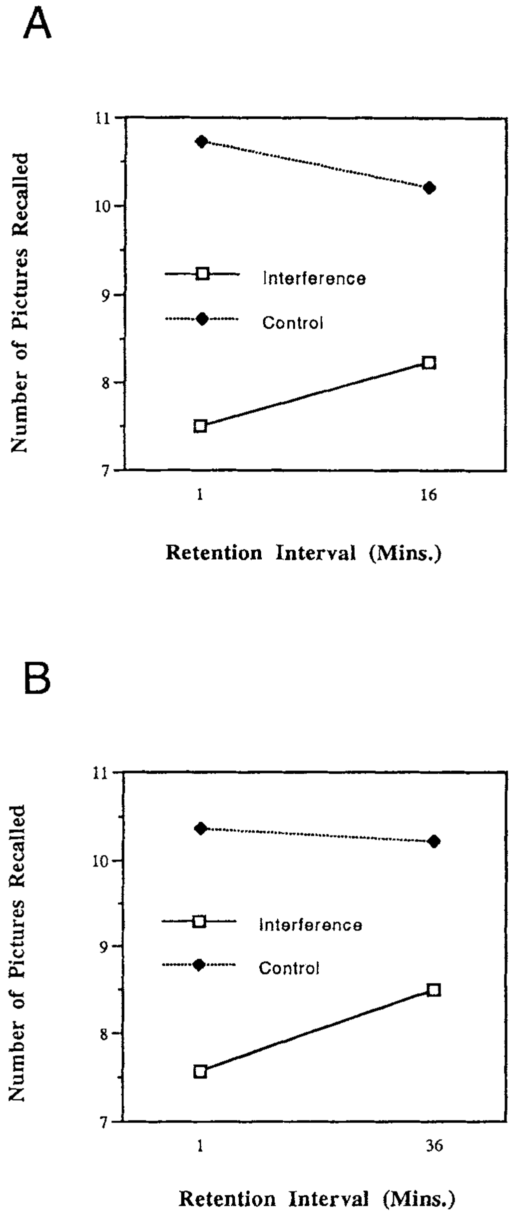


*Figure 1.* Number of pictures recalled as a function of study condition and retention interval in Experiments 1a (A) and 1b (B).

Another finding was that, on the recall tests for the target items, there were few intrusions from the interfering lists. Summed over Experiments 1a and 1b, there were only five total intrusions on the immediate test and seven on the delayed test.

### *Discussion*

The results of Experiments 1a and 1b demonstrate that the spontaneous recovery of information can occur over time, replicating a number of other studies (Forrester, 1970; Postman et al., 1968, 1969; Silverstein, 1967). Also, because there was no main effect or interaction involving the variable of experiment, the experiments can be considered replications of each other. Another finding is that extension of the retention interval (from 16 to 36 min) had no effect on either normal forgetting or spontaneous recovery.

The actual effect of recovery, however, was far from robust (a 0.9 item increase). In the combined experiments, there were 60 participants per cell, yet the recovery analysis just did reach statistical significance. Perhaps the most important step that can be taken at this point is to develop a procedure that produces reliable, robust spontaneous recovery. The details of the new procedure may shed light on the processes that are involved in spontaneous recovery. If the method used in Experiments 1a and 1b can be altered to produce a more pronounced effect, then these changes might help the understanding of the conditions that are necessary for recovery to occur.

## Experiment 2

The general paradigm used in Experiment 2 was the same as that used in Experiments 1a and 1b, with one critical change. Again, there were two study conditions; one condition studied both the target and an interfering list, whereas the other saw only the target list. Also, all participants were given a false instruction, which informed them that the target list was only a practice list. A new feature was introduced in Experiment 2 in an attempt to make the recovery effect more powerful. The target list (as well as the interfering list) consisted of 20 words, with 10 items representing each of two categories: "animals" and "fruits and vegetables." At test, participants were asked to recall the target words from one category on the first test and from the other category on the second test. Using this method, the recovery analysis was within subject rather than between subjects. This change made the analysis more sensitive to recovery.

