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Spontaneous recovery of "lost" information: The case for retrieval inhibition

Wheeler, Mark Allen, Ph.D.

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SPONTANEOUS RECOVERY OF "LOST" INFORMATION:
THE CASE FOR RETRIEVAL INHIBITION

by

MARK A. WHEELER

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE
DOCTOR OF PHILOSOPHY

APPROVED, THESIS COMMITTEE

Henry L. Roediger, III, Chair
Professor of Psychology

Michael J. Watkins,
Professor of Psychology

David J. Schneider
Professor of Psychology

Anthony A. Wright
Adjunct Professor of Psychology

Richard E. Grandy
Professor of Philosophy

Houston, Texas

April, 1993
SPONTANEOUS RECOVERY OF "LOST" INFORMATION: THE CASE FOR RETRIEVAL INHIBITION

by

MARK A. WHEELER

Abstract

Eight experiments were conducted to investigate the phenomenon of spontaneous recovery, or memory improvement over time without repeated testing. While this phenomenon has been previously studied within the verbal learning tradition, evidence for its existence has been inconclusive. Experiments 1a through 5 demonstrated the reliability of the effect. The procedure was gradually modified throughout these experiments, leading to the following conclusions. First, retroactive interference (which is a necessary condition for recovery) is maximized when subjects are led to believe that their knowledge of the target list will interfere with interpolated learning. Also, assessing spontaneous recovery in a within-, rather than a between-subjects paradigm, is a more powerful approach, and allows for a more sensitive test of the phenomenon. Most importantly, spontaneous recovery was reliably produced. The proposed explanation for the phenomenon involves retrieval inhibition, and its subsequent dissipation, as the processes underlying recovery. More specifically, inhibition prevents subjects from generating target items on immediate tests. As the inhibition dissipates, more items can be recalled on later tests; this occurs despite the presumption that normal forgetting is also operating upon the target list.

Experiment 6 attempted to extend spontaneous recovery to an implicit, word-stem completion test. Following study conditions roughly similar to
those used in the prior experiments, there was no evidence for either retroactive interference or spontaneous recovery on the implicit test. This demonstrates, at the very least, a study manipulation that dissociates explicit free recall with implicit word-stem completion. More interestingly, it suggest that retrieval inhibition might only operate upon intentional uses of retrieval, although more data would be required to confirm this hypothesis.

Experiment 7 applied the spontaneous recovery paradigm to directed forgetting. If subjects are using retrieval inhibition to "block out" to-be-forgotten items, then these items should recover over time. Results provide limited evidence for this conclusion. Retrieval inhibition, and its subsequent dissipation, are hypothesized to be the primary processes underlying directed forgetting.
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Spontaneous Recovery of "Lost" Information: The Case for Retrieval Inhibition

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 we forget over time has gone relatively unchallenged; indeed, it has been confirmed in hundreds of experiments. The purpose of this paper 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 memory tests, rather than the passage of time after it was extinguished, is the driving force behind hypermnesia (although see Shapiro & Erdelyi, 1974).

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, 1928). In his seminal study, a classically conditioned response (salivation to a metronome) was extinguished through a lack of reinforcement (the withholding of meat powder which had previously been paired with the metronome). After a twenty-three minute delay, the metronome produced a substantially larger response, as the salivation reflex regained strength over time.

Spontaneous recovery research has probably been the most prominent in instrumental conditioning experiments. In Ellson’s (1938) classic work, rats were trained to perform a lever-pressing response; the next day, the response was extinguished. After various intervals ranging from five minutes to three hours, the rats were brought back, and they showed an increased tendency to respond. Importantly, the magnitude of the increase in lever presses corresponded to the increase in retention interval; that is, the longer the retention interval, the greater the amount of spontaneous recovery.

Evidence for this phenomenon was later demonstrated in the verbal learning tradition (Underwood, 1948b). For humans, a typical paradigm in spontaneous recovery experiments involved subjects 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). Subjects learned the pairs via a procedure known as the anticipation method. They were presented with the stimulus terms (the A's) and instructed to give an oral response to anticipate its matching associate. After the subject responded, the response term (B) was shown to the subjects. This process continued for several trials until subjects reached a predetermined criterion (e.g., 75% correct). At the end of A-B learning, subjects began learning an A-C
list. This originally led subjects to respond with the appropriate B term that had been previously associated with A; this response was not reinforced, however, as the C term was then presented as the appropriate response. The A-B associations were said to eventually become extinguished, through a lack of reinforcement. Immediately after learning A-C, subjects given a cued-recall test generally showed poorer memory for the B terms, as compared to control subjects 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 to the process of extinction of conditioned responses.

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 subjects learn an A-B list, followed by an A-C list, then gave them a cued-recall test after 1 minute, 5 hours, 1 day, or 2 days. The test was known as modified free recall (MFR), as subjects were presented with the stimulus, or A, term, and instructed to report the first of the two responses, B or C, which came to mind. Results showed that B responses increased slightly, yet reliably, from 1 minute to 1 day, while C responses showed a substantial decrease over that interval. Also, while the C terms were much stronger 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, 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, 1954).

One problem with the studies of Underwood and Briggs is that they both used the MFR technique, in which only one response is given for each stimulus. This procedure, therefore, did not measure whether a response from the first list could be produced at the time of recall. Since 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, as 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 response competition. With this goal in mind, Barnes and Underwood (1959) developed a procedure called modified modified free recall (or MMFR). In MMFR, subjects are asked to produce all of the responses that had been paired with a particular stimulus. By this procedure, any correct response which can be brought to mind 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 an unlearning (or extinction) 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. While 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, and Fraser, 1968; Postman, Stark, and Henschel, 1969; 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). The lack of a consistent effect led Postman et al. (1968) to conclude that spontaneous recovery was not a dependable phenomenon.

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. The most common paradigm involved subjects learning a target list of paired associates (A-B) via the anticipation method. Control subjects saw only the first list, while experimental subjects would learn at least one more list of paired associates (usually A-C). Retention was then measured via MMFR both immediately and after some longer interval, with retention interval varied between subjects. In Table 1, most relevant studies that employed this paradigm are summarized. The left portion of the table is organized to provide information about several variables which were often manipulated in the search for recovery; these variables include the type of interpolated learning (A-C, C-D, etc.), as well as the criterion to which both the original (A-B) and interpolated lists were learned. Also described is the retention interval after which the delayed MMFR test was given. In each experiment summarized, the immediate test was taken within a few minutes of the end of interpolated learning.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>A-B crit.</th>
<th>IL</th>
<th>IL crit.</th>
<th>Interval</th>
<th>RI</th>
<th>CF</th>
<th>SR</th>
<th>RR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abra (1967)</td>
<td>1 perf.</td>
<td>A-C</td>
<td>1 perf. + 5 trials</td>
<td>24 hr.</td>
<td>.30</td>
<td>.81</td>
<td>0.91</td>
<td>No</td>
</tr>
<tr>
<td>Bimbaum (1965)</td>
<td>7/8</td>
<td>A-C</td>
<td>20 trials (OL)</td>
<td>24 hr.</td>
<td>.39</td>
<td>.82</td>
<td>0.84</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7 days</td>
<td>.39</td>
<td>.42</td>
<td>0.77</td>
<td>Yes</td>
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<tr>
<td>Ceraso &amp; Henderson (1965)</td>
<td>1 perf.</td>
<td>A-C</td>
<td>1 perf.</td>
<td>24 hr.</td>
<td>.30</td>
<td>.92</td>
<td>1.11</td>
<td>Yes</td>
</tr>
<tr>
<td>Ceraso &amp; Henderson (1966)</td>
<td>1 perf.</td>
<td>A-C</td>
<td>1 perf.</td>
<td>24 hr.</td>
<td>.39</td>
<td>.97</td>
<td>1.01</td>
<td>No</td>
</tr>
<tr>
<td>Forrester (1970)</td>
<td>1 perf.</td>
<td>A-C</td>
<td>10 trials (OL)</td>
<td>20 min.</td>
<td>.61</td>
<td>.91</td>
<td>1.40</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Howe (1967)</td>
<td>approx. 9/12</td>
<td>A-C</td>
<td>20 trials (OL)</td>
<td>4 days</td>
<td>.38</td>
<td>.53</td>
<td>0.77</td>
<td>No</td>
</tr>
<tr>
<td>Koppenaal (1963)</td>
<td>1 perf.</td>
<td>A-C</td>
<td>1 perf.</td>
<td>19 min.</td>
<td>.32</td>
<td>.96</td>
<td>1.01</td>
<td>No</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90 min.</td>
<td>.32</td>
<td>.86</td>
<td>0.96</td>
<td>No</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6 hr.</td>
<td>.32</td>
<td>.91</td>
<td>1.12</td>
<td>No*</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24 hr.</td>
<td>.32</td>
<td>.89</td>
<td>0.97</td>
<td>No</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 days</td>
<td>.32</td>
<td>.80</td>
<td>0.90</td>
<td>No</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7 days</td>
<td>.32</td>
<td>.59</td>
<td>0.76</td>
<td>No</td>
</tr>
<tr>
<td>Lehr &amp; Duncan (1970)</td>
<td>approx. 8/12</td>
<td>A-C</td>
<td>approx. 8/12</td>
<td>14 min.</td>
<td>.30</td>
<td>.84</td>
<td>0.97</td>
<td>Yes</td>
</tr>
<tr>
<td>Lehr et al., (1972)</td>
<td>approx. 8/12</td>
<td>A-C, A-D</td>
<td>approx. 8/12 each</td>
<td>14 min.</td>
<td>.77</td>
<td>.99</td>
<td>2.00</td>
<td>Yes</td>
</tr>
<tr>
<td>Postman et al., (1968)</td>
<td>approx. 7/8</td>
<td>A-C</td>
<td>approx. 7/8</td>
<td>16 min.</td>
<td>.45</td>
<td>.96</td>
<td>1.05</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>approx. 9/12</td>
<td>A-C, A-D</td>
<td>approx. 9/12</td>
<td>18 min.</td>
<td>.61</td>
<td>.92</td>
<td>1.43</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 1 Continued

| Exp. I         | 5/8       | A-C, A-D | 7 trials each (OL) | 16 min. | .62 | .95 | 0.88 | No |
|               | ""        | C-D, E-F | 7 trials each (OL) | 16 min. | .65 | .95 | 1.39 | Yes|
| Exp. III      | 5/8 + 4 trials | A-C, A-D | 7 trials each (OL) | 16 min. | .64 | .94 | 1.54 | Yes|
|               | ""        | C-D, E-F | 7 trials each (OL) | 16 min. | .47 | .94 | 1.24 | Yes|
| Slamecka (1966) | 1 perf.  | A-C       | 1 perf. + 4 trials | 6 hr.   | .31 | .95 | 0.95 | No |
|               | ""       | ""       | ""                 | 18 hr.  | .31 | .96 | 1.18 | No*|
|               | ""       | ""       | ""                 | 24 hr.  | .31 | .97 | 1.14 | No*|
|               | ""       | ""       | ""                 | 2 days  | .31 | .92 | 1.03 | No |

Notes. A-B crit.--criterion of learning of the A-B (or target) list. IL--type of interpolated learning. IL crit.--criterion of learning of the interpolated list(s). OL--overlearned; indicates that the list was learned past one perfect trial. Interval--length of retention interval. RI--percent of retroactive interference (percent of control retention “lost” on the immediate test from interference). CF--index of how retention changes across the retention interval for subjects that do not study interpolated lists; proportion of responses recalled on later test relative to those recalled on the immediate tests in control conditions. Proportions less than 1.0 indicate that forgetting has occurred. SR--spontaneous recovery; proportion of B responses recalled on the later test relative to that recalled on the immediate tests in experimental conditions. Proportions greater than 1.0 indicate numerical recovery. RR--forgetting over time was significantly less for the experimental than the control group.

