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AFOSR Grant 91-0253 supported four different lines of research, described herein. These are I. a preliminary experiment to clarify our testing procedures; II. experiments designed to examine effects of various types of repetition on several memory tests; III. experiments designed to examine the effect of distinctive events on these tests; and IV. experiments designed to examine inhibition and spontaneous recovery in memory. The progress made on each topic is described in the four sections of this Final Technical Report. Briefly, all four lines of work have been carried to a successful completion, although in two cases (II and IV) data are still being analyzed. Several publications from this research are either being published, written or planned at this writing.

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FINAL TECHNICAL REPORT

COMPARING PERFORMANCE ON IMPLICIT MEMORY TESTS

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30 September, 1992

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Final Technical Report

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Principal Investigator

This report summarizes, briefly, work supported by AFOSR Grant 91-0253. The main body of the text outlines four lines of research that were conducted. In order to be relatively brief, the writing assumes some familiarity with the topic and the original proposal. After the main body of text, I provide the other information that is requested.

Section I: Preliminary Experiment

Problem

The purpose of this first experiment was to establish that testing Air Force recruits in the Armstrong Laboratory at Lackland Air Force would yield results comparable to outcomes already reported in the recent literature. Carrying out this sort of experiment not only provided the opportunity to indirectly evaluate differences (if any) between subjects (AF recruits and college students) but to replicate recent implicit memory findings.

Experiment

The experiment conducted was a partial replication of Experiment 1 in Weldon (1991). Weldon (1991) manipulated study conditions while holding the test conditions constant. The encoding or study conditions varied format of item presentation. Subjects either (a) read a word (b) generated the word from a conceptual clue, (c) heard the word or (d) saw a picture representing the word's referent. The test was always implicit word fragment completion. In the generation condition, subjects generated targets to short cues (e.g. helium - b__________). The results of Weldon's experiment revealed significant priming compared to a nonstudied baseline for the Read (25%), Generate (12%), and Auditory (8%) conditions but not in the Picture condition (3%). The Read condition yielded significantly more priming than the other three conditions, and an orthogonal contrast showed significantly more priming for the combined Auditory and Generate conditions compared to the Picture condition. A difference in priming for the Generate and Auditory conditions was not tested statistically. The results replicated earlier work utilizing word fragment completion as an implicit test (Roediger & Blaxton, 1987; Weldon & Roediger, 1987; Srinivas & Roediger, 1990).

Differences between the present experiment and the Weldon (1991) study were: (1) the present study did not employ an auditory study condition; (2) the present study used sentences as generation cues similar to those used Srinivas and Roediger (1990) rather than the relatively short cues used in the Weldon study. Based on the Weldon (1991) findings , priming was expected to be observed in the Read and Generate study conditions but not in the Picture condition; further, the Read condition was expected to produce priming superior to both the Generate and Picture conditions. The Generate condition was predicted to produce significantly more priming than the Picture condition.

Method

Subjects. Forty-eight Air Force recruits, 3 male and 5 female, were tested in the Armstrong Laboratory at Lackland Air Force Base, San Antonio, Texas. The mean age of subjects was 20 years.

Materials. One hundred twenty pictures and their corresponding word labels were drawn from the Snodgrass and Vanderwart (1980) norms. Sentences were created as generation cues for 80 of the these items (e.g. A receptacle for tobacco that has been smoked: a ___________.). These 80 items were then divided up into four lists, 20 items per list. Word fragments were obtained from Blaxton (1989) or created for all 120 stimuli. Another 12 items, 6 words and 6 pictures were drawn from the Snodgrass and Vanderwart norms to be used as buffer stimuli. Six additional generation cues based on the Snodgrass and Vanderwart norms were made to be used as buffer stimuli. Word fragments of 20 different American states were created for practice in completing word fragments. The experiment was programmed with Micro Experimental Laboratory (MEL) software and run on Zenith 480 microcomputers with EGA monitors.

Procedure. Subjects were tested in groups of five. Each subject sat at a computer. At study, three of four lists (A, B, C, D) were presented as words, as pictures, or were generated from cues. The study lists were presented in a blocked format. The fourth list served as the nonstudied items to provide a baseline against which to assess priming. Following the study session an implicit word fragment completion test was given. The order of the test stimuli was random. Filler items resulted in half the test items being old and half being new. All six possible orders for the study blocks were presented and the 4 lists were rotated through all six orders, resulting in 24 combinations. Two subjects received each combination.

Results and Discussion

The mean percent completion rates based on study manipulation were as follows: Read, 63.4%; Generate, 52.5%; Picture, 49.9% and Nonstudied, 47.1%. The priming percentages were 16.4%, 5.4% and 2.8% for Read, Generate and Picture conditions respectively. The general pattern of the data reflects the predicted pattern. The completion rate for the Read condition is well above that of all other item types. The completion rates for both the Generate and Picture conditions are greater than baseline with the completion rate for the Generate condition being higher than that for the Picture condition.

