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STUDIES FROM THE PSYCHOLOGICAL LABORA-
TORY OF THE UNIVERSITY OF CHICAGO

Some Factors Determining the Degree of Retroactive Inhibition

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CHAPTER I

HISTORICAL INTRODUCTION

This study is concerned with the fact that the interpolation of certain forms of activity between learning and recall may positively accelerate the forgetting process. The general phenomenon is clearly demonstrated in the *retroactive inhibition* of Müller and Pilzecker¹ and in the *retrograde amnesia* of the psycho-pathologists. Taken together the several investigations of this problem that have been made during the past twenty years prove conclusively that a positive acceleration of the forgetting process does occur under certain conditions of interpolation. Just what those conditions are, however, still remains doubtful. Müller and Pilzecker, who were the first experimentalists to study this matter directly, made a number of generalizations which later work has failed to verify with anything like completeness. In light of this it has been my purpose to re-examine the facts of the case with fresh methods in order to extend or qualify previous statements.

THE EFFECT OF SIMILARITY BETWEEN ORIGINAL LEARNING AND THE INTERPOLATED ACTIVITY

Müller and Pilzecker made the statement that retroactive inhibition, as they obtained it, is not due to the similarity of the original learning to the interpolated activity. They worked with the conventional nonsense syllable material. After the study of a given series of syllables, a definite time interval was allowed to elapse before the test for the series was made. This interval was given over to "rest" or to some form of mental activity, usually the study of a second series of syllables. Both the "Right Associates" and "Saving" methods were employed. In the former case recall time was measured by means of a Hipp chron-

¹ Müller, G. E., and Pilzecker, A., *Zeitschrift für Psychologie, Ergänzungsband I*, 1900.

oscope and sound-key. Retention after work is compared with retention after rest in eight slightly differing instances. The results show that recall of a previously learned list of syllables is not as complete nor as rapid after a period of prescribed mental activity as it is after a period of rest, *i. e.*, a period during which activity is free except for the fact that the original syllables must be kept out of mind. In all but two of the experiments of Müller and Pilzecker interpolated work consisted in the study of a series of syllables. The two exceptions, however, are crucial in the minds of these investigators. In both cases the subjects studied pictures instead of syllables during the interpolated period. The process was memorial in that the subjects were called upon to describe the pictures after they were removed from view. The results here show that recall is not so good after studying the pictures as it is after an equal period of so-called rest. Moreover, a comparison of these results with those where syllables were studied during the interpolated interval shows that the forgetting process is as much accelerated in one case as it is in the other. Upon this fact Müller and Pilzecker based their conclusion that there is no relationship between similarity of interpolated activity to original learning and the amount of retroactive inhibition.

Fräulein Heine,² with methods very much like those of Müller and Pilzecker, obtained results which in the main substantiate those of the earlier investigators. Nineteen experiments in recognition memory showed no evidence of retroactive inhibition. Positive results were obtained, however, from a series of experiments in recall memory. The "Right Associates" and "Saving" methods were employed. For interpolated work the subjects studied pictures, lists of four-place numbers, or consonants. The main memorized material was again nonsense syllables. All forms of interpolation show inhibition as compared with rest. Unfortunately Heine's experiments were so arranged that no accurate estimate can be made of possible differences in effectiveness between the forms of interpolated work which she intro-

² Heine, R., *Zeitschrift für Psychologie*, 68, 1914, pp. 161-236.

duced. Unfortunately, too, her results give no basis for comparing the effectiveness of interpolated work similar to the original learning with that of interpolated work comparatively dissimilar to the original learning. Probably she accepted the comparison made by Müller and Pilzecker as needing no further test.

