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RETROACTIVE INHIBITION IN FREE RECALL: INACCESSIBILITY OF INFORMATION AVAILABLE IN THE MEMORY STORE[1]

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Retroactive inhibition was produced under free recall conditions in an experiment in which *S*s learned and subsequently recalled from one to six categorically structured lists. The observed retroactive inhibition was attributable mainly to the lowered probability of recall of word categories as higher order memory units. Recall of words within recalled categories was not greatly affected. Presentation of category names as retrieval cues largely removed retroactive effects and restored word recall to nearly its original level. It was concluded that retroactive inhibition in free recall of organized lists (*a*) represents a state of memory in which higher order units of information are available but not accessible in the memory store, (*b*) reflects altered stimulating conditions brought about by interpolated learning, and (*c*) can thus be described as an instance of cue-dependent forgetting.

Successful retrieval of mnemonic information about an encoded event requires both availability of appropriate event information in the store and access to that information at the desired time (Tulving & Pearlstone, 1966). Failure of retrieval, in this view, comes about either as a consequence of deterioration of stored event information or because of the failure of the access mechanism. To the extent that retrieval failure can be identified with "forgetting," there are thus two sources, and two kinds, of forgetting: "trace-dependent" and "cue-dependent" forgetting (Tulving & Madigan, 1970).

This paper illustrates the application of such a view of recall and forgetting to the well-known phenomenon of retroactive inhibition: loss of retrievability of information stored earlier as a consequence of subsequent storage of some other information. An experiment is described in which *S*s studied and recalled several lists of familiar words as the events to be remembered and then attempted to recall all previously seen words in a "total" free recall test. It is known that under these conditions, retroactive inhibition effects can be readily demonstrated (e.g., Postman & Keppel, 1967; Tulving & Thornton, 1959), although the processes underlying these effects are only dimly understood at the present time.

The experiment was planned to provide evidence on two specific issues. First, how is retroactive inhibition reflected in recall and forgetting of elementary and higher order units of material? One theory of free recall holds that nominal elementary units of the list, such as individual words, are organized by *S* into higher order units when the material is studied, and that recall of at least some of the nominal units is mediated through recall of their respective higher order units (Tulving, 1968). Readily iden-

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tifiable and strongly cohesive higher order units, mimicking those resulting from subjective organization, were created in this experiment through the use of lists containing words belonging to highly familiar conceptual categories, and by presenting all the words of a given category as a "block" in the input list. The usual measure of performance in free recall of categorized lists, the number of words recalled, can be expressed as a product of two independent measures, category recall and words-within-categories recall (Tulving & Pearlstone, 1966). The former reflects accessibility of higher order memory units, and the latter can be taken as a measure of recall of elementary units. Thus, retroactive inhibition observed with such tightly organized lists can be described with respect to memory units at two different levels of integrity. Given this background reasoning, our first question was simple enough: Does learning of other lists reduce the recall of previously acquired higher order units, elementary units, or both?

The second issue at stake in this experiment had to do with the status of event information that *S*s fail to retrieve under free recall conditions because of retroactive influence of storage of other items in other lists. Does such retroactive inhibition reflect unavailability of appropriate event information, its inaccessibility, or both? In other words, does retroactive inhibition represent an instance of trace-dependent forgetting, cue-dependent forgetting, or both? This second issue was clarified in this experiment by the simple expedient of providing to *S*s, after the total free recall test, powerful relevant retrieval cues in the form of names of the conceptual categories in terms of which to-be-remembered words were encoded. If retroactive inhibition is a matter of loss of event information from the store, such retrieval cues could not bring about recall of the "unlearned" items. If, on the other hand, retroactive inhibition reflects a state of memory in which appropriate event information is only inaccessible, retrieval cues could provide an efficient access "route" to that information, with the consequence that "forgotten" or unlearned items could be recalled.