*Relative recovery may be significant for these particular comparisons, but the analysis collapsed across all of the comparisons within the experiment, and did not reach significance.
The final four columns in Table 1 list the results of the experiments. Retroactive interference (RI) indicates the percentage decrement in the recall of B responses which was attributable to interpolated learning on the immediate test. In other words, it is the percentage of retroactive interference. For example, in the Birnbaum (1967) study, subjects in control conditions showed an immediate recall of 7.2 B terms, while those in interference conditions reported 4.4 terms, which was a decrement of .39 of control retention. The columns CF and SR are indices in the changes in retention over time for subjects in the control and experimental groups, respectively. The numbers listed are the proportions of B responses recalled on the delayed test to those responses recalled on the immediate test. Since control subjects did not study interpolated lists, they showed the typical forgetting over time; therefore, these proportions are all less than 1. In the cases where there was numerical recovery in experimental conditions, the proportions are greater than 1. Finally, the RR column indicates whether or not relative recovery was attained. 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 (see Brown, 1976). This interaction would suggest that spontaneous recovery is operating in opposition to normal forgetting.

Using this general paradigm (learning by anticipation, MMFR), absolute spontaneous recovery was obtained by Forrester (1970), Lehr et al. (1972), Postman et al. (1968), and Postman et al. (1969) with delay intervals of less than 30 minutes. Significant recovery was also obtained by Ceraso & Henderson (1965) and Silverstein (1967) over a 24 hour delay.
Improvement over time was not evident 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; Postman et al., 1969). They suggested that a rise in first list recall is unlikely if there is a large degree of extra-experimental forgetting demonstrated by the control groups (the groups which studied only the A-B list). Even if spontaneous recovery is occurring, it could be more than offset by the extra-experimental forgetting. In other words, even though the first list associations are regaining strength over time, they are still prone to 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 recovery, recall of the control list dropped by less than 10 percent between the immediate and delayed tests. It was the realization of extra-experimental forgetting that led to the adoption of relative recovery as an index of recovery. On this measure, Brown (1976) discovered that a large majority of relevant experiments (47 out of 53, or 88.7%) had demonstrated the effect.

Related to the issue of extra-experimental 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. Subjects 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 subject had reached a predetermined level of learning (say, one perfect trial). As subjects 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 less prone to extra-experimental forgetting, and more likely to be spontaneously recovered. In Postman et al. (1969, Experiment 1) subjects learned an A-B list of eight paired associates to a criterion of 5/8 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, the authors performed an identical experiment, except that the first list was learned to a criterion of 5/8, and then four additional trials were given. Therefore, many of the individual paired associates were overlearned. While this amount of learning resulted in approximately the same amount of retroactive interference as in the first experiment, this time spontaneous recovery was demonstrated—subjects recalled about 2.8 B terms on the immediate MMFR test and 4.2 on a similar test sixteen minutes later (these numbers are estimated from their figure). The authors 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 8/12 (Lehr & Duncan, 1976). 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 associations (A-B) are unlearned during practice of a second list (A-C). On second list learning, B terms are not reinforced and become experimentally unlearned. 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 are operating independently on the individual A-B associations. Note that the "theory" attempts to explain the recovery by analogy to conditioning phenomena, but both extinction and recovery in both situations require a theoretical explanation.

Postman and his colleagues (Postman et al., 1968; Postman et al., 1969) have offered a different interpretation of spontaneous recovery, called response set suppression (or, sometimes, 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 influences subjects to suppress the responses from prior lists while 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 second list is dominant, and the selector mechanism favors the most recent list. The inertia operating upon this mechanism is assumed to be of limited duration, and so second list
dominance is reversible. The theory is not concerned with explaining spontaneous recovery in either classical or operant conditioning.

This hypothesis differs from the unlearning-recovery hypothesis in many ways. First, it implies that interference does not result from a decrease in the strength of the associations. Unlearning theories assumed that first list responses were each gradually extinguished, because they were not reinforced during second list learning. Postman's response-set suppression explanation claimed that it is the dominance of one entire set of responses that leads to interference, rather than changes in the individual associations. Associative unlearning theories also postulated a recovery process which works in direct opposition to forgetting. The suppression hypothesis implicated a decrease in response-set suppression over time, which operated through a change in the selector mechanism. Therefore, recovery reflects the dissipation of interference, and not the "rebuilding" or "relearning" of associations.

As an empirical test of the two hypotheses, Postman et al. (1969) compared the amounts of retroactive interference and spontaneous recovery resulting from two different types of interpolated learning. All subjects learned a list of A-B pairs, and then some subjects were presented with A-C pairs, while 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, since these groups are presumably losing two kinds of associations (contextual and specific) rather than one (contextual), as in the C-D conditions (McGovern, 1964). Both types of interpolated lists are said to cause contextual interference, as the learning of new associations should have a general,
depressing effect on first list responses. Only subjects receiving the A-C list, however, are prone to specific stimulus-response interference via experimental extinction. The response set interference hypothesis, however, predicts that B responses should be depressed equally after both types of interference. Both relevant experiments (Postman et al., 1969, Experiments 1 and 3) supported this latter hypothesis: interference was equivalent for the two conditions, and the C-D condition actually led to greater recovery in Experiment 1 (but see McGovern, 1964). The authors concluded that spontaneous recovery resulted from a change in the dominance of one set of responses over the other, rather than 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 "stored" in "memory", but they cannot be produced. A test of this point was conducted by Postman et al. (1968, Experiment IV). 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), subjects were given each stimulus term and a list of all response terms, and asked to match them appropriately. There was a very 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. Probably the most damaging findings were failures to replicate 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 (Weaver, Rose, & Campbell, 1971; Wichawut & Martin, 1971). After learning an A-B list, the interpolated list was composed of both A-C and C-D pairs. Again, there was decreased retroactive interference after C-D. This finding can be taken as evidence for item-specific, rather than list-related, interference. Postman and Underwood (1973) acknowledge the problem, and suggest the possibility of "differential suppression of subgroups of items" (p. 25) within a single list.

Unfortunately, the issue was never settled and very 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 directly opposed.

When the verbal learning tradition lost popularity in the early 1970's, interference theory also diminished in popularity. The type of paired associate learning which 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 vanished, too. In more recent times, other
researchers within learning and memory 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 a repeated measures design. Also, some of the recent work by Robert Bjork and his colleagues (Bjork, 1989; Geiselman, Bjork, and Fishman, 1983) has emphasized the role of inhibitory processes which are similar to response suppression. Therefore, renewing the investigation of spontaneous recovery might lead to insights in the nature and function of human memory, even without relying upon the assumptions and methodologies of the verbal learning tradition. The primary purpose of the first set of experiments is to demonstrate that the absolute recovery of information over time is a reliable phenomenon, and can be demonstrated using somewhat different procedures from those used in the verbal learning tradition. Another goal is to provide a tentative explanation of spontaneous recovery.

From prior research in this area, it is evident that, when spontaneous recovery did occur, it was because of a reduction in retroactive interference over time; there was great retroactive interference immediately after A-C learning, and the interference dissipated over time. Therefore, all of the experiments reported here involve two different learning conditions, manipulated between subjects; one group learns a target list followed by similar, interfering lists, whereas controls receive only the target list. Subjects in both conditions are then tested either immediately or following some short delay (always less than one hour). From the Brown (1976) review, it is evident that spontaneous recovery is more likely to occur across intervals of less than one hour. There are two
potential effects of interest: the amount of interference resulting from interfering lists, and any recovery (whether absolute or relative) demonstrated in these conditions. Experiments 1a and 1b were conducted both 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 to determine whether spontaneous recovery for a target list could occur through the reduction of retroactive interference. The procedure differed from those commonly used in the verbal learning tradition in several respects. If spontaneous recovery is a reliable effect, then it should be obtainable in experiments that do not employ the specific methods which were traditionally used to study interference theory. In the current experiments, all subjects studied a target list under intentional memory instructions. In those conditions in which multiple lists were presented, subjects were given the additional instruction that they should remember which items were included in which lists. Another difference between these experiments and previous verbal learning studies was the type of recall test. Experiments 1a and 1b required subjects to complete a standard cued recall test for the response terms in the first, or A-B, list only. Traditional verbal learning experiments often employed MMFR, in which the stimulus term was presented, and subjects attempted to recall all the responses that had been paired with the stimulus in the prior lists. The experiments reported here required subjects to write down only the first response term (or the B term) as a control against output interference. A common finding under the MMFR procedure was that, for subjects who listed both responses (B and C, given A), the order of
the responses depended on the delay between study and test. On the immediate tests, the response from the later list was usually given first, while on delayed tests, the opposite was true (Postman et al., 1968). Therefore, one possible explanation for spontaneous recovery is that there is a reduction of output interference on the delayed test. Whichever list is recalled second is more vulnerable to output interference, and this reversal of list precedence may have lowered recall of the target list on the immediate test in a way that was not intended. The procedure used in these two experiments should help to diminish output interference, as subjects will have less reason to think of interfering responses. It is also preferable to MFR (Underwood, 1948b), in which subjects reported the first response (B or C) that came to mind. Since the instructions in Experiments 1a and 1b require subjects to report the B term only, the criticisms of MFR (as outlined earlier) are not problematic in these experiments.

Method

Subjects and design. Experiment 1a was conducted with 80 University of Houston undergraduates who participated in return for partial credit in a lower-division psychology course. In Experiment 1b, the subjects were 80 United States Air Force recruits at Lackland Air Force Base in San Antonio who participated as part of their requirements for basic training.

The design was composed of three factors, all varied between-subjects. They were study condition (control or interference), delay interval (immediate—1 min between study and test, or delayed—16 min between study and test), and experiment (1a or 1b). Therefore, a single analysis was performed on the combined data, with experiment (or subject population) as an independent variable.
Materials. The target items were 12 letter-word pairs. Twelve random letters of the alphabet were each arbitrarily paired with a word that represented one of the pictures in the Snodgrass and Vanderwart (1980) series. In Experiment 1a, the target list was $t$--bread, $p$--balloon, $a$--whistle, $s$--drum, $e$--belt, $d$--cake, $c$--leaf, $q$--anchor, $v$--lamp, $r$--cannon, $k$--ladder, $j$--candle. In Experiment 1b, the target list was $q$--hammer, $j$--shoe, $w$--couch, $v$--scissors, $r$--axe, $a$--cherry, $n$--bicycle, $e$--dog, $k$--snowman, $c$--screwdriver, $m$--basket, $p$--lightbulb. Subjects in interference conditions also received two additional lists of letter-word pairs, in which the same twelve letters were paired with different words, also from the Snodgrass and Vanderwart (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., $a$ could not be paired with anchor). Also, two words that began with the same letter could not be paired with the identical letter on two of the lists (i.e., if $r$--cannon was on the first list, then $r$--comb could not be on another list in the same experiment).

Procedure. The procedures for Experiments 1a and 1b were identical. Subjects were tested in groups of 2 to 10. All subjects in all conditions were informed that they would be presented with a list of 12 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 7 sec per pair, with only a very short break between lists. Subjects were instructed to keep trying to learn the list each of the three times they saw it, even if they believed that they had already memorized it completely.
Subjects in interference conditions heard additional instructions. These subjects were told that after watching List 1, they would see two additional lists, List 2 and List 3, one time apiece. The lists would contain the same twelve letters, but the letters would be paired with different words. Again, subjects were instructed that they should memorize which letters went with which words. They were also told that they should remember which letter-word pairs occurred in which lists.

When all subjects understood their respective instructions, presentation of the A-B list began. The letter-word pairs were presented by a Kodak Ektagraphic slide projector at a rate of 7 sec apiece, which included a .75 sec interval between slides. There was a 20 sec interval between lists in which the experimenter told subjects that they would see the same list another time, and they should keep trying to learn the list as well as possible. After the second presentation, there was another 20 sec delay in which the subjects were again given these instructions. The slides were shown in the same order in each of the three presentations.