A one-way within-subjects ANOVA across item types confirmed that there was a significant difference in completion rate between at least two of the item types, $F(3,141)=8.49$, $Ms_e=289.489$, $p < .001$. A Tukey test revealed that the completion rate for the Read condition was significantly greater than all other conditions. No other pairwise comparison was significant.

Although the completion rates were significantly greater in the Read condition than in all other conditions, the completion rate for the Generate condition was not significantly greater than the completion rate for nonstudied items. This latter result was not expected and contradicts earlier findings (Srinivas & Roediger, 1990; Weldon, 1991). This result is not due to subjects failing to generate the targets at study. Subjects generated 95% or better of the targets from the sentence cues as well as 95% of the names of the pictures, as evidenced from post-test picture naming and target generation tasks. As predicted, the completion rate for the Picture condition was not significantly above that for the nonstudied condition. However, while completion rates were higher in all conditions in the present experiment compared to the completion rates in Weldon (1991), the completion rate for nonstudied items was relatively much higher, reducing priming in all conditions in the present study compared to Weldon's results.

While the present experiment did not perfectly replicate Experiment 1 (Weldon, 1991), the study still supports the theory of transfer-appropriate processing (e.g., Roediger, 1990). Reading a word has been suggested to rely more on data-driven processing, while generating targets and studying pictures have been thought to emphasize conceptually-driven processing. Given the emphasis on the stimulus features of the test retrieval cues, one may comfortably assume that implicit word fragment completion is a task that depends primarily on data-driven processing. According to transfer-appropriate processing theory, the better the match between study and test operations, the better test performance ought to be. Reading words and solving word fragments appear to be both reflect data-driven processing, while this match between study and test processes does not appear to be shared with the generate and picture conditions. Thus, the Read condition yielded greater priming on this type of test than the Generate and Picture conditions. In addition, this experiment showed that the standard procedures used in our laboratory could be adapted well for Armstrong Labs and that our further research program was feasible.

Section II: Effects of Repetition

Transfer appropriate processing theory predicts that all conceptual tests (both implicit and explicit) should react similarly to conceptual or meaningful manipulations at study. In the past, free recall has been posited as the quintessential conceptual test because no overt cues, either perceptual or conceptual, are given to subjects. One study manipulation that has been found to enhance free recall is conceptual repetition. That is, following a target word (puzzles) with a word that is highly associated with the target (jigsaw) has been found to enhance free recall of the target, relative to simply presenting the target alone (Roediger & Challis, 1992; Kolers & Gonzalez, 1980). Transfer appropriate processing theory would therefore predict that other conceptual tests would show this pattern of results, but that perceptual tests would show no differential results for the two conditions (because this is not a perceptual manipulation). We tested this hypothesis in our lab at Rice in 1991, and obtained unpredicted results. We have recently followed up these results with a series of experiments at Lackland Air Force Base.

Summary of the first series of experiments. The aforementioned study manipulation was examined across five different memory tests. Two of these tests were implicit: word fragment completion and category instance production. In the category instance production test, subjects were given category labels (types of toys) and asked to generate as many instances of the category as they could in 20 seconds. The higher production rate of the target words (puzzles) by subjects who had seen the target in the study list relative to those subjects who had not seen the target is the relevant measure of priming. In addition to the two implicit tests, three explicit tests were used, two of which were explicit counterparts to the implicit tests: word fragment cued recall and category cued recall. In these two tests, the overt cues at test were the same as in the implicit tests, and only the instructions were varied. The third explicit test was free recall.

It should be noted that for purposes of comparison, two other conditions were added to the basic conceptual repetition manipulation. In one condition, the target word was presented twice at study (puzzles puzzles). In the other, only the associate was presented (jigsaw). Interest here was in how the direct repetition condition would compare to the conceptual repetition condition and whether the associate presented alone would prime the target word.

Results of these experiment are summarized in Table 1. The primary finding was that although conceptual repetition enhanced performance on the free recall test, this pattern was not found on the other two conceptual tests (category cued recall and category instance production). This result is inconsistent with the predictions made by transfer appropriate processing theory. Reliable priming was found on both implicit tests, however, in both repetition conditions as well as the condition in which the target was presented once alone.