Method

Design

The design of the experiment represented an extension of that used in the Tulving and Thornton (1959) study. It comprised eight independent groups of *S*s. The *S*s learned lists of 24 words, the number of lists varying in different groups, and were then given three successive "total" recall tests. Groups 1, 2, 3, 4, 5, and 6 differed only with respect to number of lists originally learned, this number corresponding to the numerical designation of each group. Following the learning of their last list, *S*s in these groups were given the first total free recall test for all the words they had learned. They then spent 10 min. in completing as much as possible of the Shipley-Hartford Abstraction Test. This "neutral" activity was followed by the second total free recall test of all lists previously learned and recalled. Immediately following the completion of this test, *S*s were provided with the names of all the conceptual categories of words they had seen in all their lists and asked to recall as many words as they could under such cued recall conditions. The three total recall tests of all lists, given in the same order and at the same temporal intervals to Groups 1, 2, 3, 4, 5, and 6, will be referred to as FR_1, FR_2, and CR tests.

The two remaining groups of *S*s served as controls for assessing the effects of passage of time on recall. They are designated 1D and 6D, the numeral referring to the number of lists learned and D standing for "delayed." The *S*s in Group 1D learned a single list and then worked for 20 min. on a test of abstract reasoning. Following this interpolated activity, *S*s in this group were treated exactly like *S*s in Group 1 after learning of their single list. Group 6D learned six lists, exactly as Group 6, then spent 10 min. on the Shipley-Hartford test, and then took FR_1, FR_2, and CR tests in immediate succession.

Materials

Six different lists of 24 words were used, each containing six categories of 4 words. The list words were selected from among the top 10 words in each of the 36 response hierarchies in the Cohen, Bousfield, and Whitmarsh (1957) restricted association norms. The selected words usually ranked second, fourth, sixth, and eighth in a given hierarchy. In each list, all words from a category occurred as a "block" in four immediately successive input positions. Category names were not part of the input list, but because of the blocked presentation of category words, the categorized nature of lists and the nature of each category must have been obvious to all but the most uninterested *S*s.

For each of the six lists, six different category orders were systematically constructed so that

each category appeared in each sixth of the input positions just once and followed every other category just once. The order of the four words within a category was determined randomly for each of the six category orders of a list. Lists were assigned to different groups of *S*s and to different list positions in groups learning more than a single list also with a view to optimal counterbalancing of lists and their ordinal positions in the learning sequence across groups. In brief, the handling of learning materials was designed to minimize systematic effects of specific lists or categories.

Subjects

The *S*s were 128 high school and university students paid for their services, 77 males and 51 females, ranging in age from 13 to 25 yr. with a median of 17.2 yr. The *S*s were tested in small groups ranging in size from 1 to 4, with a median of 3 *S*s per group, each *S* participating in one of the 48 experimental sessions. All *S*s in a given session belonged to a single experimental group and hence were treated identically. Within these limits, *S*s were assigned to eight experimental groups, 16 *S*s per group, in the order of their appearance in the laboratory, with each incoming group, after the first eight, being assigned to the experimental condition with the smallest number of previously tested *S*s.

Procedure

Immediate recall.—Words to be learned were presented to *S*s by means of a closed-circuit TV system. A given list was shown three times in succession before its immediate recall was tested, each time in a different order, and with an interval of 20 sec. separating successive input phases. Words were presented one at a time, at the rate of 1 sec/word. After the list had been shown for the third time, *S*s wrote down as many words from the list as they remembered, in any convenient order. The *S*s had been instructed to guess at words they could not remember for sure, trying to get as many words right as they could. They were given 90 sec. to record their recall. The next list, if there was one, was presented 60 sec. after the end of the immediate recall test of the previous list.

The FR_1 and FR_2 tests.—The immediate recall test of the last list seen by Groups 1–6 was followed, without interruption, by the first total free recall test. The *S*s were provided with new recall sheets and instructed to write down as many words from all the previously learned lists as they could, in any convenient order. Their time allotment for this FR_1 test was 90 sec. per list. When the allotted time had passed, recall sheets were collected, forms of the Shipley-Hartford Abstraction Test were distributed, and *S*s given 10 min. to complete, and check their work on, this test. The purpose of the test was to fill the retention interval between FR_1 and FR_2 with "neutral" activity. Following this test, the second total free recall test, FR_2, was administered under the same conditions as FR_1.