After the third presentation, control subjects were given a sheet of arithmetic problems, which were grouped together in pairs. They were instructed to solve the problems, and then circle the problem in each pair that was the most difficult for them to solve. Subjects in interference conditions again had a 20 sec delay between list presentations. During the interval they were told that they had just seen List 1 (which was the A-B list) and that they were about to see List 2 (the A-C list). Subjects were reminded that the list would contain the same twelve letters, but this time they would be paired with different words. They were told to memorize these letter-word associations, and also to remember that these pairs were
occurring in List 2. After the list had been viewed a single time, there was another 20 sec delay in which subjects were reminded that the next list was List 3 (the A-D list), and that they should again try to memorize the pairs, and keep in mind that these pairs were occurring in List 3. The slides in Lists 2 and 3 were also presented at a rate of 7 sec each. The stimuli (the 12 letters) were in the same order in each list.

After subjects in interference conditions viewed List 3 one time, those subjects in the immediate test conditions (whether they had seen the interfering lists or only the control list) were informed that they would take a memory test. They were given a sheet of paper with the twelve stimulus letters listed in alphabetical order. Control subjects were instructed to write down the word that was paired with each letter in the list, next to the appropriate letter. Interference subjects were told to write down the word that was paired with the letter in List 1 only. They were reminded that List 1 was the first list they saw, and it was the list they viewed three consecutive times. These subjects were told that it was very important that they did not write down any of the words from Lists 2 or 3, and that, if they happened to remember any of these words, they should not be written. Subjects were given 2 min to take the cued-recall test, which began 1 min after List 3 was shown, or 5 min 28 sec after subjects in both study conditions had last seen the target list.

These subjects in the delayed test conditions took the identical memory test 16 min after the final interfering list, or 20 min 28 sec after all subjects had last seen the target list. The delay between study and test was filled with subjects doing the arithmetic distractor task previously described. After the cued-recall test, subjects were debriefed and thanked.
Results

Results are presented in Figure 1. From the figure, it is evident that the presence of Lists 2 and 3 depressed immediate recall performance. This interference decreased over time, as subjects in interference conditions showed an absolute recovery over the retention interval. To confirm these results, the data were originally analyzed in a 2 x 2 x 2 ANOVA, with study condition (interference or control), retention interval (immediate or delayed), and experiment (1a or 1b) as between-subject factors. The analysis showed that there was no main effect of experiment on recall scores, and experiment did not interact with any other factor, all F's < 1. Therefore, the data were collapsed over this variable for subsequent analyses.

The ANOVA showed a significant interaction between study condition and time of test, F(1, 156) = 4.90, MSe = 8.99, p < .05. Simple main effects were conducted for each study condition to determine the source of the interaction. There was no effect of delay interval on recall scores for subjects in the control conditions, F(1, 156) < 1, i.e., no significant forgetting over 16 min of arithmetic problems. Subjects who received the interfering lists, however, showed a significant effect of delay interval, F(1, 156) = 5.34, MSe = 8.99, p < .025. Recall scores improved from 7.60 on the immediate test to 9.15 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, since there was no main effect or interaction involving the variable of
Figure 1. Number of B terms recalled as a function of study condition and retention interval. Experiment 1a is on the left, and 1b is on the right.
experiment, the experiments can be considered replications of one another. The experiments show a dissipation of retroactive interference over time, and they are generally consistent with either the response-set suppression hypothesis (Postman et al., 1968) or the unlearning-recovery explanation (Underwood, 1948a; 1948b). Note that spontaneous recovery was "complete", as subjects in the interference conditions recalled as many (or even slightly more) B responses as did subjects in the control conditions. Put another way, there was no evidence of retroactive interference on the delayed test.

Experiment 2 was designed both to replicate and to extend the finding of spontaneous recovery. If spontaneous recovery is caused by a dissipation of response suppression, then it should occur whether or not paired associates are the target materials. If learning a later list causes a prior list to be suppressed, then one should expect similar spontaneous recovery results in a standard free-recall experiment. While the response-set suppression hypothesis could accommodate such a finding, the unlearning-recovery explanation could not. Since there will be no A-B associations formed during study, it is unlikely that associative unlearning will be the driving force behind retroactive interference. Experiment 2 was performed to determine whether retroactive interference and absolute recovery can be observed following the learning of lists of discrete items, rather than pairs of items.

Experiment 2

The goal of Experiment 2 was to replicate the finding of spontaneous recovery with a free recall test. The phenomenon has been found in free recall before (Postman et al., 1968; Martin & Mackay, 1970); however,
these prior experiments still employed the learning-by-anticipation method of paired associations. At test, subjects simply free recalled the response terms, rather than supplying the responses next to the appropriate stimulus term. Although these experiments demonstrated that spontaneous recovery is not dependent upon a cued-recall procedure, they did not eliminate the associative nature of the learning task. Subjects still learned a target list of paired associates, followed by an interfering list. If spontaneous recovery is driven by suppression of the first list, followed by a release of this suppression, then the simple recall of single items should also lead to the effect.

Tulving and Psotka (1971) reported data that support this claim. In their conditions of interest here, subjects studied six consecutive lists of words, then took a final free recall test for all words either immediately after the final list, or following a ten-minute interval. Recall performance on words from Lists 1 through 4 was better on the delayed test, demonstrating spontaneous recovery from retroactive interference.

Experiment 2 was conceptually similar to 1a and 1b. All subjects studied a target list of twelve pictures, then subjects in interference conditions viewed three more similar lists, while the remainder did an arithmetic distractor task. Half of the subjects took an immediate free recall test for the target list, and the other half received this test fifteen minutes later. Spontaneous recovery was predicted for the groups experiencing interference, because the retroactive interference should depress initial recall, and then diminish over time.
Method

Subjects and Design. The 112 subjects were Rice University undergraduates enrolled in lower-division psychology courses. They participated in partial fulfillment of course requirements. The design was a 2 x 2, completely between subjects. The factors were study condition (interference or control) and time of test (immediate or delayed), with 28 subjects serving in each of the four conditions.

Materials. Twelve picture slides from the Snodgrass and Vanderwart (1980) norms were selected as target items. They were fish, airplane, pencil, belt, kite, toothbrush, bicycle, television, piano, broom, saw, sailboat. The three interfering lists were comprised of twelve slides each, drawn from the same source.

Procedure.

The experimental procedure was similar to that of the prior experiments. All subjects viewed a list of slides (List 1) at a rate of 7 sec per slide, which included a .75 sec interval between slides. They saw List 1 twice, with a 15 sec delay between list presentations. During this interval, the experimenter explained that they would see the same list again, and that they should keep trying to remember the names of the pictures in the list. After List 1 had been shown for the second time, control subjects were given the arithmetic distractor task, while interference subjects saw Lists 2, 3, and 4 one time each. Each list was comprised of 12 different pictures, and the lists were presented at the same rate as the first list, again with a 15 sec delay between lists. During each interval, the experimenter told subjects the number of the list that they would see next. Subjects were
reminded that they should try to remember the pictures, and they should also remember which pictures occurred in which lists.

After List 4 was presented to subjects in interference conditions (or 5 min 12 sec after all subjects saw the target list), those half of the subjects in immediate testing conditions heard their test instructions. Subjects in control conditions were asked to write down the names of as many of the twelve pictures as they could in 2 min. Subjects in interference conditions were told to recall the pictures from List 1 only. They were reminded that List 1 was the first list they had seen, and that it was the list that they had watched twice. These subjects were also warned that they should not write down any of the picture names from Lists 2, 3, or 4. The immediate test began 6 min 12 sec after all subjects had seen List 1.

Subjects in the immediate test groups then took their free recall test. After 2 min, the subjects were told to pass their recall sheets to the experimenter, at which point they were debriefed and thanked. Subjects in the delayed test conditions received the identical recall test 15 min after immediate test subjects began their test. This retention interval was filled with the arithmetic distractor task.

**Results**

Means are displayed in Figure 2. Results showed that subjects in interference conditions had poorer initial recall of the target list than subjects who did not view the interfering lists. Spontaneous recovery occurred after interference, as subjects recalled more of the target pictures after the longer interval than the shorter interval. To confirm these observations, the number of target pictures correctly recalled was analyzed in a 2 x 2 ANOVA with study condition and retention interval as between-
Figure 2. Number of pictures recalled as a function of study condition and retention interval in Experiment 2.
subject factors. The overall analysis showed a marginally significant interaction of the two variables, $F(1,108) = 3.19$, $MSE = 5.93$, $p < .08$. Next, simple main effects of retention interval were computed for each study condition. Based on prior results, the directions of these effects were predicted in advance, therefore, the analyses are one-tailed. Subjects in control (non-interference) conditions were expected to show forgetting over time, while subjects in interference conditions should show an absolute recovery over time.

Subjects in control conditions did not show statistically significant forgetting over the retention interval, $F(1,108) < 1$, although their recall scores dropped from 10.6 to 10.0. Subjects in interference conditions showed only marginally significant recovery, with the number of pictures recalled increasing from 8.0 to 9.0, $F(1,108) = 2.53$, $MSE = 5.93$, $p < .07$.

**Discussion**

Results supported the prediction that spontaneous recovery (albeit, marginal recovery) is obtainable in the free recall of lists of single items. Once again, this recovery occurred because of the dissipation of retroactive interference caused by Lists 2, 3, and 4. The results cannot be explained by unlearning-recovery theories (i.e. Underwood, 1948a, 1948b). Since there were no discrete associations being formed between pairs, it is difficult to explain how there could have been experimental extinction occurring during subsequent list learning. This experiment demonstrates that spontaneous recovery can be observed, even without the verbal learning trademark of paired-associate learning.

Results of these first experiments (1a, 1b, and 2) differ from the prior findings in spontaneous recovery research in additional ways. One is the
relatively small amount of interference obtained in Experiments 1a, 1b, and 2, as compared with earlier research. A typical finding in the literature involved substantial forgetting of the target list immediately after interference; often the interference led to a retention loss of greater than 60 percent of control group retention (Forrester, 1970; Postman et al., 1968; Postman et al., 1969). In the experiments presented in this dissertation, interfering lists never led to more than a 30 percent loss. This disparity probably has to do with the experimental instructions. In the anticipation method of learning, subjects had no reason to continue remembering the target list after the learning trials for that list were completed. In some paradigms (especially A-B, A-C), subjects learning a second list were better off if they could not remember the first list, as it could only cause response confusion and proactive interference. In the current paradigm, the original instructions were to remember all of the lists for a subsequent memory test; subjects were not motivated to forget first list responses while learning subsequent lists. This motivational difference is one possible reason for the disparity in the two levels of interference.

While the preceding experiments all led to an absolute recovery of information over time, the effects were small, averaging about 1.2 items out of 12, or 10%. Because the level of retroactive interference was also small, however, subjects did show about as much recovery as was possible. In Experiments 3, the study instructions were changed so that more interference would occur. After learning List 1 (a target list of twelve pictures), all subjects were falsely informed that List 1 was only a practice list, and that their memory for the list would not be tested. Then subjects in interference conditions saw two additional lists. Before viewing each of
these two interfering lists, they were informed that, immediately after seeing the list, they would be asked to write down the names of as many of the second list pictures as they could remember. After subjects saw List 2 and took their recall tests, they were informed that they would repeat this procedure for a third list. Immediately after List 3 recall was complete (or would have been complete, for control groups), half of the subjects took a surprise free recall test for the items in List 1. Other subjects took this test 35 minutes later. (The retention interval was increased to 35 minutes in this experiment. Pilot experiments had shown that spontaneous recovery was at least as evident after 35 minutes as after 15 minutes.)

It was expected that this procedure would produce substantially greater retroactive interference than was found in Experiments 1a, 1b, and 2. Subjects should be motivated to forget the target list while learning subsequent lists, since retaining List 1 could only impair their performance on their tests for Lists 2 and 3. The question of interest was, would subjects still show an absolute recovery for List 1 following retroactive interference?