Before Heine's work was published in full, DeCamp³ carried out a series of experiments which he hoped might give more exact definition to the conception of retroactive inhibition formulated by Müller and Pilzecker. In most of his experiments DeCamp used nonsense syllables for original learning and multiplication for interpolated work. DeCamp's results, unlike those of Heine, show little evidence of retroactive inhibition being at work. On the whole recall after rest is better than recall after work, but, considering the individual experiments, this result is not very decisive. DeCamp concludes from his own results that retroactive inhibition is of questionable importance where original learning and interpolated work are of a different nature. He suggests that the effects of retroactive inhibition may vary directly as the similarity of interpolated work to the learning. This is by way of an aftermath, however, since he has no data to support this hypothesis except in the negative sense that he obtained little inhibition where learning and interpolated work were dissimilar.

Tolman,⁴ like DeCamp, was interested in further investigating retroactive inhibition where interpolated work and original learning are comparatively dissimilar. The originally memorized materials were words, numbers and nonsense syllables. For interpolated work the subjects memorized numbers or consonants. The method of "Right Associates" was used throughout. Although no attempt was made to compare the effects of similar and dissimilar interpolated work, the results throw further light upon DeCamp's suggestion that retroactive inhibition is of doubtful importance where interpolated work and original learning are

³ DeCamp, J. E., *Psychol. Monog.*, 1915, 19.

⁴ Tolman, E. C., *Psychol. Monog.* 1917-1918, 25.

dissimilar. Tolman's results are more in accord with those of Müller and Pilzecker and Heine. Out of eleven experiments bearing on this point, eight give positive evidence of inhibition being present, two are ambiguous, while one shows better recall after work than after rest. Thus, under certain conditions at least, the retroactive effects of dissimilar interpolated work may be quite marked.

Webb⁵ and Brockbank⁶ studied the effects of interpolated activities upon the retention of motor habits. Both used mazes for the original learning. Webb, who worked on both rats and humans, employed similar interpolation, *i. e.*, the mastery of other mazes. His results are positive. The learning of a second maze has a disintegrating effect upon a maze previously learned for all but 37% of his subjects in one experiment and for all but 26.7% in another. In Brockbank's investigation, where only rats were used, the interpolation was comparatively dissimilar to the original learning. After acquiring a maze habit his test group began practice on a rope-ladder problem. A comparison of the retention of the original maze habit by this group with that of a group which did not work on a second problem shows a lack of disintegrating effect for the interpolated learning. In fact the rats who learned the second problem show better retention than those who did not. The positive findings of Webb and the negative findings of Brockbank (that is, negative so far as a disintegration process is concerned) suggest that at least in the field of motor learning there may be a very real relationship between the similarity of interpolated activity to original learning and the amount of retroactive inhibition.

Von Kries,⁷ E. Meyer,⁸ Bigham⁹ and McC.Gamble¹⁰ mention indirectly the disintegrative effects of interpolated activities, but they bring out few facts which throw any light upon the results of the major investigations in this field.

⁵ Webb, L. W., *Psychol. Monog.*, 1917, 24.

⁶ Brockbank, T. W., *Behav. Monog.*, 1919, 4.

⁷ and ⁸ See Müller and Pilzecker, S. 194 and DeCamp, p. 7.

⁹ Bigham, J., *Psychol. Rev.*, 1894, 4.

¹⁰ McC.Gamble, E. A., *Psychol. Monog.*, 1909, 10.

It seems then that aside from the meagre results of Müller and Pilzecker and a rather questionable comparison of the results of Webb and Brockbank, we have no grounds for generalizing about the influence similarity between interpolation and learning may have on the process of forgetting. Evidently the problem demands further experimentation.

TEMPORAL POSITION OF INTERPOLATED WORK

In an experiment with a single subject Müller and Pilzecker compared the amount of retroactive inhibition where the interpolated work followed 17.2 seconds after memorizing with the amount of retroactive inhibition where the work followed 6 minutes after memorizing. Considering amount of recall, the inhibition is greater under the first condition. The average recall time shows the opposite result, but there are more very short recall times under the second condition. Müller and Pilzecker conclude from these not unequivocal results that the earlier the work is engaged in after memorizing, the greater is the resulting inhibition.

DeCamp was mainly concerned with the degrees of retroactive inhibition for different amounts and distributions of interpolated work. His results fail to verify the Müller and Pilzecker generalization regarding the effect of variation in the temporal position of interpolated work. Quite possibly, however, this is due to the fact that under few of DeCamp's conditions was retroactive inhibition clearly present.