Experiments performed at Lackland AFB. Because the results of this experiment are clearly inconsistent with transfer appropriate processing, we next decided to try to instantiate conceptual repetition in another way to see if it too would produce a dissociation between free recall and other conceptual tests. Specifically, the idea was to present the target item as a word and then follow it by picture of the word (or vice versa: picture followed by word). For example, the word onion was presented immediately followed by a picture of an onion. As in the previous set of experiments, other conditions were included for comparison. Thus the study conditions were: picture presented once, word presented once, picture presented twice, word presented twice, picture followed by word, and word followed by picture.

The memory tests used in these experiments are the same as those in the previous ones, with one addition: recognition memory. Transfer appropriate processing theory would predict the three conceptual tests to behave similarly in the following way: conceptual repetition to enhance memory relative to presenting an item once, exact repetition to do the same, and pictures to be remembered better than words. Results in the previous set of experiments, however, guide a different set of predictions: although free recall should show this pattern, the other two conceptual tests may not show enhancement from repetition or show the picture superiority effect. Some 260 subjects have been tested; however, data from these experiments have just been collected and have just arrived at Rice within the last few weeks, so the results cannot yet be reported.

Table 1

Mean Proportion of Target Items Produced as a Function of Study Condition and Test Type

		Study Condition				
Test Cue	Test Instructions	T	TA	TT	A	NS
Word Fragment	Implicit	.41	.41	.45	.20	.19
	priming	.22	.22	.26	.01	
	Explicit	.47	.55	.49	.02	.02
Category Names	Implicit	.41	.40	.44	.22	.20
	priming	.21	.20	.24	.02	
	Explicit	.62	.62	.57	.02	.00

Free Recall	Explicit	.25	.45	.43	.00

Note. T refers to the study condition in which the target word was presented once, TA to that in which the target was followed by a semantic associate, TT to the condition in which the target was presented twice in succession, A to that in which the associate was presented alone, and NS to the nonstudied (baseline) condition.

Section III: Effects of High-priority Events on an Explicit and an Implicit Test

Most memory research involves studying memory as revealed by explicit tests. Explicit memory tests refer to situations in which subjects are explicitly asked to recall or to recognize studied material.

Recently, however, more memory research has involved studying memory as revealed by implicit tests (Roediger, 1990; Schacter, 1987). On implicit memory tests, subjects are not explicitly reminded of material that they studied. Subjects are instead asked to perform an ostensibly unrelated task, and memory for the studied material is revealed to the extent that prior study of the material affects task performance. For example, subjects might be presented with a list of 20 words to learn, and later asked to complete word stems (e.g., the first three letters of words) with the first word that comes to mind. Subjects are not informed that some of the word stems can be completed with studied words, yet memory for the studied words is revealed to the extent that subjects are more likely to complete the word stems with studied words than with nonstudied words.

An interesting difference between explicit and implicit memory tests is that certain variables produce different effects on the two types of test. For example, although attending to the meaning of studied information usually enhances performance on explicit tests, processing of meaning rarely affects the most popular implicit tests (Blaxton, 1989; Jacoby, 1983). Alternatively, although matching modality (e.g., visual or auditory) of information between study and test usually enhances performance on the most popular (perceptual) implicit tests, match of modality rarely affects explicit tests (Roediger & Blaxton, 1987).

Roediger and his colleagues (Roediger, Weldon, & Challis, 1989) proposed a theory of transfer-appropriate processing as a parsimonious account of the disparate effects of variables on explicit and implicit memory tests. The theory first assumes that memory test performance benefits to the extent that the processes used in performing the test are the same as the processes used at study. With this assumption, the disparate effects of certain variables can be explained as follows. Most explicit tests (e.g., free recall or recognition) rely on conceptual processing (i.e., processing of meaning), and not perceptual processing (i.e., processing of surface features). Therefore these tests should benefit from attention to the meaning of studied material. Most implicit tests (e.g., word stem completion), however, rely primarily on perceptual processing, not conceptual processing. Therefore these tests should benefit from attention to surface features of studied material, and from similarity of surface features between the studied and tested material. These predictions are supported by the data that have already been mentioned. Specifically, processing of meaning benefits explicit but not implicit tests (Blaxton, 1989; Jacoby, 1983), and the match of study and test modality benefits implicit but not explicit tests (Roediger & Blaxton, 1987).

The purpose of the present research was to explore the effects on a perceptually-driven implicit test of a variable whose effects on conceptually-driven explicit tests are well known. The variable is a high-priority event, or an event that subjects are told to be especially sure to remember. Tulving (1969) was one of the first researchers in the modern era to explore the effects of high-priority events on memory. His method was to present subjects with lists of common nouns to recall. Embedded in each list was the name of a famous person. Subjects were instructed to try to remember all the words in a list, but especially the famous name in each list.