Groups 1D and 6D were tested identically with other groups, with the exceptions of spacing of tests as described above.

The CR test.—Following the FR_2 test, each *S* was given cued recall sheets, the number of such sheets corresponding to the number of previously learned lists. Each cued recall sheet corresponded to one list, containing its six category names, each category name followed by four lines on which the appropriate list items were to be recorded. The order of category names had no systematic relation to the order of categories in the input lists, but the recall sheets handed to *S*s were stacked in the order corresponding to their lists at input. Again, for each list previously seen, 90 sec. were allowed for the cued recall test.

Results

Original Learning

The mean number of words recalled in the immediate recall tests, with the data pooled over all 28 lists in the eight groups, was 17.3. These "original learning" scores were quite stable in different groups and across stages of practice, all deviations of means of individual lists from the overall mean, with the exception of 1 out of 28, being less than one word. The mean number of categories per list represented in immediate recall tests was 5.27, and the mean number of words/category was 3.28.

Three Measures of Total Recall

One of the major findings of the experiment was the invariance of the words/category measure under conditions where the other two measures, word recall and category recall, showed large changes. While the words/category measure did appear to vary as a function of number of interpolated lists and as a function of recall test, these changes were quite small and did not approach statistical significance in several analyses that were done.

Two sets of data are presented here to illustrate the relative effects of retroaction and type of test on the three measures. First, Fig. 1 depicts mean recall of words, categories, and words/category from the first list learned by each of Groups 1–6 as observed in the first total free recall test. Since these lists, in these groups, were fol-

lowed by the learning of from zero to five additional lists, Fig. 1 also presents a picture of the general retroactive inhibition effect observed in this experiment, showing how the percentage of words recalled from a list declined from approximately 70% in absence of any interpolated learning to less than 30% with three or more interpolated lists. Similar pronounced changes as a function of interpolated learning can be observed in the recall of categories, from approximately 90% in the single list to approximately 40% in lists whose learning was followed by the learning of three or more additional lists. The number of words recalled per category, however, showed no corresponding loss as a function of the amount of interpolated material, varying irregularly in the neighborhood of 75% in Group 1 and 68% in Group 6.

For the second example, lists learned by Groups 1–6 were divided into two classes: (*a*) those followed by no other lists, that is, the last list learned by each of the six groups and (*b*) those followed by at least one interpolated list and thus subject to experimentally manipulated retroaction. The mean number of words, categories, and words/category recalled from these two classes of lists in all three total recall tests, FR_1, FR_2, and CR, are presented in Table 1. Table 1 shows that the number of recalled words and number of recalled categories were (*a*) higher in the cued recall test than in free recall tests for all lists, (*b*) higher for lists subject to no retroaction than for lists subject to retroaction in both free recall tests, and (*c*) higher in FR_2 than in FR_1 for those lists subject to at least one list of retroaction. The corresponding differences in words/category measure were either absent or negligible.

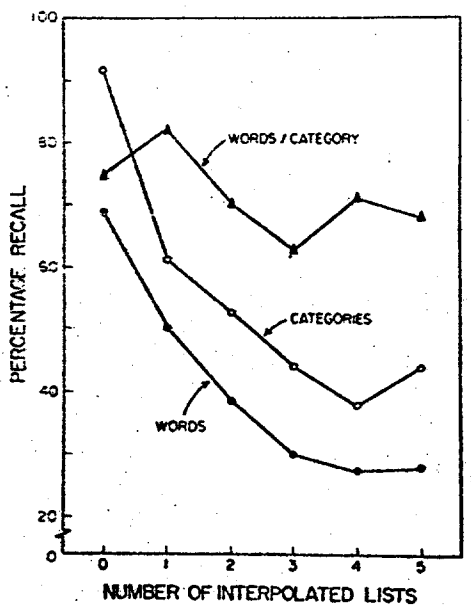

FIG. 1. The effect of interpolated learning of other lists on the recall of words, categories, and words within categories.