Because the target and interfering lists contained items from the same two semantic categories, it is important that participants are able to discriminate between the two lists. This was not a problem in Experiments 1a and 1b, but when items are from the same categories, discrimination may become a more difficult task. Failure of list discrimination could be a potential confound in this type of experiment. In other words, on the immediate test, participants may simply be confused as to which items belong to which list. Over time, it may be that this list confusion dissipates rather than the retroactive interference. In order to rule out this potentially confounding interpretation, target list items differed from items in the interfering list on the basis of their first letters. Target list items began with certain letters (e.g., A through L), whereas interfering items began with the remaining letters (M through Z). Before recalling the target list, participants were informed of this fact. Therefore, there was no problem of list discrimination; if participants could recall an item, they knew its list membership. Several prior studies have demonstrated that, if participants can recall a response, they are highly accurate at identifying its list membership (Barnes & Underwood, 1959; Koppenaal, 1963; Postman & Underwood, 1973; but see Geiselman et al., 1983). In this experiment, however, spontaneous recovery may be relatively small; therefore, it is important to establish both interference and recovery in an experiment in which list discrimination difficulties could not be a factor.

## Method

*Participants and design.* The 64 observers were Rice University undergraduates enrolled in lower division psychology courses. They participated in partial fulfillment of course requirements. The experiment used a 2 × 2 mixed-variable design. The between-subjects variable was study condition (interference or control), whereas retention interval (short or long delay) varied within subjects.

*Materials.* The target list (as well as an interfering list) consisted of 20 words, with 10 words representing each of two categories: "animals" and "fruits and vegetables." The items were taken from the Battig and Montague (1969) norms; no items were taken from the first 10 exemplars in each category. The target items for the fruits and vegetables category consisted of words beginning with the letters A through L, whereas all items within the animals category began with M through Z. In order of presentation, the words were *blueberry, beet, rabbit, wolf, zebra, raccoon, eggplant, cantaloupe, otter, squirrel, walrus, kumquat, artichoke, coconut, panther, avocado, turtle, cucumber, weasel,* and *fig*. The interfering list was drawn from the same source, using the same criteria, except that the exemplars from each category began with the opposite set of letters.

*Procedure.* The procedure was conceptually similar to that used in Experiments 1a and 1b. Participants were tested in groups of 1–6. The experimenter informed participants that they were to memorize a list of slides (List 1). They were told that there would be 20 words in the list, with 10 words from the category animals and 10 from the category fruits and vegetables. Participants were informed that they would view the list three consecutive times and they should use each repetition to improve their memory for the list.

When the instructions were clear, the experimenter presented the list of slides, at a rate of 5 s per slide, which included 0.75 s between slides. The list was presented three times, with a 15-s interval between presentations, during which the experimenter reminded subjects that they should keep paying attention to the slides and try to memorize them as well as possible.

After the third presentation, all participants were informed that List 1 was only a practice list. They were told that later in the experiment, they would be presented with another list and that their memory for the later list would be tested. Participants in control conditions were then given the arithmetic distractor test, whereas participants in interference conditions received instructions for List 2. These participants were told that they were to study a second list, which was highly similar to List 1. Again, the list contained 20 items: 10 animals and 10 fruits and vegetables. The experimenter told participants that they would be given a memory test for the second list immediately following study. It was stressed to participants that, on their recall test, they were to make sure not to report any of the items from List 1.

List 2 was then presented at the same rate as the first had been presented. Immediately after the final slide, participants were given blank sheets of paper and instructed to write down as many of the words from List 2 as possible in any order. They were reminded not to report any items from List 1. Participants were given 2 min for this test; the experimenter then collected the test sheets.

At this point, all participants (those in both interference and control conditions) were given a surprise recall test for List 1. The experimenter passed out sheets of paper, with one of the two category names printed at the top. Participants were told that they were going to take a memory test for List 1 but that they should report only items from the category printed on their recall sheet. They were also given information about the first letter of each word. The experimenter explained that all of the List 1 items within each category began with a certain set of letters, either A through L or M through Z. (This information was also printed at the top of the recall sheet.) Participants in interference conditions were also told that, for each category, the items in List 2 began with the opposite set of letters than those items in List 1. Therefore, if they could remember an item, they would know in what list it appeared.

Participants were given 1 min for recall. This short delay test began 1 min 30 s after participants in interference conditions had completed their test for List 2 or 10 min 30 s after all participants had studied List 1. Following the recall period, the test sheets were collected and all participants worked on the arithmetic distractor task.

The long delay test began 30 min after the beginning of the short delay test. For this later test, participants were given sheets of paper with one of the two categories printed at the top. They were always tested over the category from which they had not previously recalled. Complete instructions were repeated for all participants, including the information about the set of letters that would begin each correct response. Again, participants were given 1 min for recall. After the test period, participants were debriefed and thanked. During the debriefing, participants were told why it had been necessary to falsely inform them that their memory for List 1 would not be tested.