Tulving found, predictably, that the famous names were better recalled than the common nouns in the list. Other researchers have duplicated and extended this result, showing, for example, that this beneficial effect of a high-priority event also occurs on a recognition test of memory (Schulz, 1971; Schulz & Straub, 1972), and that it is not necessary to tell subjects to be sure to remember the famous name to get the effect in free recall and in recognition (Saufley & Winograd, 1970; Schulz, 1971). One area to which study of this effect has not been extended, however, is in the study of implicit memory.

Interpreting Tulving's (1969) results in terms of transfer-appropriate processing, it is not too surprising that he found a beneficial effect of the famous name high-priority events on a free recall test. This is because free recall tests are conceptually-driven tests. Tulving's famous names, being from a different category than the other words in the list (i.e., common nouns), were conceptually distinctive relative to the other words in the list. It does not seem likely, however, that these conceptually-distinctive events would affect an implicit memory test that is affected by surface features of material (i.e., a perceptually-driven test), unless subjects also process them more fully (e.g., look at them longer). The present experiments were conducted to test this possibility.

In the present experiments, our high-priority events were exemplars of the taxonomic categories <u>animals</u> and <u>sports</u>. We used these items as high-priority events because, in a list of common words, these items could be made conceptually distinctive without also being made perceptually distinctive. Famous names, on the other hand, are both conceptually distinctive (being from a different category) and perceptually distinctive (being the only capitalized words in the list). We instructed subjects that high-priority events were exemplars from either the category <u>animals</u> (Animal Group) or the category <u>sports</u> (Sport Group) to assess the effects of a conceptually-distinctive, but not perceptually-distinctive, event on a conceptually-driven explicit test (free recall) and a data-driven implicit test (word stem completion).

In two experiments (one with Rice University undergraduates and one with Air Force recruits on their 11th day of basic training at Lackland Air Force Base), subjects were presented with 12 lists (with 15 words per list) to learn. Words were presented one at a time. Each list consisted of one word referring to an animal, one word referring to a sport, and 13 other words. Half of the subjects were told that the animals were high-priority events (Animal Group), and the other half were told that the sports were high-priority events (Sport Group). Thus all subjects tried to remember as many items as possible from a list, with the Animal Group especially trying to remember the animals and the Sport Group especially trying to remember the sports.

After each of six lists, subjects were asked to write down as many of the words from the list as possible. After each of the remaining six lists, subjects were asked to complete 25 word stems with the first word that came to mind. Ten of the 25 word stems could be completed with words from the studied list.

On the free recall tests, we compared free recall of the animals and sports for subjects who were told that animals were high-priority events to that for subjects who were told that sports were high-priority events. We expected that on the conceptually-driven free recall tests, the Animal Group would recall more animals than the Sport Group, and the Sport Group would recall more sports than the Animal Group.

On the word stem completion tests, we compared priming scores for the animals and sports for subjects who were told that animals were high-priority events to those for subjects who were told that sports were high-priority events. Priming scores were computed by subtracting the proportion of word stems completed with the desired target when that target had not actually been studied from the proportion of word stems completed with the desired target when that target had been studied. We expected that on the perceptual word stem completion tests, the Animal Group and the Sport Group would not differ in priming for the animals or for the sports.

The results for free recall confirmed our expectations, but the results for word stem completion were surprising. We found better free recall for animals when they were treated as high-priority events (by the Animal Group) than when they were not (by the Sport Group). And we found better recall for sports when they were treated as high-priority events (by the Sport Group) than when they were not (by the Animal Group). The results for the Air Force recruits can be seen in the Table 2.

Table 2

<u>Free Recall Scores for Animals and Sports</u>

	Animals	Sports
Animal Group		
<u>M</u>	.81	.23
Sport Group		
<u>M</u>	.28	.85

In word stem completion, we expected no difference in priming for animals or for sports when they were treated as high-priority events (by the Animal and the Sport Groups, respectively) than when they were not (by the Sport and the Animal Groups, respectively). Surprisingly, we obtained the same results for word stem completion that we obtained for free recall. Items (either animals or sports) experienced greater priming when they were treated as high-priority events than when they were not. The results for the Air Force Recruits can be seen in the Table 3.

Table 3

Priming Scores for Animals and Sports

	Animals	Sports
Animal Group		
M	.72	.37
Sport Group		
M	.48	.66

The word stem completion results are not consistent with the predictions of transfer-appropriate processing theory, unless it is assumed that the distinctive event is processed different perceptually. The theory predicts that a conceptual manipulation (e.g., a conceptual high-priority event) should affect a conceptually-driven memory test like free recall, but not a data-driven memory test like word stem completion.

Before we conclude that this result is truly inconsistent with transfer-appropriate processing theory, we must rule out the possibility that subjects were explicitly trying to remember the studied words while they were completing the word stems. Explicitly trying to remember the studied words could make the word stem completion test sensitive to conceptual manipulations, which would explain the effect of a conceptual high-priority event on this test. A third experiment is currently being conducted to test this possibility.