An additional task was introduced in Experiment 3 for some subjects. Subjects in immediate testing conditions took two tests over the target list; one test immediately followed the interfering lists, while a second, identical test was given after the 35 minute retention interval. This repeated testing procedure is conceptually similar to those used in hypermnesia research (e.g., Erdelyi & Becker, 1974; Roediger & Thorpe, 1978). If there is a dissipation of retroactive interference, then hypermnesia (or improved recall over repeated tests) should result.
Experiment 3

Method

Subjects and Design. Subjects were 152 undergraduates at the University of Houston. They participated as part of the requirements for an introductory psychology course. There were two experimental designs, which were analyzed separately. In the spontaneous recovery analysis, the design was a 2 x 2, completely between subjects. Independent variables were study condition (interference or control) and retention interval (immediate or delayed). For the repeated testing, or hypermnnesia, analysis, a 2 x 2 mixed-factor design was employed. Study condition (interference or control) was the between-subjects factor, while test number (Test 1 or Test 2) varied within subjects. Only subjects receiving immediate tests were considered here.

Materials. A target list of 12 pictures was constructed from the Snodgrass and Vanderwart (1980) series. In order of presentation, the words were foot, butterfly, purse, guitar, clown, wagon, fork, clock, telephone, apple, glasses, sun. Subjects in interference conditions viewed two additional lists of 12 pictures each, selected from the same source.

Procedure.

Subjects were tested in groups of 4-16. The experimenter told subjects that the first part of the experiment had to do with memory, and that they would be shown a list of pictures (called List 1), which they should memorize. Subjects viewed the slides from a slide projector at a rate of 5 sec per slide, which included a .75 sec between slides. The list was presented three consecutive times, with a 15 sec break between presentations, during which the experimenters reminded subjects 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 experimenters told all subjects that List 1 was just a practice list, and that their memory for the list would not be tested. Control subjects were informed that they would have to learn a different list later in the experiment. They were then given the arithmetic distractor test that was used in the previous experiments. Subjects in interference conditions were told that they were going to see another list, List 2, which would be comprised of 12 different pictures. These subjects 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. Subjects viewed the list one time, at a rate of 5 sec per slide, with .75 sec 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. It was stressed that nothing from List 1 should be written.

After List 2 recall, subjects were told that they would see List 3, which again would be comprised of 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 subjects were asked to leave the testing room and wait in another room. (This half had been 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 subjects were warned not to talk about the experiment in any way while they were out of
the room. The remaining subjects comprised the immediate test conditions. They were told that they would take a free recall test for the names of the pictures in List 1. In addition, subjects 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 subjects were given 2 min to recall the picture names. The immediate test occurred 1 min 15 sec after subjects in interference conditions had completed their recall test for List 3 or 7 min 30 sec after all subjects had studied the target list. After the test, the experimenter collected the recall sheets, and brought the rest of the subjects back into the testing room.

All subjects then worked on the arithmetic distractor task, until it was time for the delayed test. All subjects took this delayed test, whether they had taken the immediate test or not, and recall instructions were repeated for all subjects. The delayed test began 15 min after the beginning of the immediate test. When the test was completed, the experimenter collected the test sheets, then subjects were debriefed and thanked. During the debriefing, subjects 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 3. Results showed that Lists 2 and 3 produced a substantial amount of retroactive interference for the target list. There was also a small amount of spontaneous recovery demonstrated by subjects in interference conditions. For those subjects taking repeated recall tests, there was improvement over the retention interval. Subjects in
Figure 3. Number of pictures recalled as a function of study condition and retention interval in the spontaneous recovery and hypermnesia analyses in Experiment 3.
control conditions showed a small decrease in recall performance, while those in interference conditions demonstrated better retention on the second test, as compared to the first.

These findings were confirmed in two separate analyses. The first analysis was conducted on the spontaneous recovery data, using a 2 x 2 analysis of variance, with study condition (interference or control) and retention interval (immediate or delayed) as between subject variables. The overall ANOVA showed a main effect of study condition, $F(1,148) = 88.36$, MSe = 4.72, $p < .001$. There was no effect of retention interval, $F(1,104) < 1$, and the two factors showed a marginally significant interaction, $F(1,148) = 3.49$, MSe = 4.72, $p < .07$.

To determine the source of the interaction (albeit, the marginally significant interaction), simple main effects of retention interval were conducted for each study condition to determine whether or not spontaneous recovery occurred. As in Experiment 2, these effects were conducted as one-tailed tests, with the expectations that control groups would show a decline in recall over the interval, while interference conditions should show an increase. There was a small, but nonsignificant decrease for control conditions, as retention dropped over time, from 10.9 to 10.4. As expected subjects in interference conditions demonstrated better retention after the 35 min interval (8.3 items to 7.5 items). The increase was only marginally significant, however, $F(1,148) = 2.51$, MSe = 4.72, $p < .06$.

Another analysis was performed on the repeated test data. A 2 x 2 analysis of variance was conducted with study condition (interference or control) as a between-subjects variable and test number (Test 1 or Test 2)
as a within-subjects variable. Note that the data comprising Test 1 in this analysis are identical to the data comprising the immediate test conditions in the previous analysis. The overall ANOVA showed main effects of both study condition, $F(1, 74) = 48.62$, $MSe = 7.79$, $p < .001$, and test number, $F(1, 74) = 5.53$, $MSe = 1.07$, $p < .025$. The two variables showed a marginally significant interaction, $F(1, 74) = 3.54$, $MSe = 1.07$, $p < .07$.

To determine the source of the interaction, the simple main effect of test number was computed for both study conditions. For subjects in the control conditions, there was no significant effect of test number, $F(1, 74) < 1$. For subjects in interference conditions, there was a significant increase over time, $F(1, 74) = 4.80$, $MSe = 2.00$, $p < .05$, as recall increased from 7.5 items on the immediate test to 8.2 items on the delayed test.

**Discussion**

There were two different types of memory improvement over time investigated in Experiment 3; one used a pure, between subjects design, and the other employed a within-subjects, repeated measures procedure. Although both comparisons have implications for theories of remembering, it is the between-subjects comparison that is the most relevant to the present investigation of spontaneous recovery; therefore, this discussion will concentrate largely on that set of results.

This experiment differed procedurally from Experiments 1a, 1b, and 2. Subjects were incorrectly led to believe that they would not be tested for the target lists. As expected, this change led to a greater amount of retroactive interference than had been demonstrated in the prior experiments. Like the prior experiments, however, there was only a small
effect of spontaneous recovery. Subjects in interference conditions showed only a .8 item increase over time. Recovery was far from "complete"; at the delayed test, there was still a substantial difference in retention between interference and control conditions.

Taken together, the consistent outcome shows that spontaneous recovery of information can occur over time. The recovery effect in each experiment has, however, been less than robust. In light of these experiments, it is not surprising that researchers often failed to find recovery in the past. It is a small effect, and can be overwhelmed by the variance in memorial capabilities of subjects within each condition.

Despite the size of the effect, it does appear that spontaneous recovery is occurring. Experiments 4 and 5 (described later) were conducted, in part, to look for recovery under conditions that were designed to enhance the effect. Perhaps the most important step that can be taken at this point is to develop a procedure that produces reliable, robust spontaneous recovery, for two reasons. One is that the very details of the new procedure will shed light on the processes that are involved in spontaneous recovery. If the method used in Experiment 3 can be altered, and the alterations lead to a more pronounced effect, then these changes will help our understanding of the conditions that are necessary for recovery to occur.

Second, if a procedure can be developed that leads to robust absolute recovery, then the procedure can be extended to other areas of interest. For example, within the directed forgetting and posthypnotic amnesia literatures, processes similar to suppression have been advocated as explanatory concepts (see Coe, Basden, Basden, Fikes, Gargano, and Webb, 1989). An excellent test of these proposals would be to investigate the
phenomena with a spontaneous recovery paradigm; that is, any decrement in retention caused by instructed forgetting or posthypnotic amnesia should recover over time if temporary suppression is a causal factor.

My explanation for the results of Experiments 1a through 3 implicates a process of retrieval inhibition and the subsequent release from this inhibition as the driving forces behind spontaneous recovery. Within the last ten years, the concept of retrieval inhibition has been advocated in the work of Robert Bjork and his colleagues (Bjork, 1989; Geiselman, Bjork, & Fishman, 1983; Geiselman & Bagheri, 1985). Inhibition, in this sense, refers to a loss of access to certain items that have not yet been permanently forgotten. A response may be considered inhibited if it has been learned and cannot be produced (evidence as to how this can be ascertained will be discussed later). This production failure is only temporary, and is usually caused by some conscious intent to suppress. This explanation is not unlike that endorsed by Postman and colleagues (Postman et al., 1968; Postman et al., 1969). The response-set suppression hypothesis assumed that a selector mechanism influenced response selection during interpolated learning. On an immediate recall test, it was difficult to shift back to the first set of responses; this difficulty was said to diminish over time, and spontaneous recovery of first-list responses was the result.

While this theory is broadly consistent with the results obtained in the first few experiments, there are reasons to doubt the accuracy of response-set suppression in its entirety. One of the central tenets of the hypothesis is that suppression operates upon an entire set of responses, rather than on the individual associations. As Crowder (1976) pointed out, however, pair-specific effects have been found which are not consistent with response-set
suppression. Delprato (1971) presented A-B pairs and then, in a single interpolated list, presented paired associates conforming to either the A-C, or C-D paradigms. The A-C pairs led to greater retroactive interference than C-D (see also Wichawut & Martin, 1971). If the entire set of B responses was being suppressed, then interference should have been equally great for all items.

While suppression may not operate uniformly upon the entire set of first-list responses, the notion of suppression, or inhibition, may still be useful as an explanatory concept for spontaneous recovery. As subjects learn interpolated lists, it is to their advantage to suppress, or inhibit, items learned in the target list. Rather than endorse the presence of a selector mechanism which suppresses List 1 responses, a process of inhibition may operate upon the suddenly "unwanted" items. This process temporarily blocks access to List 1 items, accounting for the retroactive interference which is evident on immediate recall tests. The inhibition diminishes over time, which allows for the absolute recovery of information. Note that this hypothesis does not attempt to explain the results of Delprato (1971) and Wichawut & Martin (1971). The question of whether retrieval inhibition can be item-specific, or list-specific, or some combination of the two, is an important one, but the question will not be addressed directly in this dissertation. The concept of retrieval inhibition, as commonly expressed (Bjork, 1989; Geiselman et al., 1983) does not make a prediction on the issue.

The repeated testing data in Experiment 3 are also consistent with the hypothesis of retrieval inhibition. One would except hypermnesia over the retention intervals, as inhibition dissipates. Postman et al. (1968,
Experiment III) included repeated testing conditions which also showed memory improvement over time following retroactive interference. Of course, the finding of memory improvement over repeated tests is not new, and cannot be considered convincing evidence towards an inhibition hypothesis. The results merely demonstrate that the two groups (immediate and delayed test subjects in interference conditions) likely did not differ in terms of some pre-experimental memory ability. (Subjects in control conditions did not show significant hypermnesia; these subjects likely reached their asymptotic level of recall on the first test.)

While the major goal of the first set of experiments has been to document the presence of spontaneous recovery, another objective will be to make the case for retrieval inhibition as the explanation. While the results so far are perfectly consistent with a retrieval suppression or inhibition hypothesis, there are always other possible explanations. Experiment 4 was designed in an attempt to evaluate some of the other explanations.

In *The Psychology of Learning and Memory*, Hintzman (1974, pp. 352-353) describes six different mechanisms that could produce retroactive interference or, in his terminology, the decreased recall of X, if Y is learned immediately following the learning of X:

1. *Permanent unlearning*--The activity of learning Y partly destroys X.

2. *Temporary inhibition*--The activity of learning Y makes X temporarily inaccessible, but X recovers with time.

3. "*Acid bath*" hypotesis--Highly similar memory traces "eat away" at each other for as long as they coexist in storage (from Posner and Konick, 1966).
4. **Retrieval confusion**--The subject retrieves both X and Y, but cannot discriminate their recencies, to determine which one occurred first.