TABLE 1

MEAN NUMBER OF WORDS, CATEGORIES, AND WORDS/CATEGORY RECALLED IN THREE SUCCESSIVE TESTS FROM LISTS FOLLOWED OR NOT FOLLOWED BY OTHER INTERPOLATED LISTS

Unit	Number of interpolated lists	Recall test		
		FR_1	FR_2	CR
Words	0	15.92	15.55	18.22
	≥1	10.02	11.71	17.13
Categories	0	5.02	4.93	5.69
	≥1	3.29	3.76	5.55
Words/category	0	3.15	3.13	3.16
	≥1	2.97	3.06	3.04

Note.—Data pooled for Groups 1–6.

Since the words/category measure was practically constant for all lists on all recall tests, no further mention will be made of words/category results. Subsequent description and analysis of the findings will focus on the word recall measure. For all practical purposes, the category recall measure yielded results identical with those on the word recall measure.

Noncued Recall Tests

Summaries of the word recall data on the first and second total free recall tests are presented in Tables 2 and 3, respectively. Mean number of words recalled is shown for each ordered list in each of the eight groups. The main conclusions derived from these data are as follows:

1. Sizable amounts of retroactive inhibition were shown by each group learning two

TABLE 2

MEAN NUMBER OF WORDS RECALLED IN THE FIRST TOTAL FREE RECALL TEST

Group	Ordered lists						*M*
	1	2	3	4	5	6	
1D	15.7						15.7
1	16.6						16.6
2	12.1	17.2					14.7
3	9.4	10.8	15.4				11.9
4	7.1	10.0	11.4	14.8			10.8
5	6.6	9.6	10.7	13.1	17.1		11.4
6	6.8	9.6	8.6	10.3	14.2	14.4	10.6
6D	7.3	10.9	9.4	12.4	13.1	14.2	11.2

or more lists. Number of words recalled from a list was an inverse function of the number of interpolated lists.

2. No evidence for proactive inhibition was observed. Indeed, the trend in the data was toward proactive facilitation: With the amount of retroaction held constant, at a level greater than zero lists, recall of a list tended to be higher, the greater the number of lists learned prior to the list in question. Table 2 shows, for instance, that List 1 in Group 2 yielded the mean of 12.1 words recalled, while List 5 in Group 6, also subject to one list of retroaction but learned following four other lists, yielded the mean of 14.2 recalled words. The tendency toward proactive facilitation in presence of one or more lists of retroaction, that is, the Retroaction × Proaction interaction, was not quite reliable statistically, but it closely resembles a similar finding in the Tulving and Thornton (1959) experiment and in a recent experiment by Shuell and Koehler (1970).

3. No statistically reliable forgetting was observed over an interval of 20 min. filled with "neutral" activity in Group 1D, which learned a single list. (The mean number of words recalled in the immediate test by Group 1D was 16.6) Furthermore, no forgetting occurred over the 10-min. retention interval preceding the FR_1 test in Group 6D. All decrements in recall that did occur can thus be safely attributed to interpolated learning of other lists.

4. Recall was higher in the FR_2 test than in the FR_1 test for lists whose learning had been followed by at least one other list, a fact already noted in Table 1. Such "spontaneous recovery" occurred in each of the 15 relevant lists in Groups 2–6, the overall increase amounting to approximately 17%. The "recovery" was completely absent for lists learned last by each group.

5. Comparison of word recall data from Groups 6 and 6D suggests that "recovery" in lists subject to retroaction was to a large extent attributable to the 10-min. interval between the two total free recall tests. The mean increase for the first five lists from the FR_1 test to the FR_2 test was 1.82 in Group 6, and .52 in Group 6D. A three-way analysis of variance with groups (6 and 6D), lists (1–6), and tests (first and second) as treatment variables yielded a significant Groups × Tests interaction, F (1, 180) = 5.07, $p < .05$, although the Groups × Lists × Tests interaction was not significant ($F \cong 1.0$). Lists and tests, of course, were highly significant in this analysis, F (5, 150) = 10.87 and F (1, 180) = 19.44, respectively.