Section IV.: Inhibition and Recovery

This series of experiments has been concerned with the phenomenon of retrieval inhibition, and the time course of inhibitory effects on various types of retention tests. Retrieval inhibition has been characterized as a temporary, suppression-like process which blocks the retrieval of the inhibited information (Bjork, 1989; Geiselman & Bagheri, 1985). The process is thought to be initiated consciously by the individual, usually for some adaptive reason. This phenomenon has received scant attention in recent years; when mentioned, it has usually been related to the directed forgetting literature (see Bjork, 1989). For experimental purposes, subjects might suppress previously learned information in order to reduce proactive interference. In the experiments reported here, a typical paradigm requires subjects to learn a series of similar lists. During the learning of a second list, it may be advantageous for subjects to forget, or at least inhibit, the items in the first list; these items can only create interference and confusion, therefore it is to a subject's advantage to "block out" first list information.

While it is well known that there is a loss in retention of the first list following second list learning, inhibition is only one of many possible explanations. For example, rather than inhibiting, or suppressing, items from a first list, these items might be completely erased, or forgotten. When memory is measured after only a single retention interval, it is difficult, if not impossible, to distinguish between inhibition and forgetting explanations. The experiments in this series were designed to investigate the time course of retroactive interference, and point to an explanation for the phenomenon. All experiments in this series followed the same general procedure: Subjects studied a target list, which was presented several times to ensure a high level of retention. Following the target list, one half of the subjects studied additional lists (which were actually interfering lists), while remaining subjects completed a neutral distractor task (by solving arithmetic problems). All subjects later took some type of retention test for the target list. The test was given either immediately following the interfering lists, or after some lengthy retention interval.

This experimental design was created with the following logic: Interfering lists should cause a decrement in retention for the target list. This assertion is noncontroversial, and has been demonstrated in numerous prior studies. If this decrement is caused by the forgetting, or erasing, or target list information, then interference should persist at roughly the same level over different retention intervals. If the decrement is a result of a temporary retrieval inhibition, however, then one might expect the effect of interference to diminish over time, through the dissipation of retrieval inhibition. A prediction of the retrieval inhibition hypothesis is that subjects in interference conditions might actually show improved memory over a longer retention interval. This phenomenon, known as spontaneous recovery, would presumably occur because of a release of retrieval inhibition. Spontaneous recovery is interesting in its own right, because it is a counterintuitive finding which is seemingly contrary to the typical process of forgetting. If recovery over time is observed, it would represent strong evidence of the process of temporary retrieval inhibition.

EXPERIMENT 1

The first experiment was performed to demonstrate the basic phenomena of retroactive interference and its potential recovery over time. Stimulus materials were paired associates, in this case, letters associated with words (e.g., *q--hammer*). In interfering lists, the pairs of associates shared the same stimulus terms, which were paired with different responses (e.g., *q--candle*). These stimuli were selected so substantial interference and/or confusion could result from the learning of the separate lists.

Method

Subjects and design. 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 two factors, both varied between-subjects. They were study condition (control or interference), and retention interval (immediate--1 min between study and test, or delayed--16 min between study and test).

Materials. The target items were 12 letter-word pairs. Twelve random letters of the alphabet were each arbitrarily paired with a words: *q--hammer, j--shoe, w--couch, v--scissors, r--axe, a--cherry, n--bicycle, e--dog, k--snowman, c--screwdriver, m--basket, p--lightbulb*. 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 which 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. Subjects were tested in groups of 8 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 List 1 began. The letter-word pairs were presented by a Kodak Ektagraphic slide projector at a rate of 7 sec apiece, with 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 and that they were about to see List 2. 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 was viewed, there was another 20 sec delay in which subjects were reminded that the next list was List 3, 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 this list 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, those subjects in 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 which 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 as 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 ANOVA, with study condition (interference or control) and retention interval (immediate or delayed) as between-subject factors. The overall ANOVA showed a significant interaction between study condition and time of test, $F(1, 76) = 2.89$, $MSe = 9.56$, $p < .05$. 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, $F(1, 76) < 1$. Subjects which received the interfering lists, however, showed a marginally