5. **Blocking**--The subject retrieves Y, which he knows is incorrect, but this prevents or delays retrieval of X.

6. **Altered cues**--The subject establishes retrieval cues during the learning of Y which are inappropriate for X. These persist into the recall test.

The preferred hypothesis so far is the second, the learning of Y (or List 2) makes memory for X (List 1) temporarily inaccessible. The hypothesis is broadly consistent with both response-set suppression and retrieval inhibition ideas. To make a convincing argument, some of these competing explanations must be refuted. As for the first hypothesis, permanent unlearning, the finding of spontaneous recovery demonstrates that permanent unlearning cannot be the sole cause of interference. Since subjects improved their recall performance over time, the information was not permanently unlearned. The "acid bath" hypothesis is no longer viable (see Watkins, Watkins, & Crowder, 1974; Crowder, 1976), and will not be seriously considered here. The fourth explanation, retrieval confusion, cannot be excluded on the basis of the results reported so far, however. In all four of the experiments, interference has been greater on the immediate test than the delayed test. These experiments have not ruled out the possibility that, immediately after receiving interfering lists, subjects are unable to discriminate between lists; in other words, they may remember the correct responses, yet not which list the responses appeared in. Given the instructions, which asked subjects to write down a word only if they
were sure the word had appeared in List 1, confused subjects may have withheld correct responses on the immediate test if they were unsure of list membership. Over time, it may have been this list confusion that dissipated, rather than retrieval inhibition. While it is very doubtful that this has been a serious confound, Experiments 4 and 5 included a control to rule out this alternative explanation.

Hintzman's fifth explanation, blocking, is also a possibility. It has been reported (Postman et al., 1968) that, on immediate MMFR tests, the response term from the interfering list was produced before the term from the first, or target, list. This ordering was often reversed on delayed tests (see also Underwood 1948a, 1948b). Their experiments were designed to minimize output interference by requiring subjects to only report items from the target list. It is still possible, however, that subjects were mentally retrieving responses from interfering lists, which resulted in a blocking of the target list. Though this blocking may also constitute a form of retrieval inhibition (Mueller & Watkins, 1977; Roediger, 1974), it is not the type of inhibition being investigated in this dissertation. The experiments here are aimed at revealing a "suppression-like" inhibition, rather than a general capacity limitation or blocking; this inhibition is largely intentional and is directed at a particular set of stimulus materials. There may be no test between the blocking explanation and a retrieval inhibition explanation. In order to show retroactive interference, obviously some interfering material must be presented. As subjects recall the target list, there is no way to prohibit them from mentally generating the incorrect, or interfering, items. Therefore, the retrieval interference explanation cannot be experimentally refuted. A way to potentially diminish
output interference, however, is to provide subjects with retrieval cues which cannot be completed with any interfering material. Therefore, it is unlikely that items from interfering lists will be generated.

This type of manipulation has been performed in the past and has led to both interference and subsequent recovery. Several researchers have required subjects to learn an A-B list, then a C-D list (Forrester, 1970; McGovern, 1964; Postman et al., 1969; Shulman & Martin, 1970). Although the magnitude of spontaneous recovery of the B terms was not consistent throughout the experiments, at least some numerical recovery was reported in each case (it was significant in Postman et al., 1969, Experiments 1 and 3). It is unlikely that subjects, after receiving the A cues at test, would retrieve the D responses, since A and D were never paired together. Therefore, any interference and recovery that occurred must be mediated by a more general type of interference, and not item-specific interference or confusion.

Hintzman's sixth explanation is alternate retrieval cues. As an example, suppose subjects learn BALL--DANCE in a first, or A-B list. Then the subjects are presented with BALL--SCORE in an A-C list. The first pair might evoke images of a formal ballroom, while the second pair leads the subjects to think about sports. This latter definition of the word BALL might persist into the recall test, thereby depressing subjects' abilities to retrieve DANCE. While this explanation is possible, it cannot explain the large amounts of retroactive interference commonly found in paired-associate paradigms (presumably, most stimulus words are not as semantically ambiguous as BALL). Also, the explanation is not readily
compatible with the finding of interference and recovery in the recall of lists of discrete items.

Experiment 4

While the first four experiments in this series have produced evidence in favor of retrieval inhibition, they have not ruled out the possibility that either a failure of list discrimination or retrieval blocking is behind the effect. Several prior studies have demonstrated that, if subjects can recall a response, they are highly accurate at identifying its list membership (Barnes & Underwood, 1959; Koppenaal, 1963; Postman & Underwood, 1973). In the experiments reported here, however, retroactive interference was 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. Experiment 4 solved this problem by having the target list differ from the interfering list on the basis of the first letter of each item. Target list items began with certain letters (for example, A through L), while interfering items began with the remaining letters (M through Z). At recall, subjects were informed of this fact; therefore, there was no problem of list discrimination; if subjects could recall an item, they knew its list membership.

Another manipulation was introduced in Experiment 4 to try to make the recovery effect more powerful. The target list consisted of 20 words, with 10 items representing each of two categories. At test, subjects were asked to recall the words from one category on the immediate test, and from the other category on the delayed test. Using this method, the recovery analysis was within-, rather than between-subjects. Since there is
a great deal of variance in subjects' abilities to remember, this change will make the analysis more sensitive to recovery.

**Method**

**Subjects and Design.** The 64 subjects were Rice undergraduates enrolled in lower division psychology courses. They participated in partial fulfillment of course requirements. The experiment employed a 2 x 2 mixed-factor design. The between-subjects factor was study condition (interference or control), while retention interval (immediate or delayed) 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 ten exemplars in each category. The target items for the "fruits and vegetables" consisted of words beginning with the letters A through L, while 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, fig. The interfering list was drawn from the same source, except that the exemplars from each category began with the opposite set of letters.

**Procedure.**

The procedure was conceptually similar to that used in Experiment 3. Subjects were tested in groups of 1-6. The experimenter informed subjects that they were to memorize a list of slides (called 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". Subjects were informed that they would view the list three consecutive times, and that 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 sec per slide, which included .75 sec between slides. The list was presented three times, with a 15 sec 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 subjects 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 their memory for the later list would be tested. Then subjects in control conditions were given the arithmetic distractor test, while subjects in interference conditions received instructions for List 2. These subjects were told that they were to study a second list, which was very similar to List 1. Again the list contained 20 items, 10 animals and 10 fruits and vegetables. The experimenter told subjects that they would be given a memory test for the second list immediately following study. It was stressed to subjects 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, subjects 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. Subjects were given 2 min for this test, then the experimenter collected the test sheets.
At this point, all subjects (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. Subjects were told that they were going to take a memory test for List 1, but that they should only report 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.) Subjects 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.

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

The delayed test began 30 min after the beginning of the immediate test. For the delayed test, subjects 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 subjects, including the information about the set of letters which would begin each correct response. Again, subjects were given 1 min for recall. After the test period, subjects were debriefed and thanked.
Results

Means are graphed in Figure 4. Results showed that learning List 2 substantially decreased recall of List 1. While subjects in control conditions showed a slight drop in retention from the immediate to the delayed test, subjects in interference conditions showed increased recall over the retention interval.

These findings were confirmed in a 2 x 2 analysis-of-variance, with study condition as a between-subjects factor, and retention interval as the within-subjects variable. The overall ANOVA showed a significant interaction between the two factors, $F(1,62) = 9.30$, MSe = 1.78, $p < .005$. The simple main effect of retention interval was computed for both study conditions. Subjects in control conditions did not show a statistically significant difference in recall across the two tests, $F(1,31) = 1.95$, MSe = 0.95, $p > .2$, as their scores dropped from a mean of 7.4 items on the immediate test to 7.1 items on the delayed test. Subjects in interference conditions showed a significant absolute recovery, $F(1,31) = 7.77$, MSe = 2.60, $p < .01$. Mean recall improved from 4.5 items to 5.6 items over the retention interval.

Discussion

Once again, spontaneous recovery was demonstrated. This experiment, however, ruled out at least one explanation of the effect. Experiments 1a through 3 could be criticized because subjects in interference conditions may have had a difficult time assigning list membership to retrieved items, and any absolute recovery could have resulted simply because of a dissipation of their list confusion. Experiment 4 eliminated list confusion as a possible confound by discriminating between target and interpolated
Figure 4. Number of words per category recalled as a function of study condition and retention interval in Experiment 4.
items on the basis of their first letter. The recovery effect was, numerically, roughly equivalent to that obtained in previous experiments.

Another feature of Experiment 4 proved to be useful; recovery was assessed in a within-, rather than a between-subjects design. This made the analysis more sensitive to changes in recall level over time. Related to this point is the fact that fewer subjects were required to complete the experiment. Future experiments in this dissertation were, therefore, designed so that recovery could be assessed within subjects.

Experiment 5 was conceptually similar to Experiment 4. Since the within-subjects analysis seems to be the ideal way to test for spontaneous recovery, the procedure was used to replicate Experiment 4 with paired associates, rather than discrete items, as stimulus materials. Although paired-associate learning has already led to recovery (in Experiments 1a and 1b), it was desirable to replicate the finding using the new, improved procedure. For the immediate test, subjects were presented with half of the stimulus terms and asked to produce the appropriate response terms. After a half-hour delay, subjects were tested for the remaining pairs. It was expected that there would again be substantial retroactive interference, followed by recovery.

**Experiment 5**

**Method**

**Subjects and Design.** Subjects were 40 Univeristy of Houston undergraduates enrolled in an introductory psychology course. They participated in return for course credit. The experiment employed a 2 x 2 mixed-factor design. The between-subjects factor was study condition
(interference or control), while retention interval (immediate or delayed) varied within subjects.

**Materials.** The target and interfering lists each consisted of 20 letter-word pairs. (Materials are reproduced in the Appendix.) All of the words represented pictures in the Snodgrass and Vanderwart (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: *b--chicken, c--needle, d--bottle, e--cloud, f--pliers, g--belt, h--lightbulb, j--airplane, k--toaster, m--piano, n--television, p--door, q--tie, r--cannon, s--toothbrush, t--padlock, v--kite, w--sled, x--trumpet, z--leaf.*

**Procedure.** The procedure was generally similar to that of Experiment 4. Subjects were tested in groups of 5 to 10. All subjects 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 sec per pair, with only a very short break between list presentations. Subjects were instructed to keep trying to memorize the associations each of the three times they saw them, even if they believed that they had already memorized them completely.

The letter-word pairs were then presented by a Kodak Ektographic slide projector at a rate of 5 sec apiece, which included a .75 sec interval between slides. There was a 15 sec 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 subjects were told that the list they had just seen was only a practice list. The experimenter said that they would study another list later in the experiment, in which the same twenty letters would be matched with different words, and that they would then be tested over the second list only. Subjects in control conditions were then given the arithmetic distractor task. Subjects 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 very important that they did not write down any of the words from List 1.

Subjects in interference conditions were then presented with List 2, under the same conditions in which they had studied List 1. The twenty letters were shown in the same order on both lists. After the third list presentation, subjects were given a sheet of paper with all twenty letters listed alphabetically. They were instructed to write the word which was paired with each letter in List 2. They were reminded that it was very important that they not write the words from List 1. Subjects were given two-and-a-half minutes for this test, then their test sheets were collected.

At this point, all subjects were given their instructions for a test of List 1. Each subject was given a sheet of paper, with ten of the twenty 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, while those paired with words beginning with M through Z appeared on the others. Subjects were told that they were to write the name of the word that was paired with each letter in List 1 only. 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.) Subjects 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, based on its first letter. Subjects were given 1 min 15 sec for the test, which began 1 min 30 sec after the end of the test for List 2, or 12 min 30 sec after all subjects had studied List 1.