Cued Recall Test

The cued recall data are summarized in Table 4. The pattern of the data in Table 4 shows that the retroactive inhibition effects so apparent in the preceding free recall tests largely disappeared in the cued test One-way analyses of variance done separately for each group that had learned more than a single list yielded only one significant effect for lists, namely in Group 4, F (3, 45) = 2.85, $p < .05$. Moreover, it was only the recall of the first list in each of Groups 3, 4, 5, 6, and 6D that was out of line with

TABLE 3

MEAN NUMBER OF WORDS RECALLED IN THE SECOND TOTAL FREE RECALL TEST

Group	Ordered lists						*M*
	1	2	3	4	5	6	
1D	16.4						16.4
1	16.6						16.6
2	13.9	17.2					15.6
3	11.4	13.3	14.4				13.1
4	9.8	11.2	12.1	14.0			11.8
5	9.0	11.8	11.7	13.8	16.2		12.5
6	9.0	11.2	11.4	11.7	14.3	14.9	12.1
6D	8.1	11.1	10.1	12.4	14.0	14.4	11.7

TABLE 4

MEAN NUMBER OF WORDS RECALLED IN THE CUED RECALL TEST

Group	Ordered lists						M
	1	2	3	4	5	6	
1D	17.6						17.6
1	18.1						18.1
2	20.5	20.2					20.4
3	16.4	17.7	17.1				17.1
4	15.4	17.2	18.3	17.6			17.1
5	16.2	17.6	17.5	16.9	18.3		17.3
6	16.1	16.8	16.4	17.5	16.2	17.9	16.8
6D	15.9	17.1	17.7	17.8	18.4	17.2	17.4

other lists. The mean cued recall of these five lists, calculable from Table 4, was 16.0, while the mean cued recall of the last list learned by each of the eight groups was 18.0, and the mean for all other lists, whose learning had been followed by at least one interpolated list, was only slightly less at 17.6. The three corresponding means in the FR_1 test, as determined from Table 2, were 7.4, 15.7, and 11.1, respectively. The comparison of the free recall and cued recall means for these three mutually exclusive subsets of lists illustrates and conveniently summarizes one of the major conclusions of this experiment: Retroactive inhibition observed in free recall reflects inaccessibility of relevant event information, since no such inhibition occurs in cued recall.

Other Data

There were virtually no intrusions that did not fit the categories contained in lists. The mean number of extralist intrusions per *S* per list was .59 in the FR_1 test, .79 in the FR_2 test, and 1.66 in the cued recall test.

The order of recall of words from different lists by groups recalling more than one list, in the two noncued tests, was also examined and quantified, using the method described by Postman and Keppel (1967). In the FR_1 test, *S*s tended to recall their last-seen list first, and first-seen list last, confirming similar observations by Postman and Keppel for their two-list group, while this tendency all but disappeared in the FR_2 test.

DISCUSSION

Two major conclusions emerge from the data. First, retroactive inhibition in free recall of categorically organized lists represents a decrement in recall of categories without any significant reduction in recallability of words within recalled categories. Second, retroactive inhibition in free recall of categorically organized lists reflects inaccessibility of relevant event information rather than loss of that information from the store. The two conclusions are logically unrelated, but psychologically they can both be subsumed under a general principle: Retroactive inhibition in free recall of organized lists represents a state of memory in which higher order units of information are available but not accessible.