## Results

Means are graphed in Figure 2. Results show that learning List 2 substantially decreased recall of List 1. Although participants in control conditions showed a slight drop in retention from the first to the second test, participants in interference conditions showed increased recall over the retention interval.

These findings were confirmed in a 2 × 2 ANOVA, with study condition as a between-subjects variable and retention interval as the within-subject variable. The overall ANOVA showed a significant interaction between the two variables, $F(1, 62) = 9.30, p < .005, MSE = 1.78$. The simple main effect of retention interval was computed for both study conditions.

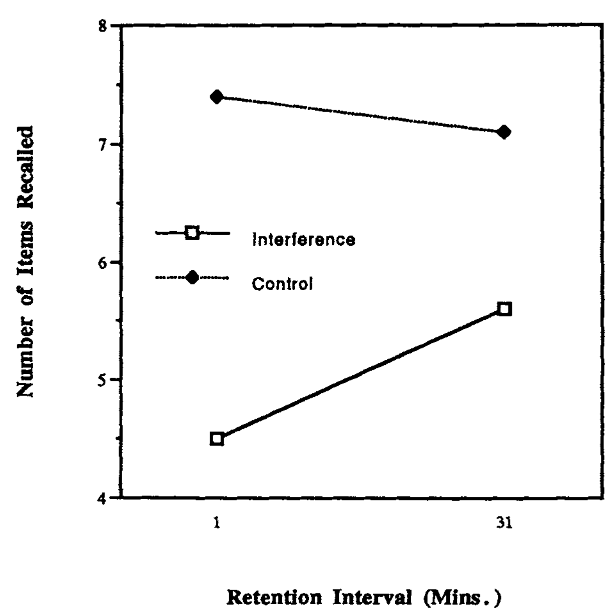


*Figure 2.* Number of words recalled as a function of study condition and retention interval in Experiment 2.

Participants in control conditions did not show a statistically significant difference in recall across the two tests, $F(1, 31) = 1.95, p > .2, MSE = 0.95$, because their scores dropped from a mean of 7.4 items on the first test to 7.1 items on the second test. Participants in interference conditions showed a significant absolute recovery, $F(1, 31) = 7.77, p < .01, MSE = 2.60$. Mean recall improved from 4.5 items to 5.6 items over the retention interval.

### Discussion

Once again, spontaneous recovery was demonstrated. Results are partly consistent with a previous finding of absolute recovery, as reported by Shuell (1968). In two of the conditions of his experiment, participants studied two consecutive categorized lists, which comprised words from the same semantic categories. The group of participants tested immediately after second-list learning showed lower recall of the first list than a different group that was tested 20 min later. Shuell, however, did not find a significant interaction between retention interval and study condition, as his control group (which only learned the first list), somewhat unexpectedly, also showed a small improvement over time. Therefore, although his finding is a valid example of significant absolute recovery over time following retroactive interference, he claimed that the experiment (because of the lack of an interaction) could not be considered evidence for spontaneous recovery.

Experiment 2 also eliminated list confusion as a possible confound by discriminating between target and interfering items on the basis of their first letters. Another feature of Experiment 2 proved to be useful; recovery was assessed in a within-subjects rather than a between-subjects design. This made the analysis more sensitive to changes over time. Related to this point is the fact that fewer subjects were required to complete the experiment. Perhaps if those studies from the verbal learning tradition had assessed recovery in a within-subjects rather than a between-subjects design, the evidence for spontaneous recovery would have been more consistent.

## Experiment 3

Experiment 3 was conducted to replicate the findings of spontaneous recovery in a within-subject analysis. The design was conceptually similar to that of Experiment 2, but the stimulus materials were different. Participants learned pairs of associates conforming to the A–B, A–C paradigm; they were given a cued-recall test for one half of the target (or B) terms immediately and the others after a 30-min delay. This replication should demonstrate that the type of spontaneous recovery in Experiment 2 generalizes to associative learning, providing a closer link between this research and that of the verbal learning tradition.

### Method

*Participants and design.* Participants were 40 University of Houston undergraduates enrolled in an introductory psychology course. They participated in return for course credit. The experiment used a 2 × 2 mixed-variable design. The between-subjects variable was study condition (interference or control), whereas retention interval (short or long delay) varied within subjects.