Following the first test, the response sheets were collected. All subjects then worked on the arithmetic distractor task. Instructions for the delayed test were identical to those given for the immediate test. Again, subjects were given a sheet of paper with one-half of the letters listed alphabetically. Each subject received the ten 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 that set which had been correct on the immediate test. Subjects were given 1 min 15 sec for the test, which began 31 min 30 sec after the end of the test for List 2, or 42 min 30 sec after all subjects had studied List 1. Upon completion of the test, all subjects were debriefed and thanked.
Results

Basic data are reproduced in Figure 5. List 2 produced a substantial amount of retroactive interference for List 1. Subjects in control conditions performed better on the first test than the second, displaying forgetting over time. Subjects in interference conditions improved over time, showing spontaneous recovery.

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

Discussion

Experiment 5 replicated the finding of spontaneous recovery in a within-subjects analysis, this time with paired-associates as the stimulus materials. Although Experiments 1a and 1b also demonstrated the recovery of paired associates, the within-subjects design is clearly preferable. Over the first several experiments, a procedure has been developed which leads to the absolute recovery of information over time. Although all of the experiments so far have demonstrated at least numerical recovery, the
Figure 5. Number of response terms recalled as a function of study condition and retention interval in Experiment 5.
procedures have gradually improved; by Experiment 5, there was a statistically robust effect of recovery with only 40 subjects tested. In contrast, recovery in the combined Experiments 1a and 1b barely reached statistical significance, despite the data of 160 subjects. There were two changes that, together, led to this methodological improvement. Although neither of these factors was examined directly within a single experiment, cross-experiment comparisons support the idea that they strongly facilitated the likelihood of showing recovery over time.

One involved the motivation of subjects to inhibit, or forget, the target list. In Experiments 1a, 1b, and 2, the instructions required subjects to keep remembering the target list during interpolated learning. In retrospect, it is not surprising that there was a relatively small effect (about 20%) of retroactive interference produced by interpolated lists. Experiments 4 and 5, however, gave subjects motivation to forget the target list, as it was either implied or explicitly stated (in Experiments 4 and 5, respectively) that memory of the target list would only hinder the learning of later lists. In these experiments, retroactive interference averaged over 50%.

This outcome has implications for spontaneous recovery in at least one important way. For information to show recovery over time, it must "recover" from some negative influence, such as interference, counterconditioning, or extinction. (While this point may not have been made explicitly in the past, it is consistently implied within all proposed theories of the phenomenon, including Estes, 1955; Postman et al., 1968; Underwood, 1948b.) Clearly there is the greatest opportunity for recovery
following a large amount of retroactive interference; stated differently, the
greater the decrement, the more that can be potentially regained.

There was one additional procedural change which allowed for a
greater effect of recovery. By switching from a between- to a within-
subjects design, the statistical test for recovery became more powerful.
Although this is a sufficient reason to employ the within-subjects analysis,
the change may have had another beneficial effect. If spontaneous recovery
occurs because of a dissipation of retrieval inhibition, then it is possible that
the presence of the immediate test might hasten the dissipation of inhibition.
In other words, once subjects are instructed to recall target items, they have
strong motivation to overcome any prior suppression. This might help to
"lift" the inhibition on the delayed test. While this hypothesis is admittedly
speculative, it is a logical possibility. Since the motivation to inhibit the
target list helps to create retroactive interference, motivation to remember
half of the target list might make the other half of the list more easily
recallable.

To repeat, the preferred explanation for the results of the first several
experiments implicates a process of retrieval inhibition. So far, in both this
dissertation and in previous research, retrieval inhibition has been
investigated using explicit memory tests, usually free or cued recall.
Experiment 6 was designed to look for retroactive interference and/or
spontaneous recovery on an implicit, word-stem completion task. The
study procedure was very similar to that used in Experiments 4 and 5. At
test, subjects were given an implicit stem-completion task rather than a
recall test. The experiment was performed in an attempt to extend the
phenomena of inhibition and recovery to retention tests other than explicit
tests. The finding of interference in word-stem completion would also be interesting in its own right, because others have failed to find such effects (e.g., Sloman, Hayman, Ohta, Law, & Tulving, 1988; but see Graf & Schacter, 1987).

Experiment 6

Method

Subjects and Design. Subjects were 48 United States Air Force recruits at Lackland Air Force Base in San Antonio who participated as part of their requirements for basic training. A 2 x 2 mixed-factor design was employed, with study condition (interference or control) as the between-subjects factor, and retention interval (immediate or delayed) as the within-subjects factor. The stem-completion test was counterbalanced so that each word was a possible completion in the immediate and delayed test an equal number of times in each condition.

Materials. Two different target lists, List A and List B, were constructed, with 16 words in both lists. The words were selected from the materials used by Roediger, Weldon, Stadler, and Riegler (1992). Two distractor lists, also comprised of 16 words, were also selected from the Roediger et al. materials. None of the words selected shared the same initial three letters.

Procedure. Subjects were tested in groups of 12. At the beginning of the experiment, subjects took part in an initial word-stem completion task, which was intended to acquaint subjects with the procedure, and also make them less "suspicious" of the later completion tasks. First, the experimenter passed out a sheet of word stems which were obscured by two blank sheets of paper. Subjects were instructed that they were to lower the cover sheets
when instructed, to reveal the first stem. They were told that they would have 12 seconds to complete the stem with a common, English word, and they that should write down the first appropriate word that came to mind. The experimenter told subjects that, after 12 seconds, they would be told to lower the cover sheet and advance to the next word stem. Subjects were warned not to go back to any stem that they had left unanswered. When all subjects understood the instructions, the word-stem completion task began.

At the completion of the test, subjects passed their papers to the experimenter. They were then told that they would see a list of words, presented from a slide projector, and that they should attempt to memorize the words. Subjects viewed the list of 16 words twice, with a 15 sec delay between presentations. The slides were presented at a rate of 5 sec per slide, which included a .75 sec delay between slides. After the second presentation, subjects were told that they had just seen List 1, and that List 1 was only a practice list. Subjects in control conditions worked on the arithmetic distractor during this time. Subjects in interference conditions were informed that they would then see List 2, which would also consist of 16 words, presented at a rate of 5 sec each. They were told that, immediately following the presentation of List 2, they were to write down as many List 2 words as they could remember. They were warned that words from List 1 should not be reported on the memory test. After viewing List 2 a single time, subjects in interference conditions were given 90 sec to write down as many of the words as they could remember. The experimenter told subjects to turn their recall sheets face down inside their desk. Then subjects were instructed that they would be presented with List 3, and their instructions for List 3 were identical to the instructions for List
2. After viewing List 3, they were given 90 sec to write down all the words they could remember from List 3 only. Subjects then passed their recall sheets from Lists 2 and 3 to the experimenter. After viewing List 1, subjects in control conditions were told that they would study a different list at a later time in the experiment; they were then given the arithmetic distractor task.

When the memory test for List 3 was completed (or would have been completed, in control conditions), subjects received another word-stem completion test. Subjects were told that the instructions were identical to the last completion test, and they were reminded to complete each stem with the first appropriate word that came to mind. There were 29 stems on the test, with the first five stems serving as buffer items. Of the remaining 24 stems, eight led to possible completions for words from each of the two target lists. (There were two target lists, or List 1's, and half of the subjects saw each one.) The other eight items were fillers, which could not be completed with words on any of the study lists. Therefore, only eight of the 29 stems could be completed with "old" words. After passing these sheets to the experimenter, all subjects worked on the arithmetic distractor task.

Subjects began their delayed word-stem completion test 20 min after the beginning of the immediate test. Again, there were 29 stems on the test, with the first five stems serving as fillers. The eight "old" words which had not been tested on the immediate test were included in the remaining stems. At the end of the completion test, subjects passed their sheets to the experimenter, and were then debriefed and thanked.
Results

Means are depicted in Table 2. Results showed that the only effect was overall priming. There was no interference demonstrated on word-stem completion performance (actually, greater priming was demonstrated in interference conditions). Also, priming did not change over the retention interval. These observations were confirmed in a 2 x 2 x 2 ANOVA with study condition as the between-subjects factor; retention interval and priming (primed vs. nonprimed words) as within-subjects factors. The overall analysis showed a main effect of priming, $F(1, 46) = 44.40$, MSe = .033, $p < .001$. No other main effects or interactions reached significance (largest $F(1, 46) = 2.70$, $p > .10$).

Discussion

Experiment 6 demonstrated that the same manipulation (albeit, with slightly different materials) which produced substantial interference in free recall had no effect on word-stem completion. Results add converging evidence to the claim that recall and stem completion rely on different processes (e.g., Roediger, 1990). More importantly for the present project, the results demonstrate a limitation of retroactive interference. That is, the same basic conditions which create substantial retroactive interference on explicit, free recall tests had no effect on the implicit, stem-completion test. The data could be handled by referring to the distinction between the conceptual nature of study, and the perceptual nature of word-stem completion, as compared to the conceptual aspects of free recall. One could also explain the results by positing multiple cognitive representations of the target list items (e.g., Tulving & Schacter, 1990); at least one of the
Table 2

Proportions of word stems successfully completed in Experiment 6

<table>
<thead>
<tr>
<th>Condition</th>
<th>Prime</th>
<th>Retention Interval (Mins.)</th>
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representations was suppressed by the interference, while another (perhaps in the word form system) was not suppressed.

**RELEASE OF INTENTIONAL FORGETTING**

The prior experiments have used a spontaneous recovery paradigm, and have implicated retrieval inhibition as a possible explanatory construct. The paradigm is useful, for it allows one to look at (1) the level of retroactive interference, and (2) the fate of this interference over time. If there is a large amount of interference on immediate tests, and it abates over time, then this is excellent evidence for the existence of temporary retrieval inhibition. It could be argued that this interpretation is circular; since the effect involves a temporary drop in retention, a hypothesis of temporary retrieval inhibition does little more than rename the phenomenon. What is needed is some converging evidence to support the idea of inhibition. Experiment 7 was conducted to apply the spontaneous recovery paradigm to another line of research, directed forgetting, whose explanation has also involved retrieval inhibition (e.g., Bjork, 1989).

In directed forgetting experiments, subjects are instructed to forget items they have recently learned, before learning new items. The instructions have at least two interesting effects on later recall (Bjork, 1972; Epstein, 1972). First, if subjects are asked to recall the to-be-forgotten (TBF) items, their performance is significantly impaired, even though they originally studied the items with the intent to learn them (Bjork & Woodward, 1973; Davis & Okada, 1971; Weiner, 1968). This impairment is not evident on recognition tests, however. The other effect of intentional forgetting is that the TBF items do not create proactive interference for new, intentionally remembered items (Bjork, 1970).
The most prevalent theory that has been advanced to explain directed forgetting has been a "selective rehearsal" hypothesis (Bjork, 1970; MacLeod, 1975; Reitman, Malin, Bjork, and Higman, 1973). The most basic version of the theory suggests that all items are rehearsed upon presentation but rehearsal is discontinued for TBF items when the forget cue is presented. Presumably, the time that subjects would have spent on TBF items is, from that point, devoted to rehearsing the TBR items.

Although the theory is surely correct at some level (subjects do rehearse TBR items more than TBF items), it seems insufficient as an explanation for the size of the effect. Immediate recall of TBF words is often less than twelve percent, with TBR items being recalled at least six times this well (Bjork & Woodward, 1973; Davis & Okada, 1971; Woodward & Bjork, 1971). Selective rehearsal of TBR items is probably not a powerful enough strategy to fully explain the magnitude of this effect. Another line of evidence arguing against a selective rehearsal hypothesis is the finding that the recognition of TBF items is equal (or nearly equal) to that of TBR items (Block, 1971; Elmes, Adams, and Roediger, 1970; but see Davis and Okada, 1971).

Recently, retrieval inhibition has been implicated as a factor in directed forgetting. Geiselman and Bagheri (1985) proposed that the forget cue initiates an inhibition or blocking to the items in memory. This idea was endorsed by Bjork (1989), who argued that inhibition is an adaptive process. When subjects believe that they no longer need to remember information, they are capable of suppressing, or inhibiting, the information to reduce interference. Evidence for this position is discussed in Bjork (1989). Researchers have begun to look for a "release" from retrieval
inhibition in directed forgetting experiments. Bjork (1989) and Basden, Basden, and Gargano (in press) reported results in which the re-exposure of TBF items in a recognition test has overridden or released these items from inhibition. This release is evidenced on a subsequent free recall test, which showed no effect of directed forgetting.