It would have been quite possible to think, before doing this experiment, that learning of other lists following the learning of a particular list would produce retroactive inhibition consisting of lowered recall of both categories and words within recalled categories. The actual finding that retroaction under the free recall conditions of the present experiment affected primarily higher order S-units, that is, categories rather than individual words, therefore, tells us something we did not know before. The finding is also worthy of attention because of its close parallel with a finding reported by Tulving and Pearlstone (1966): Smaller proportions of words are recalled from categorically organized lists of 48 words than similar lists of 24 words, but the difference is independent of recall of words within recalled categories, being completely accounted for in terms of recall of categories only. Thus, immediate recall of a part of a single list appears to be affected by storage of other parts of the same list very much as recall of one list is affected by storage of other lists. In both cases, storage of other categorically grouped words reduces the accessibility of higher order units of information without affecting recall of words within these units. One implication of this kind of a picture of inhibition of recall is that if categories of one list are readily accessible, interpolation of another list produces no retroactive inhibition, while loss of access to categories, as may happen over a longer retention interval, should lead to a decrement in recall. Such data have been reported by Winograd (1968).

A strong implication of the state of affairs just described is that words in a given category, that is, a higher order unit, are, in some as

yet unknown sense, "stored together." Under these conditions, retrieval of one member of the higher order unit necessarily means retrieval of the whole unit. The *S* may recall individual members of the larger aggregate sequentially, one word at a time, as he always must "recall" letters or phonemes of a retrieved word sequentially, one letter or phoneme at a time; but in both cases the separation of what, at the level of overt behavior, correspond to individual parts of the stored unit may well take place at a stage *following* the act of retrieval of the whole unit as such. Recall of higher order units, in the present experiment as well as in others (e.g., Cohen, 1966; Tulving & Pearlstone, 1966), is "all-or-none" since the memory traces of its constituents exist in the store only as integral components of the aggregate trace of the higher order unit and cannot be retrieved without affecting the whole unit (cf., Slamecka, 1968).

Sizable amounts of retroactive inhibition observed under the conditions of free recall all but disappeared when appropriate retrieval cues were introduced. Such an outcome suggests that retroactive inhibition observed under free recall conditions represents an instance of cue-dependent forgetting. At least, we think that retroactive inhibition occurred in the present experiment solely because of inadequate retrieval cues and not because of a "weakening of traces" or "unlearning of responses."

The unlearning-recovery version of the interference theory (Keppel, 1968; Postman & Keppel, 1967; Shuell, 1968) does not appear to be able to handle these data, since the theory does not contain any constructs corresponding to experimentally manipulable retrieval cues. Both in paired-associate and free recall learning, the stimuli to which the learned responses are thought to become attached are always present, and observed decrements in recall are thought to reflect the "unlearning" of learned associations. Our data imply that something is missing in the recall environment at the time of the total free recall test that would permit *S* to retrieve all of the stored information, but it is unclear exactly what kinds of associations are involved and how.

The response-set suppression version of the interference theory (Postman, Stark, & Fraser, 1968; Postman & Stark, 1969) would also have some difficulty in accommodating the findings from the present experiment, since it, too, so far has failed to consider the role of retrieval cues in providing access to available information. But otherwise, it appears to be more readily applicable to the present situation. The "suppressed response sets" parallel the available but inaccessible mnemonic information coded by lists, "selector mechanism" corresponds to the retrieval system guided by retrieval cues that provide access to such information, and its "inertia" reflects the lack of appropriate retrieval cues. The presentation of category names as retrieval cues in a memory task, such as the one used in our experiment, frees the selector mechanism from the lingering influence of the most recently learned or recalled list by recreating the original encoding pattern of which each to-be-remembered word is an integral part, and thus brings about the recovery of "suppressed" responses. The "spontaneous" recovery of suppressed responses that we observed in the second total free recall test—a finding highly compatible with the general spirit of the response-set suppression theory—is explainable in a similar vein.

The development of the interference theory along these lines—conceptualization of recall failure as reflecting inaccessibility of available information because of insufficient or inappropriate retrieval cues—would mean that two fundamental conditions of decrements in retention, "interference by intervening activities" and "altered stimulating conditions" (McGeoch, 1942, p. 457), can be reduced to one: altered stimulating conditions brought about by intervening activities. This generalization seems to fit our findings quite well, and it is not impossible that it might also describe the basic cause of forgetting in many other situations.

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