*Materials.* The target and interfering lists each consisted of 20 letter–word pairs. All of the words represented pictures in Snodgrass and Vanderwart's (1980) series. Letters and words were paired arbitrarily with two constraints. A word could not be paired with a letter if it began with that letter (i.e., *s* could not be paired with *sled*). Also, if a letter was paired with a word that began with the letters A through L in the first list, then it was paired with a word beginning with the letters M through Z on the second list, and vice versa. The target list was *p–door, c–needle, s–toothbrush, g–belt, k–toaster, w–sled, b–chicken, q–tie, z–leaf, f–pliers, v–kite, d–bottle, h–lightbulb, r–cannon, t–padlock, e–cloud, n–television, m–piano, x–trumpet,* and *j–airplane.*

*Procedure.* The procedure was generally similar to that of Experiment 2. Participants were tested in groups of 5–10. All participants in all conditions were informed that they would be presented with a list of 20 letter–word pairs and that they should try to memorize which letters were matched with which words. They were told that they would see the list three times in a row, at a rate of 5 s per pair, with only a short break between list presentations. Participants were instructed to keep trying to memorize the associations each time they saw the pairs, even if they believed that they had already memorized them. The experimenter told them that at test, they would be given the letters and asked to write down the appropriate word that had been paired with each letter.

The letter–word pairs were then presented by a Kodak Ektagraphic slide projector at a rate of 5 s apiece, which included a 0.75-s interval between slides. There was a 15-s interval between list presentations in which the experimenter told subjects that they would see the same list another time and that they should continue trying to memorize the list as well as possible. The slides were shown in the same order in each of the three presentations.

After the third presentation, all participants were told that the list they had just seen was only a practice list and that they would not be tested for it. The experimenter said that they would study another list later in the experiment, in which the same 20 letters would be matched with different words, and that they would then be tested only on the second list. Participants in control conditions were then given the arithmetic distractor task. Participants in interference conditions were given List 2 instructions. They were told that the same 20 letters would be paired with different words and that they would again view the list three times, at the same rate as List 1. The experimenter informed them that at test, they would have to write down the word that was paired with each letter in the second list and that it would be important that they did not write down any of the words from List 1.

Participants in interference conditions were then presented with List 2, under the same conditions in which they had studied List 1. The 20 letters were shown in the same order on both lists. After the third list presentation, participants were given a sheet of paper with all 20 letters listed alphabetically. They were instructed to write the word that was paired with each letter in List 2. They were reminded that it was important that they not write the words from List 1. Participants were given 2 min 30 s for this test; their test sheets were then collected.

At this point, all participants were given their instructions for a test of List 1 (the short delay test). Each subject was given a sheet of paper, with 10 of the 20 letters listed alphabetically in the left column. The letters were subdivided so that, those half whose corresponding words in List 1 began with the letters *A* through *L* appeared on one half of the test sheets, whereas those paired with words beginning with *M* through *Z* appeared on the others. Participants were told that they were to write the name of the word that was paired with each letter only in List 1. They were instructed which set of letters (A through L, or M through Z) began all of the correct responses. (This information was also printed at the top of each test sheet.) Participants in interference conditions were also told that the words in List 2 began with the opposite set of letters. They were assured that, if they could remember a word that was paired with the letters, then they would know which list the word appeared in on the basis of its first letter. Participants were given 1 min 15 s for the test, which began 1 min 30 s after the end of the test for List 2, or 12 min 30 s after all participants had studied List 1.

Following the first test, the response sheets were collected. All participants then worked on the arithmetic distractor task. Instructions for the long delay test were identical to those given for the short delay test. Again, participants were given a sheet of paper with one half of the letters listed alphabetically. Each participant received the 10 letters that had not been tested previously. They were also told what set of letters would begin each of the correct responses, A through L or M through Z. The correct set of letters was always the one opposite to the set that had been correct on the first test. Participants were given 1 min 15 s for the test, which began 31 min 30 s after the end of the test for List 2, or 42 min 30 s after all subjects had studied List 1. On completion of the test, all subjects were debriefed and thanked.

### Results

Basic data are reproduced in Figure 3. List 2 produced a substantial amount of retroactive interference for List 1. Participants in control conditions performed better on the first test than the second, displaying forgetting over time. Participants in interference conditions improved over time, showing spontaneous recovery.

These findings were confirmed in a 2 × 2 ANOVA, with study condition (interference or control) as a between-subjects variable and retention interval (short or long delay) as a within-subject variable. The overall ANOVA showed an interaction between these two variables, $F(1, 38) = 18.00, p < .001$, $MSE = 1.61$. The simple main effect of retention interval was computed for both study conditions. For participants in control conditions, there was significant forgetting over the retention interval, $F(1, 19) = 5.94, p < .025, MSE = 2.23$, as the mean number recalled dropped from 5.2 items to 4.0 items. Participants in interference conditions showed a significant increase in retention across the interval, $F(1, 19) = 15.22, p < .001, MSE = 1.11$. Recall improved from 2.0 items on the short delay test to 3.3 items on the long delay test.