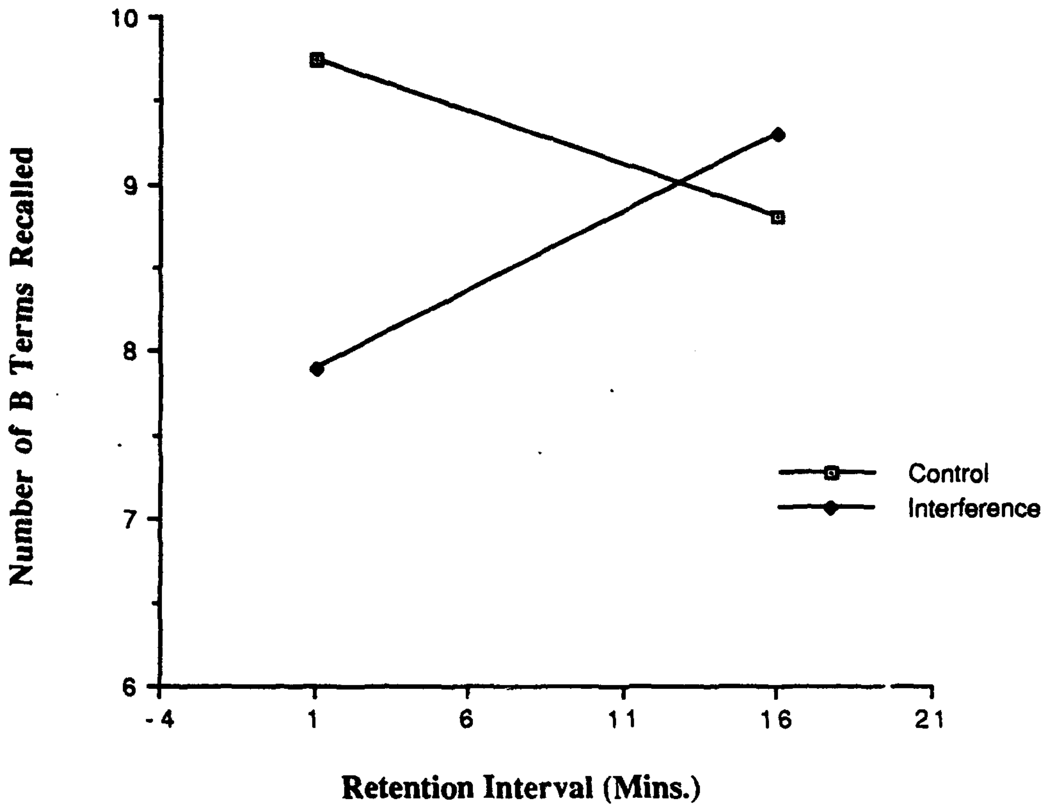

Figure 1. Number of response terms recalled as a function of study condition and retention interval in Experiment 1.

significant effect of delay interval, $F(1, 156) = 2.05$, $MSe = 9.56$, $p < .08$. Recall scores improved from 7.90 on the immediate test, to 9.30 on the delayed test.

DISCUSSION

Results of Experiments 1 demonstrate that the spontaneous recovery of information can occur over time. They also lend some evidence to the retrieval inhibition hypothesis. If retroactive interference caused List 1 information to be erased, or forgotten, then it is very unlikely that subjects in interference conditions could have shown marginally significant improvement over time. If target list responses were only temporarily suppressed, or inhibited, however, then one might expect improved recall performance over longer retention intervals.

One surprise in this experiment was the relatively small amount of retroactive interfence: only about three items. This may have been a result of the experimental instructions. Subjects always anticipated an eventual memory test for the associates in List 1. Therefore, they were not truly motivated to block List 1 items. In Experiment 2, the procedure was changed, so that subjects would believe that their memory of List 1 would not be tested. In this situation, there is no reason for subjects to continue remembering List 1 items. Therefore, List 1 could only cause proactive interference for subsequent lists, and it was to a subject's advantage to forget, or inhibit, the first list.

In Experiment 2, the stimulus materials were changed. Rather than pairs of associates, subjects learned lists of discrete items. Prior research on interference has primarily employed paired-associate learning; although this research is certainly valid, findings should extend to different kinds of stimuli.

Experiment 2

Method

Subjects and Design. Subjects were 108 Air Force recruits at Lackland Air Force Base in San Antonio. They participated as part of the requirements for basic training. The design was a 2 x 2, completely between subjects. Independent variables were study condition (interference or control) and retention interval (immediate or delayed).

Materials. A target list of 12 pictures was constructed. Subjects in interference conditions viewed two additional lists, with an additional 12 pictures in each.

Procedure.

Subjects were tested in groups of 6-16. 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, with .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 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.