These experiments are useful, as they demonstrate that inhibition can be overcome through cues in the environment. It is proposed, however, that retrieval inhibition is only a temporary phenomenon, and should dissipate over time (as was discussed after Experiments 3 and 5, above), even without any impetus from the environment. A similar idea was advanced to support the theory of response-set suppression (Postman et al., 1968). Postman's selector mechanism was said to favor the most recent list over the prior "suppressed" list during interpolated learning. The inertia operating upon the selector mechanism was limited, however, and list dominance was reversible. Similarly, retrieval inhibition should be a reversible phenomenon. Over time, intentionally forgotten items should recover.

The way to test this hypothesis is with a spontaneous recovery paradigm. There is one study directly relevant to this issue, and its results were inconsistent with a retrieval inhibition hypothesis. MacLeod (1975) had subjects study a categorized-word list (items were presented in blocks of categories, along with the category name). After studying each category, subjects were told whether to remember or forget the category. A category-cued recall test was administered either immediately or following a one-week retention interval. Retention of both TBF and TBR words decreased over the interval, and the interaction of study instructions
(TBR vs. TBF) and retention interval was not significant. Therefore, no evidence of even relative recovery was demonstrated, which is not consistent with the presence of a temporary, "suppression-like" inhibition. (In this dissertation, the terms "suppression" and "inhibition" are used as synonyms, although their precise definitions may vary slightly in the literature.)

Despite this finding, MacLeod's experiment may not have been a fair test of the retrieval inhibition hypothesis. (Note that it was not designed to test this hypothesis.) Subjects were given powerful semantic cues to facilitate recall and these cues may have, to a great degree, released any inhibition (as in Tulving & Psotka, 1971). Recognition tests, which also have strong cues, might similarly release inhibition. The immediate test also showed a relatively high rate of retention of TBF items (approximately .35), which is substantially higher than the rate found by other researchers (Bjork & Woodward, 1973; Davis & Okada, 1971; Woodward & Bjork, 1971).

Experiment 7 was designed to investigate the fate of TBF items within a spontaneous recovery paradigm. As Experiments 1a through 5 attest, absolute recovery is not easily obtained; therefore, the experimental procedure was designed to capitalize on the knowledge of spontaneous recovery that was gained from the first several experiments. Basden et al. (in press) present evidence that retrieval inhibition is responsible for directed forgetting only when items are cued by whole lists or sets, rather than on an item-by-item basis in Experiment 7. Subjects learned a number of items, and then received a cue instructing them to forget the recently studied items. Next, they memorized additional items, under the false
belief that items before the cue would not be tested. On an immediate test, subjects were cued to recall one-half of the studied items. The items requested for recall, however, consisted equally of items from before and after the 'forget' instruction (TBF and TBR items, respectively). Other items were cued for recall on the delayed test.

Clearly, this design is very similar to that used in Experiments 1a through 5; this similarity is intentional. The primary difference between Experiment 7 and Experiments 1 through 5 is that, at test, subjects were asked to recall items from both before and after the 'forget' cue, while in previous experiments, only the first, or target, list was recalled. This design permits examination of the fate of both TBF and TBR items at the two retention intervals. If there is a temporary retrieval inhibition operating upon items in the first-half of the list, then they should be poorly recalled on the immediate test, and recover on the delayed test.

Experiment 7

Subjects and design. Subjects were 36 Rice undergraduates enrolled in lower-division psychology courses. They participated in exchange for partial course credit. The design was composed of two factors, both manipulated within subjects. They were word type (TBR or TBF items) and retention interval (immediate--1 min between study and test, or delayed--31 min between study and test).

Materials. The target items were 40 words, with 20 words from the category "animals" and 20 from the category "fruits and vegetables". Exemplars were taken from the Battig and Montague (1969) norms; none of the words were taken from the first ten exemplars in their category. The list was divided into two groups, with ten items from each category in
a group. One group of words was: artichoke, kumquat, turnip, strawberry, watermelon, coconut, squash, fig, mushroom, eggplant, wolf, weasel, chipmunk, squirrel, turtle, aardvark, hippopotamus, fox, goat, panther. The other was: canteloupe, radish, nectarine, blueberry, avocado, cucumber, prune, onion, raisin, beet, walrus, zebra, raccoon, buffalo, camel, llama, donkey, badger, otter, rabbit.

Procedure. Subjects were tested in groups of 1-6. The experimenter began by explaining the directed forgetting procedure. Subjects were told that they would hear a series of lists from a tape recorder and that, immediately after each one, they would take a memory test for the list. They were informed that in the middle of each list there would be a cue which would tell them what to do with the items in the first half of the list. If the cue was, "Remember those items", then subjects were to keep remembering all of the items in the first half of the list, and also memorize the second half of the list, in anticipation for a recall test over the entire list. If the cue was, "Forget those items", then the subjects were told that they should try to forget the first half of the list. The experimenter instructed them to try to "block the first half of the list out of your mind" while studying the second half of the list. Subjects were told that, following these "Forget" lists, they would be tested for their recall of the second half of the list only. The experimenter warned them that it was very important that they not report any items from the first half of the list. Subjects were instructed that their memory of the second half of the list would be better to the extent that they could forget the first half of the list, as the first half items would only create interference and confusion. The experimenter told them not to guess which lists contained "Remember" cues and which had
"Forget" cues. Instead they were told that they should attempt to memorize each item as they heard it. Then, if they heard the "Forget" cue, they were to suddenly begin trying to forget, or "block out" the first half of the list.

There were two practice lists before the target list. Subjects were told that the first list was composed of 16 two-digit numbers, and that after the eighth number, they would hear the "Remember" or "Forget" cue. After all subjects understood the instructions, the list began. The numbers were played from the tape recorder at a rate of one number every five seconds. (This is the rate at which subjects heard all of the lists in this experiment.) After the eighth item, subjects heard the cue, which was always "Remember those items" in the first list. At the end of the list, subjects were each given a sheet of paper and instructed to recall as many of the 16 numbers as possible within 1 min 30 sec.

After the first practice test, subjects were told that they would hear another list, for which the instructions were the same. The experimenter informed them that the second list was composed of 24 items, and the items were names of objects that could be found "on or around a house" (window, lamp, etc.). The subjects were told that, to help them learn more of the items, they would hear the list twice. The twelve items in the first half of the list would be presented, and then, the first half would be presented again, in a different order. Then subjects would hear the cue telling them whether they should continue remembering the first twelve items, or suddenly begin trying to forget them. After the cue, the second half of the list would be heard, again twice, and in a different order each time.
Subjects listened to the second list, which always contained a cue instructing them to forget the first half of the list. Then subjects were given a sheet of paper on which they were told to recall as many items as possible from the second half of the list. They were warned not to report anything from the first half of the list. Subjects were given 1 min 30 sec for this recall test.

After the recall period, the experimenter collected the test sheets and told subjects that they would listen to a third list. This list was said to be composed of 40 items, of which 20 were animals and 20 were fruits and vegetables. To prevent any list confusion, subjects were informed that none of the items in the previous lists had been animals, fruits, or vegetables. The experimenter told subjects that they would hear the first half of the list three times in a row, but in a different order each time. This would be followed by a cue, that would instruct subjects whether to remember or forget the first 20 items. Subjects were reminded that, if they heard a "Forget" cue, they should try to "block out", or forget the first half of the list. Failure to do so, they were told, would create confusion, especially since all of the items came from only two categories. Then the experimenter told them that they would hear the second half of the list, again three times, and in a different order each time. When subjects understood the instructions, they listened to the target list, which always contained a "Forget" cue.

The target list had been divided into two groups of 20 words, with each group containing 10 animals and 10 fruits and vegetables. The list presentation was counterbalanced so that each group of items served as the first half of the list for one half of the subjects. After studying the list,
subjects were given a sheet of paper with one of the categories, "animals" or "fruits and vegetables" written at the top. The experimenter told them that their instructions would be different for this test. Subjects were instructed that, instead of recalling the second half of the list, they were to attempt to recall of the items from the category which was written at the top of their recall sheet. They were told not to worry if the items came before or after the forget cue; they were simply to report of many of the twenty items as they could in any order. The immediate test began 1 min after completion of the study period. Subjects were given two-and-a-half minutes for the recall test. Then the test sheets were collected, and subjects worked on the arithmetic distractor task.

The delayed test began 31 min after the study period. Subjects were again given test sheets with one of the category names written at the top. They were always tested over the category that they had not previously recalled. Again, the experimenter told subjects that they should write down as many members of the category as possible in the 2.5 min, regardless of whether the items appeared before or after the cue. Following this delayed test, all subjects were debriefed and thanked.

Results

Data were scored in terms of the number of TBR and TBF items recalled. Items occurring in the first half of the list (before the "Forget" cue) were considered TBF items, while those in the second-half of the list were designated as TBR items. Basic data are reproduced in Figure 6. On the immediate test, subjects recalled a greater number of TBR than TBF items. By the delayed test, however, this TBR advantage had vanished, and TBF items were slightly better recalled. There was a decrement in TBR
Figure 6. Number of words per category recalled as a function of word type and retention interval in Experiment 7.
retention over the retention interval, while TBF recall showed a small improvement.

These findings were confirmed in a 2 x 2 within-subjects analysis of variance, with word type (TBF or TBR) and retention interval (immediate or delayed test) as factors. The overall ANOVA showed an interaction of these two variables, $F(1, 35) = 17.39$, MSe = 2.62, $p < .001$, which demonstrates that at least relative recovery occurred for TBF items. The simple main effect of test was computed for both word types. TBR items were forgotten over the retention interval, $F(1, 35) = 35.81$, MSe = 1.79, $p < .001$, as the mean number recalled dropped from 8.0 items to 6.1 items. TBF items demonstrated a nonsignificant increase in retention across the interval, $F(1, 35) < 1$. Recall improved from 6.0 items on the immediate test to 6.4 items on the delayed test.

Discussion

The results gave limited support to the hypothesis that intentionally-forgotten items spontaneously recover over time. While the overall effect of recovery was small and not did not reach statistical significance, there were two signs that recovery was occurring, at least in some subjects. One is the presence of relative recovery, as defined by Brown (1976). While recall of TBF items increased only slightly over time, this pattern was markedly different from that of TBR items, which showed a substantial decrease over the retention interval. Since normal forgetting is presumably operating upon the entire study list, the fact that TBF items items showed no overall decrease in retention over time is evidence that some positive process was occurring simultaneously to offset normal forgetting.
Another piece of evidence comes from a fact noticed during data analysis: not all subjects demonstrated the basic directed forgetting effect. In other words, many subjects showed an equal or slightly greater recall of TBF items as TBR items on the immediate test. Since the superior recall of TBR items to TBF items on an immediate test is an often-replicated phenomenon, many of the subjects must have been either unwilling or unable to produce the effect. This point is crucial to the current experiment because, if a subject does not demonstrate directed forgetting, it is very unlikely that the subject can "spontaneously recover" the TBF items. In other words, there must be some initial decrement in retention from which subjects can recover. It may be that subjects who did not show the basic directed forgetting effect prevented recovery of TBF items from reaching significance.

Again, although there was an overall effect of directed forgetting on the immediate test, the size of this effect varied greatly among subjects. This variability is especially likely with the list-method of directed forgetting; following the word-by-word method, virtually all subjects show directed forgetting, because of differential rehearsal of TBR and TBF items. This variability is consistent with prior findings in the literature (B. Basden, personal communication), but it is particularly important in this experiment, because without impaired retention of TBF words, it is unlikely that they could recover over time. The best way to "solve" a problem of this nature is to, in the future, create an experimental procedure which influences all subjects to show inhibition (or at least interference) on the immediate test. Given this situation, all subjects have the potential to show spontaneous recovery.
GENERAL DISCUSSION

This dissertation was performed to investigate several questions about spontaneous recovery. First, can the phenomenon be reliably demonstrated in human memory research? The answer appears to be yes. In all of the experiments that used explicit tests of memory, some absolute recovery occurred. While the statistical significance of the effect varied from experiment to experiment, evidence for the reliability of recovery is strong owing to the repeated finding of at least numerical improvement in retention 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 support the Brown conclusion, because spontaneous recovery has now been demonstrated in several new paradigms.