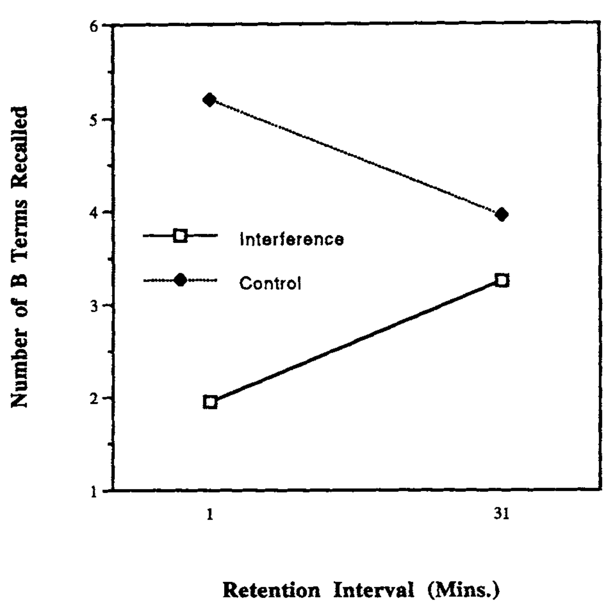


*Figure 3.* Number of response terms recalled as a function of study condition and retention interval in Experiment 3.

### Discussion

Experiment 3 replicated the finding of spontaneous recovery in a within-subject analysis, this time with paired associates as the stimulus materials. Although all of the experiments so far have demonstrated spontaneous recovery, the procedures have gradually improved; by Experiment 3, there was a statistically robust effect of recovery with only 40 participants tested. By contrast, recovery in the combined Experiments 1a and 1b just reached statistical significance, despite the data of 240 participants. The actual magnitude of the effect has been roughly the same in each experiment, however.

The results of Experiment 3 also contradict the conclusion of Postman et al. (1969) that some degree of overlearning is necessary for the detection of spontaneous recovery. Participants in control conditions barely recalled more than half of the items, even on the first memory test. Despite this surprisingly low level of performance, there was only about a 20% drop (from 5.2 to 4.0 items) in retention on the second test; more important, participants in interference conditions demonstrated significant recovery (from 2.0 to 3.3 items) over the same interval. This finding supports the conclusion that a relatively small amount of extraexperimental forgetting is an important precursor to spontaneous recovery, whereas a high degree of original learning is not.

The experiments reported here are inconsistent with another observation of Postman et al. (1968). In one condition of their Experiment 3, only the first-list (or B) responses were required at recall, rather than the typical MMFR requirement, which instructed participants to report responses from both the first and second lists. There was no recovery over time in this condition, as retention remained essentially flat across a 16-min interval. Because their instructions were similar to those used in the experiments reported here, there is a disparity between the two findings. Postman et al. (1968) suggested that this procedure might not lead to improved recall because of the possibility of errors from response competition and failures of list differentiation. In retrospect, it is difficult to explain their lack of recovery, but it is worth noting that spontaneous recovery was found under similar conditions in all of the experiments reported here, including Experiments 2 and 3, in which there could be no failure of list discrimination.

## General Discussion

The most important question motivating this research was, Can spontaneous recovery be reliably demonstrated in human memory research? The answer appears to be yes. In all experiments, there was significant absolute recovery over time. These findings are consistent with Brown's (1976) conclusion that the evidence does generally support the reality of spontaneous recovery. Of course, the experiments reported here do more than simply reinforce Brown's conclusion, because spontaneous recovery has now been demonstrated in several new paradigms.

Given that spontaneous recovery is a reliable effect, it is important to consider explanations for the seemingly counterintuitive phenomenon. The unlearning–recovery hypothesis (Underwood, 1948a, 1948b) would have a difficult time explaining the results of these experiments. This hypothesis considers first-list associations (A–B) to be gradually unlearned during interpolated (A–C) learning. Because there were no A–B associations presented during study in the experiments reported here (except in Experiment 3), it is difficult to argue that associative unlearning was the driving force behind the retroactive interference. (Although one might argue that some types of associations are still being formed during the study of discrete items.) Still, the unlearning–recovery approach is probably not well suited for explaining memory phenomena, except when the stimulus materials conform to a paired-associates paradigm, as was typical of experiments within the verbal learning tradition.