RESULTS

Means are graphed in Figure 2. Results showed that Lists 2 and 3 produced a substantial amount of retroactive interference for the target list. There was also a

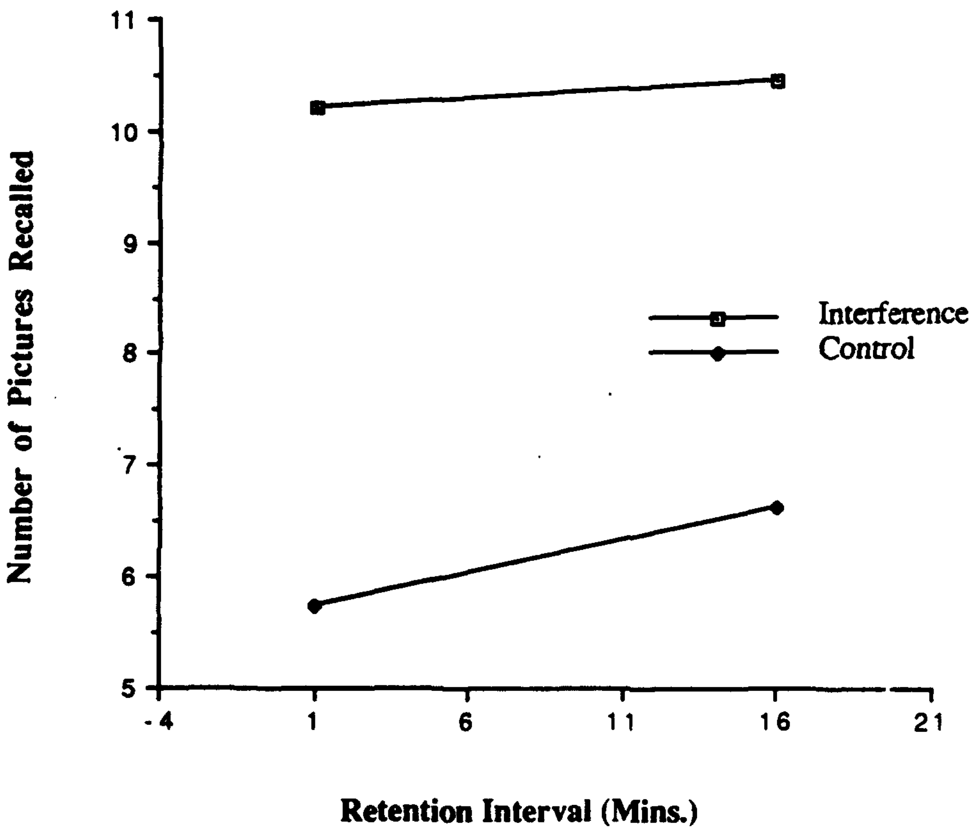

Figure 2. Number of pictures recalled as a function of study condition and retention interval in Experiment 2.

small amount of spontaneous recovery demonstrated by subjects in interference conditions. These findings were confirmed 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, $\underline{F}(1,104) = 88.36$, $MSe = 5.26$, $p < .001$. There was no effect of retention interval, $\underline{F}(1,104) = 1.58$, $MSe = 5.26$, $p > .21$, and the two factors did not interact, $\underline{F}(1,104) < 1$.

Despite the lack of an 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. Clearly there was no significant decrease for control conditions, as recall increased slightly over time, from 10.22 to 10.44. As expected subjects in interference conditions demonstrated better retention after the 15 min interval (6.6 items to 5.7 items). The increase was marginally significant, $\underline{F}(1,104) = 2.02$, $MSe = 5.26$, $p < .08$.

DISCUSSION

Results of this experiment are generally supportive of the presence of retrieval inhibition. There was substantially greater interference demonstrated in this experiment than in Experiment 1. Since subjects believed that they had no reason to continue remembering the target list, they were motivated to "block out" this list while learning subsequent lists. There is evidence that this "blocking" took the form of a temporary retrieval inhibition rather than forgetting. The evidence comes from the small amount of recovery that was demonstrated over time. Unfortunately for an inhibition hypothesis, the recovery was very small (just less than 1 item out of 12), so support for the hypothesis is far from overwhelming. A possible reason for the small size of this effect is the length of the retention interval (sixteen minutes). It is possible that sixteen minutes is not sufficient time for retrieval inhibition to dissipate. This hypothesis has been tested in a subsequent experiment, using University of Houston undergraduates. The experimental procedure was identical to that used in Experiment 2, with the exception that the delayed recall test was given after a 36-minute retention interval. With this interval, a greater amount of spontaneous recovery was observed (the effect was roughly twice as large as in Experiment 2). The experiments together suggest that retrieval inhibition is a very viable hypothesis for the results, and also that different levels of inhibition require different amounts of time to dissipate. For example, in Experiment 1, subjects in interference conditions were able to "completely" recover from inhibition in fifteen minutes. Recovery is considered complete because subjects in interference were already able to recall as many correct responses as subjects in control conditions. In Experiment 2, however, there was a greater amount of interference, or inhibition. Therefore, a longer retention interval was required to demonstrate recovery, or dissipation of the inhibition.