Recent experiments from the animal learning literature provide converging evidence for spontaneous recovery. In a counterconditioning experiment performed with rats, Bouton and Peck (1992) employed an A-B, A-C paradigm by pairing a conditioned stimulus (a tone) with two successive conditioned stimuli (a positive stimulus--food, and a negative stimulus--shock). When the "interpolated" (or C) stimulus was presented, there was quick extinction of the responses that had been learned with the "original" (or B) stimulus. After four weeks, however, the original (B) responses had recovered, while interpolated (C) responses had greatly diminished. The Bouton and Peck study provides a nice analog to the typical verbal learning results, in which there was a reversal in list dominance over time (Postman et al., 1968).
Recovery has also been demonstrated under very different experimental conditions. Using the Sternberg paradigm, Wright, Santiago, Sands, Kendrick, and Cook (1985) documented the effect in pigeons, monkeys, and humans. All subjects viewed lists of four complex pictures and then made a yes-no recognition decision on a single probe item. For items occurring in the first serial position, recognition on an immediate probe trial was close to chance; with increasingly longer delays (on the order of seconds), the first item showed recovery (e.g., was more likely to be recognized). Once again, there was absolute recovery of primacy over time, although in the Wright et al. (1985) study, it was the first item, rather than the first list which benefitted from the passing of time.

Given that spontaneous recovery is reliable, it is important to delineate the conditions that produce the effect. The following conditions are all either necessary to obtain spontaneous recovery in human memory experiments, or at least to increase the probability of doing so:

1. Some substantial decrement in target-list retention. In order for information to recover over time, it is necessary to drive down retention through some experimental manipulation. This point was first made by Underwood (1948b), who suggested that the recovery of verbal associations is comparable to that of extinguished conditioned responses. In traditional verbal learning experiments, retroactive interference (i.e., learning A-C after A-B) served to decrease recall of the target list. In this dissertation, it was discovered that the retroactive interference is much more powerful if accompanied by a false instruction to subjects, implying that target list items will not be tested. While this point was not tested directly within a single experiment, cross-experimental comparisons give it strong support.
Retroactive interference was much greater in Experiments 3 through 5, than in Experiments 1 and 2 (in which subjects were never given any motivation to forget the target list).

2. A relatively small amount of extra-experimental forgetting between the immediate and delayed tests. Spontaneous recovery is a counterintuitive phenomenon precisely because it is seemingly at odds with the typical finding of forgetting over time. It is still the case, however, that the processes involved in forgetting are operating upon target-list items, even as they are "recovering". Therefore, absolute recovery can be overwhelmed by conditions under which there is a substantial amount of extra-experimental forgetting during the retention interval. This point has been noted previously by Postman et al. (1968). They examined prior studies and compared the presence of absolute recovery to the amount of forgetting demonstrated by control groups (i.e., those which learned only A-B). The authors found a direct relationship; if control groups showed a substantial drop in retention from the immediate to the delayed test, then absolute recovery for interference groups (i.e., those that studied A-B followed by A-C) was unlikely. For many of the studies which failed to show recovery, great extra-experimental forgetting is the likely reason.

Interestingly, it is not the case that spontaneous recovery depends upon a high degree of original learning of the target list, contradicting Postman et al. (1969). In Experiment 5, subjects in control conditions barely recalled over half of the target items on the immediate test. Despite the surprisingly low level of performance, there was only about a 20% drop in retention on the delayed test; more importantly, subjects in interference conditions demonstrated robust (over 50%) recovery over the same
interval. This finding reinforces the conclusion that a relatively small amount of extra-experimental forgetting is important, while a high degree of original learning is not.

3. Use of a within-, rather than a between-subjects, design. Although significant absolute recovery has been found numerous times in between-subjects analyses, the increased experimental power gained by making the comparison within subjects is surely beneficial. Since spontaneous recovery can be a small effect, the more sensitive the test, the better. While this finding is of methodological, rather than theoretical, importance, it may prove to be critical for any new investigations into spontaneous recovery. Virtually all spontaneous recovery experiments within the verbal learning tradition employed between-, rather than within-subjects, designs. If the within-subjects analysis had been used, the phenomenon would have been much easier to demonstrate, and might have led to a greater amount of research on the topic. Also, as described previously, the very presence of the immediate test might enhance retention on the delayed test, possibly by helping to "lift" retrieval inhibition.

Although this idea has not been (and will not be) tested directly in this dissertation, it can be examined empirically. Two groups of subjects could study paired associates under conditions identical to those in interference conditions in Experiment 5. One group would receive an immediate cued recall test for one-half of the target list, while the other would not. After some retention interval, all subjects would be tested over the other half of the items. If the immediate test has a beneficial effect on the later test, then there should be a "testing effect" (Glover, 1989). That is, subjects should recall more items on the delayed test if they have taken a prior test for the
target list, even if nonoverlapping items are cued on the two tests. While this research question is not immediately relevant to the research questions at hand, it could be a useful experiment later.

4. Length of the retention interval. While the experiments in this dissertation have not systematically manipulated the retention interval, it is almost surely the case that absolute recovery is only observable under a relatively specific range of intervals. As mentioned before, the interval must be short enough to preclude substantial extra-experimental forgetting. There is another potential problem: an interval can be too short. There is evidence to support this hypothesis in the literature, although it is somewhat puzzling. Koppenaal (1963) found absolute recovery after six hours, although not after 90 minutes. An even more extreme case was reported by Slamecka (1966), in which recovery occurred after 24 hours, yet not after six hours. Although the reasons for the shapes of these recovery functions are far from clear, at least one conclusion can be drawn from them: sometimes spontaneous recovery cannot be discovered because the retention interval is inappropriate. For example, neither Koppenaal nor Slamecka would have likely found recovery with very short retention intervals of an hour or less, although these intervals have resulted in absolute recovery in other research (Forrester, 1970; Lehr & Duncan, 1970; Lehr et al., 1972; Postman et al., 1968; Postman et al., 1969), as well as in the experiments reported here.

The following thought experiment can illustrate how a retention interval can be too short. Suppose subjects are asked to study two lists, similar to those in the interference condition of Experiment 5. Then the subjects are given a surprise test for the first, or target, list, either
immediately, or following a thirty-second interval. Surely spontaneous recovery would not result. Whatever cognitive processes are behind the effect, they take some amount of time to operate. Ironically, just as some failures to find spontaneous recovery resulted from retention intervals that were too long (leading to increased extra-experimental forgetting), other failures may have come from the interval being too short.

This is a complicated issue, and it has never been rigorously examined, although the studies of Koppenaal (1963) and Slamecka (1966) provide a starting point. Presumably, different levels of retroactive interference would require different intervals to begin recovering, so it may be impossible to describe a general recovery function which generalizes across materials and instructions. Since retention intervals of a half hour or so proved useful in this dissertation and also in the past, there is probably no reason to abandon this interval, as long as one is only interested in demonstrating the effect. Future experiments might manipulate the retention interval, however, to examine the time course of recovery.

When one considers all of these factors which must be considered simply to observe spontaneous recovery, it is not surprising that research on the phenomenon has been sparse since the mid 1970's. The fact that the phenomenon might be a relatively rare occurrence was anticipated by Underwood (1948b), who suggested that the "conditions which produce such an effect may be highly specialized" (p. 429). Therefore, it might never be possible to investigate spontaneous recovery the way researchers study a phenomenon such as priming, for example. Simply obtaining a significant effect of spontaneous recovery has proven to be difficult;
designing an experiment in which one compares the different magnitudes of recovery displayed by different conditions may prove to be unfeasible (or at least less feasible than the current fad of assessing the differing amounts of priming resulting from various study and test manipulations). Despite the relative difficulty in demonstrating spontaneous recovery, our understanding of the effect is still important. The very fact that the absolute recovery of information over time runs counter to virtually all of our 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.

Again, the working hypothesis for spontaneous recovery postulates a process of retrieval inhibition, which serves to actively prevent us from accessing learned material. Although retrieval inhibition, as a cognitive explanation, is relatively modern, there have been related hypotheses within the animal learning literature for some time. In fact, Pavlov (1927) described the extinction processes as the accumulation of "internal inhibition". According to this view, as the conditioned stimulus becomes "inhibited" through a lack of reinforcement, it suffers from a general decline in processing; therefore, the stimulus commands little attention. The "inhibition", or lack of attention, was said to dissipate over time, resulting in spontaneous recovery.

Subsequent theories of instrumental conditioning proposed the formation of new, inhibitory associations between the conditioned and unconditioned stimuli during extinction (Konorski, 1948; 1967). Inhibitory associations directly oppose the excitatory connections that were created during original learning. These inhibitory links are considered to be the
more labile associations and, consequently, they lose strength over time, leading to spontaneous recovery. Probably the most important difference between this approach and that of Pavlov (1928) is that Pavlov did not postulate the inhibition to be associative; his theory implied a general inhibition of the conditioned stimulus, while Konorski (1948; 1967) suggested an inhibitory association between the conditioned and unconditioned stimuli. These and other theories of the spontaneous recovery of conditioned responses are reviewed by Robbins (1990).

As described by Bjork (1989), retrieval inhibition has adaptive benefits. Perhaps the main benefit is that, since the inhibited (or TBF) items become less retrievable, they are much less likely to interfere with new (or TBR) learning. Another adaptive feature is its impermanence. Rather than permanently forgetting or unlearning old items (which would also negate their potential for interference), inhibition allows them to only be temporarily nonproduceable. The fact that inhibited material remains in memory is surely beneficial; it would be disastrous for us to permanently forget information simply because it created interference for new material. So retrieval inhibition is the adaptive mechanism which allows us to temporarily suppress learned knowledge as we acquire additional knowledge.

Stated this way, the retrieval inhibition hypothesis is very 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, since they make similar, if not identical, predictions. Ironically, in the majority of articles in which retrieval inhibition has been suggested (Basden et al., in press; Coe et al., 1989;
Geiselman & Bagheri, 1985; Geiselman, Bjork, & Fishman, 1983), the
response-set suppression hypothesis is not even cited as an historical
predecessor. These two theories should certainly be compared, however;
by jointly considering the evidence which has been collected to test the two
approaches, a broader theory of inhibition can be developed.

While response-set suppression theory fell out of favor many years ago,
it is argued that this happened primarily because of two factors. Probably
the main reason was the finding of Wichawut & Martin (1971; also,
Delprato, 1971) as discussed previously, which cast doubt on the list-wide
nature of suppression that had been proposed in the theory. 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 psychology.

The important point from this is that the concept of suppression itself
was not attacked. Only some of the specifics of the theory were criticized.
Therefore, suppressing or inhibitory mechanisms may play a large role in
remembering, even if there is little or no support for a "list-wide"
suppression. If so, the processes involved in retrieval inhibition have been
relatively understudied in cognitive psychology, and warrant further
investigation. An excellent paradigm from which to study inhibition is in a
spontaneous recovery paradigm. This approach illustrates (1) a decrement
in retention, usually caused by retroactive interference, and (2) the
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.

It is probably important to note that this dissertation was not designed to exhume the majority of issues raised in the name of interference theory. While there were several other issues which were often jointly considered along with spontaneous recovery (see Crowder, 1976, for a review), it is beyond the scope of this project to re-evaluate those ideas. Spontaneous recovery is one phenomenon from the verbal learning tradition which, when rigorously examined, can lead to insights into our current understanding of remembering. There are, almost surely, other areas of interest within verbal learning and interference theory that warrant similar consideration.
REFERENCES