Another previous explanation, response-set suppression (Postman et al., 1968, 1969), is generally consistent with the results reported here. Again, this theory postulates the mental construct of a "selector mechanism," which serves to direct response selection. During interpolated learning, the mechanism selects items from the current list for attention and rehearsal, whereas previous lists, or sets, of items are said to be avoided, or "suppressed." This suppression remains active for some period of time after interpolated learning and, during this time, first-list responses suffer from reduced accessibility. As the power of the selector mechanism dissipates, suppression also dissipates, which results in a "spontaneous" recovery of first-list items.

Clearly, this explanation could be applied to Experiments 1a–3. Of course, response-set suppression theory was discredited many years ago, but it is argued that this happened primarily because of two factors. Probably the main reason was the finding of Wichawut and Martin (1971; see also Delprato, 1971), as discussed previously, which refuted the listwide nature of suppression that had been proposed in the theory (for other criticisms, see Brown, 1976; Crowder, 1976). Another reason, however, was the general decline in interest in the verbal learning framework and interference theory. The merits of many theories of interference were never clearly resolved, largely because of paradigmatic shifts within cognitive psychology. The important point from this is that the concept of suppression itself was never refuted. Only some of the specifics of the theory were criticized. Therefore, mechanisms of suppression may play a significant role in remembering, even if there is little or no support for a "listwide," or "response-set," suppression. If so, these processes have been relatively understudied in cognitive psychology and warrant further investigation.

Within the past 10 years, a related concept, known as *retrieval inhibition,* has been proposed to account for many of the findings in the directed forgetting literature. Geiselman and Bagheri (1985) suggested that, if participants are instructed to forget recently studied items, they are capable of *inhibiting* (or suppressing) the items in memory. This idea was endorsed by Bjork (1989), who argued that inhibition is an adaptive process. One of the main adaptive benefits is that as the inhibited items become less retrievable, they are much less likely to interfere with new learning. Researchers have also begun to look for a "release" from retrieval inhibition in directed forgetting experiments. This release is evidenced on a subsequent free-recall test, in which there was no effect of the directed forgetting manipulation. Bjork (1989) and Basden, Basden, and Gargano (1993) reported results in which the reexposure of intentionally forgotten items in a recognition test overrode or released these items from inhibition. More recently, Anderson, Bjork, and Bjork (1994) showed that the act of retrieving recently learned information can impair the cued recall of related, unpracticed information (a phenomenon they called *retrieval-induced forgetting*). In addition, impairment was greatest for items with a strong relationship to the category cue. (For example, within the category "fruits," "orange" is more likely to suffer from retrieval-induced forgetting than "fig.") The authors suggested that strong category members are inhibited during retrieval practice; the inhibition "isolates" target responses from potentially competitive responses within the same category. By this logic, it follows that items with a greater associative strength to the cue should suffer the most inhibition because they will provide the greatest interference or competition to the other items. So far, none of the proponents of this retrieval inhibition hypothesis have attempted to explain the results of Delprato (1971) and Wichawut and Martin (1971). The question of whether inhibition can be item specific, or list specific, or some combination of the two, is a potentially important one, but the concept of retrieval inhibition, as commonly expressed (Bjork, 1989; Geiselman et al., 1983) does not make a prediction on the issue. For a review of cognitive theories of inhibition, see Anderson and Bjork (1994).

The retrieval inhibition hypothesis is similar to response-set suppression, as proposed by Postman et al. (1968). In fact, there is probably no experiment that could be performed to distinguish between the two theories, because they make similar predictions. Ironically, in many of the articles in which retrieval inhibition has been suggested (Basden et al., 1993; Coe et al., 1989; Geiselman & Bagheri, 1985; Geiselman et al., 1983), the response-set suppression hypothesis is not even cited as an historical predecessor. The two theories should certainly be compared, however; by jointly considering the evidence that has been collected to test the two approaches, a broader theory of inhibition and suppression can be developed.

The working hypothesis for the experiments reported here postulates a process of retrieval inhibition, which serves to actively prevent subjects from accessing previously learned material (i.e., the target list) during interpolated learning. An important feature should be added to the understanding of inhibition, however; like the response-set suppression advocated by Postman et al. (1968), there is now evidence that retrieval inhibition dissipates over time. The impermanence of inhibition might be considered as another adaptive attribute, as it would surely not be beneficial for suppressed information to remain inaccessible for a prolonged period of time.