EXPERIMENT 3

So far, retrieval inhibition has been investigated using explicit memory tests, such as free or cued recall. The next experiment was designed to look for response suppression in an implicit, word-stem completion task. Subjects studied words under similar conditions as those in Experiment 2. Then, subjects took two word-stem completion tests, one immediately and one after a 20-minute delay. Words from the target list (but not the interfering lists) were possible completions for the stems. 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 theoretically interesting in its own right.

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. 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. The purpose of this test was to acquaint subjects with the procedure, and make them less "suspicious" of the later completion tasks.

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, with 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 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 1. Results showed that the only effect was overall priming. There was no interference demonstrated on word-stem completion performance. 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

Table 1

Proportions of word stems successfully completed in Experiment 3

Condition	Prime	Retention Interval (Mins.) 2	22
Interference			
	Studied	.31	.26
	Nonstudied	.09	.06
	Priming	.22	.20
Control			
	Studied	.22	.25
	Nonstudied	.08	.11
	Priming	.14	.14

(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

This experiment demonstrated that the same manipulation which produced substantial interference in free recall had no effect on word-stem completion. Results suggest that recall and stem completion are processed differently. More importantly for the present project, the results demonstrate a limitation of suppression. 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; at least one of the representations was suppressed by the interference, while another (perhaps in the word form system) was not suppressed.

GENERAL DISCUSSION

These experiments conducted at Lackland Air Force Base have been part of a series of experiments designed to identify and investigate the cognitive process of retrieval inhibition. So far the results have been generally supportive of such a phenomenon, but more work remains to be done. The following conclusions can be tentatively advanced:

1. The spontaneous recovery of material over time is a reliable phenomenon. This is consistent with the idea that we can temporarily suppress, or inhibit, information. Because the effect is temporary, we can "recover" information over time, which is seemingly in opposition to the typical process of forgetting.

2. More retroactive interference is observed when subjects are not motivated to remember the target information. There was greater interference in Experiment 2, when subjects believed that they would not be tested on the target list, than in

Experiment 1. This is consistent with the notion that inhibition can be consciously controlled, or initiated, by the subject. More inhibition occurred when subjects had reason to completely block the target list from memory.

3. Retrieval inhibition does not affect implicit tests (at least not word-stem completion). This represents an important class of tests to which the phenomenon does not generalize. Although further research needs to be done on this issue before firm conclusions can be drawn, the experiments certainly indicate that the different retrieval processes occurring for the two types of retention tests (implicit and explicit) are differentially affected by interference manipulations.

CONCLUSION

This final technical report summarizes four lines of research sponsored by Grant AFOSR-91-0253 to Henry L. Roediger, III.

Figure Captions

Figure 1. Number of response terms recalled as a function of study condition and retention interval in Experiment 1.

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

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5. Mark A. Wheeler; Graduate student; Rice University; B.S. in Psychology from Trinity University; M.S. in Psychology from Rice. Ph.D. candidate in 1992-93. Research in Section IV will form part of his dissertation.

Articles

Included in this section are articles supported by the Grant either directly or indirectly (i.e., in preparation of manuscripts of previously conducted work).

Published, In Press, or In Preparation

Chapters

Roediger, H.L. (in press). Retrieval processes in memory. In L.R. Squire (Ed.), Encyclopedia of Learning and memory. New York: Macmillan.

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Planned Publications

McDermott, K.B. & Roediger, H.L. Effects of exact and conceptual repetition on perceptual and conceptual memory tests. This will probably be submitted to the Journal of Memory and Language.

Guynn, M.J. & Roediger, H.L. Effects of distinctive events on explicit and implicit memory tests. This will probably be submitted to the European Journal of Cognitive Psychology.

Wheeler, M.A. Spontaneous recovery following retroactive interference: A re-examination. This will probably be submitted to the Journal of Experimental Psychology: Learning, Memory and Cognition.

Talks

Invited addresses

Roediger, H.L. (1991). Transfer appropriate processing. American Psychological Society. Washington, D.C.

Roediger, H.L. (1991). Remembering, knowing, and reconstructing the past. American Psychological Association. San Francisco.

Roediger, H.L. (1992). Implicit memory: An overview. International Congress of Psychology. Brussels.

Roediger, H.L. (1992). Specificity of operations in perceptual priming. In Symposium on Implicit Memory at the International Congress of Psychology. Brussels.

Papers presented at conferences

Srinivas, K. & Roediger, H.L. (1991). Specificity of priming on nonverbal tests. Midwestern Psychological Association, Chicago.

Rajaram, S. & Roediger, H.L. (1991). Components of recollective experience: Remembering and knowing. Midwestern Psychological Association, Chicago.

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