Although a hypothesis that is based on retrieval inhibition is a useful framework from which to interpret the results, it should be noted that the experiments reported here were not designed to discriminate between competing theoretical explanations. Other theories of interference might also account for the results, especially approaches that emphasize the competitive relationship between the target and interfering lists. One explanation of this type was proposed by Miller and Stevenson (1936). When earlier (or, in this case, target) and later (interfering) learning episodes involve different responses of the same response type (A–B, A–C), they are in competition with one another. If it is assumed that the forgetting functions of each episode are negatively accelerated (from Ebbinghaus, 1885/1964), then there should be some period of time following interpolated learning that newer (or C) responses are being forgotten at a faster rate than the older (or B) responses. The accelerated forgetting of the newer responses should lead to apparent relative growth of the older responses. If the two responses are truly competitive, then one might imagine that, as the newer responses are forgotten, the older responses could grow absolutely over time.

Similar ideas have recently been expressed within theories of retrieval blocking. Chandler (1993) reported reduced retroactive interference with the passage of time in experiments in which subjects studied different last names for the same first name in two successive lists (thus, functionally replicating an A–B, A–C design). On a matching test (on which subjects matched the appropriate As with Bs), retroactive interference was greatest when interfering (or A–C) names were encountered just before the test. The conclusion was that the interfering names "blocked" access to target names. As the interfering items were forgotten, the magnitude of retrieval blocking decreased.

Again, the major purpose of this research was to demonstrate that the spontaneous recovery of information over time can be shown reliably in human memory research. Considering that spontaneous recovery is a relatively small effect, it is not surprising that research on the phenomenon has been sparse since the early 1970s. The assessment of recovery in a within-subjects, rather than a between-subjects, design has proved to be a useful step. This change has made the test for recovery more sensitive. Despite the relative difficulty in demonstrating spontaneous recovery, an understanding of the effect is still important. The fact that the absolute recovery of information over time runs counter to virtually all of the beliefs and intuitions about remembering is itself a compelling reason to seek an explanation for the phenomenon. Whatever processes operate to produce spontaneous recovery, they are not well understood.

Retrieval inhibition, as a potential explanation for recovery, is an idea that will require further testing. The concept of inhibition itself is somewhat ambiguous and will eventually require a more detailed theoretical explanation. Here, retrieval inhibition is defined as a suppression-type process that can be directed at specific previously learned information for some adaptive purpose (from Bjork, 1989). Another aspect of inhibition, suggested from the experiments reported here, is its impermanence; any effects caused by inhibition should dissipate over time. An excellent paradigm from which to study inhibition is a spontaneous recovery paradigm. This approach illustrates (a) a decrement in retention, usually caused by retroactive interference from interpolated learning, and (b) an eventual recovery from interference. The absolute recovery is important, not only because it is counterintuitive but also because it demonstrates that the target material was not permanently forgotten; rather, it was only temporarily nonproduceable. If information has not been permanently forgotten, why can it not be recalled on an immediate memory test? The answer to this question will provide the explanation for spontaneous recovery.

## References


Abra, J. C. (1967). Time changes in the strength of forward and backward associations. *Journal of Verbal Learning and Verbal Behavior, 6,* 640–645.

Anderson, M. C., & Bjork, R. A. (1994). Mechanisms of inhibition in long-term memory: A new taxonomy. In D. Dagenbach & T. Carr (Eds.), *Inhibition 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: Explorations in the retrieval dynamics of long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1063–1087.

Ballard, P. B. (1913). Oblivescence and reminiscence. *British Journal of Psychology Monograph Supplements, 1,* 1–82.

Barnes, J. M., & Underwood, B. J. (1959). "Fate" of first-list associations in transfer theory. *Journal of Experimental Psychology, 58,* 97–105.

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

Battig, W. F., & Montague, W. E. (1969). Category nouns for verbal items in 56 categories: A replication and extension of the Connecticut category norms. *Journal of Experimental Psychology Monograph, 80*(3, Pt. 2), 1–46.

Birnbaum, I. M. (1965). Long-term retention of first-list associations in the A–B, A–C paradigm. *Journal of Verbal Learning and Verbal Behavior, 4,* 515–520.

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). San Diego, CA: Academic Press.

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

Briggs, G. E. (1954). Acquisition, extinction, and recovery functions in retroactive inhibition. *Journal of Experimental Psychology, 47,* 285–293.

Briggs, G. E., Thompson, R. F., & Brogden, W. J. (1955). Retention functions in reproductive inhibition. *Journal of Experimental Psychology, 48,* 419–423.

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

Ceraso, J., & Henderson, A. (1965). Unavailability and associative loss in RI and PI. *Journal of Experimental Psychology, 70,* 300–303.

Ceraso, J., & Henderson, A. (1966). Unavailability and associative loss in RI and PI: Second try. *Journal of Experimental Psychology, 72,* 314–316.

Chandler, C. C. (1993). Accessing related events increases retroactive interference in a matching recognition task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 967–974.

Coe, W. C., Basden, B. H., Basden, D. R., Fikes, T., Gargano, G. J., & Webb, M. (1989). Directed forgetting and posthypnotic amnesia: Information processing and social contexts. *Journal of Personality and Social Psychology, 56,* 189–198.

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

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

Ebbinghaus, H. (1964). *Memory: A contribution to experimental psychology.* New York: Dover. (Original work published 1885)

Erdelyi, M. H., & Becker, J. (1974). Hypermnesia for pictures: Incremental memory for pictures but not for words in multiple recall trials. *Cognitive Psychology, 6,* 159–171.

Estes, W. K. (1955). Statistical theory of spontaneous recovery and regression. *Psychological Review, 62,* 145–154.

Forrester, W. E. (1970). Retroactive inhibition and spontaneous recovery in the A–B, D–C paradigm. *Journal of Verbal Learning and Verbal Behavior, 9,* 525–528.

Geiselman, R. E., & Bagheri, B. (1985). Repetition effects in directed forgetting: Evidence for retrieval inhibition. *Memory & Cognition, 13,* 57–62.

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.

Houston, J. P. (1966). First-list retention and time and method of recall. *Journal of Experimental Psychology, 71,* 839–843.

Koppenaal, R. J. (1963). Time changes in the strengths of A–B, A–C lists: Spontaneous recovery? *Journal of Verbal Learning and Verbal Behavior, 2,* 310–319.

Lehr, D. J., & Duncan, C. P. (1970). Effects of priming on spontaneous recovery of verbal lists. *Journal of Verbal Learning and Verbal Behavior, 9,* 106–110.

Lehr, D. J., Frank, R. C., & Mattison, D. W. (1972). Retroactive inhibition, spontaneous recovery, and type of interpolated learning. *Journal of Experimental Psychology, 92,* 232–236.

McGovern, J. B. (1964). Extinction of associations in four transfer paradigms. *Psychological Monographs, 78*(16, Whole No. 593).

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, 53,* 173–203.

Miller, N. E., & Stevenson, S. S. (1936). Agitated behavior of rats during experimental extinction and a theory of spontaneous recovery. *Journal of Comparative Psychology, 21,* 205–231.

Pavlov, I. P. (1927). *Conditioned reflexes: An investigation of the physiological activity of the cerebral cortex.* London: Oxford University Press.

Payne, D. G. (1987). Hypermnesia and reminiscence in recall: A historical and empirical review. *Psychological Bulletin, 101,* 5–27.

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

Postman, L., Stark, K., & Henschel, D. (1969). Conditions of recovery after unlearning. *Journal of Experimental Psychology Monograph, 82*(1, Pt. 2).

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

Roediger, H. L., III, & Payne, D. G. (1982). Hypermnesia: The role of repeated testing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 66–72.

Shuell, T. J. (1968). Retroactive inhibition in free-recall learning of categorized lists. *Journal of Verbal Learning and Verbal Behavior, 7,* 797–805.

Shulman, H. G., & Martin, E. (1970). Effects of response-set similarity on unlearning and spontaneous recovery. *Journal of Experimental Psychology, 75,* 267–273.

Silverstein, A. (1967). Unlearning, spontaneous recovery, and the partial-reinforcement effect in paired-associate learning. *Journal of Experimental Psychology, 73,* 15–21.

Slamecka, N. J. (1966). A search for spontaneous recovery of verbal associations. *Journal of Verbal Learning and Verbal Behavior, 5,* 205–207.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Nouns for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.

Tulving, E., & Psotka, J. (1971). Retroactive inhibition in free recall: Inaccessibility of information available in the memory store. *Journal of Experimental Psychology, 87,* 1–8.

Underwood, B. J. (1948a). Retroactive and proactive inhibition after five and forty-eight hours. *Journal of Experimental Psychology, 38,* 29–38.

Underwood, B. J. (1948b). "Spontaneous recovery" of verbal associations. *Journal of Experimental Psychology, 38,* 429–439.

Underwood, B. J., & Schulz, R. W. (1960). *Meaningfulness and verbal learning.* Philadelphia: Lippincott.

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.

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.

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