INFLUENCE OF DEGREE OF LEARNING

Heine carried out seven experiments in order to discover the relationship between degree of learning and susceptibility to retroactive inhibition. Two of these employed the "Saving" method and five the method of "Right Associates." Each experiment was a comparison of the amount of inhibition present where original lists of nonsense syllables were given more or fewer repetitions. Each experiment used one subject and two degrees of learning. Her results in all cases show greater inhibition for the lists given the fewer repetitions. This fact suggests that the

amount of inhibition is inversely related to the degree to which the disintegrated material is learned.

INFLUENCE OF CONDITIONS OF LEARNING

Tolman studied the relationship between conditions of learning and susceptibility to retroactive inhibition. He measured this susceptibility under the following four pairs of conditions:

- (1) Pleasant vs. Indifferent Materials
- (2) Normal vs. Distracted Attention
- (3) With Caffeine vs. Without Caffeine
- (4) Efficient vs. Inefficient Working Periods

(1) The memorized material in this series of experiments consisted of word lists or lists made up of numbers and words. These lists, by reference to the words they contained, were pleasant or indifferent according to the judgments of a number of observers. Four experiments were carried out. In the first of these retroactive inhibition is plainly evident and it is greater for the indifferent lists. The next three experiments show little evidence for the presence of inhibition, but what evidence there is favors greater inhibition for the indifferent lists.

(2) In the single experiment under this head the subject learned lists of alternate nonsense syllables and words. As each pair of list elements was shown, a telegraph key clicked once, twice, or three times and the subject duplicated the taps by striking on the table with a pencil. Less inhibition is shown for lists learned under distracted attention, but the inhibition is so small in both cases that no certain conclusion can be drawn.

(3) In these experiments the subjects took one and one-half grain capsules of caffeine on alternate days and sugar of milk capsules on the days between. They were unaware of which were caffeine and which non-caffeine days. Of the two experiments conducted, both give some evidence for greater inhibition on the non-caffeine days.

(4) There were six experiments in the last group. Lists of nonsense syllables learned in a morning period were compared with lists learned directly after the midday meal or in the eve-

ning. The results are pretty clearly in favor of greater inhibition for the afternoon and evening lists.

It is evident from Tolman's work that susceptibility to retroactive inhibition is affected by the conditions of learning. Under what he calls more stimulating conditions of learning—learning pleasant material, learning after taking caffeine, learning in an efficient hour of the day—there is less probability of retroactive inhibition being effective than under less stimulating conditions—with indifferent material, without caffeine or in an inefficient hour of the day.

RELATIVE SUSCEPTIBILITY OF MEN AND RATS TO RETROACTIVE INHIBITION

In Webb's work human subjects show greater susceptibility to retroactive effects than do rats. Under six conditions where comparison is possible a larger percentage of human subjects manifested some degree of what Webb calls negative retroaction. In three groups of human subjects 100% of the individuals were affected, while in no instance were all the rats of a group affected. In terms of absolute and relative loss the average disturbance for the human groups is clearly greater than for the rat groups.

DIRECTION OF ACQUIRING TWO HABITS AND RETROACTIVE INHIBITION

Webb's experiments were so arranged that he could determine whether the retroactive effects of two activities upon each other were the same or different. For instance, it was possible to compare the effect of learning maze B after maze A upon the relearning of A with the effect of learning maze A after B upon the relearning of B. Various pairs of conditions or sequences, as A — B and B — A, were ranked according to the amount of retroaction present. While the correlations between these rankings are not perfect, Webb concludes that they are high enough to indicate that direction of learning is not a deciding factor in determining the amount of retroactive inhibition.

INFLUENCE OF THE DIFFICULTY OF INTERPOLATED ACTIVITY

Webb found that the easier an interpolated maze is mastered the greater is the resulting negative retroaction. His various mazes were ranked in their order of difficulty. They were also ranked according to their retroactive effects. Correlation coefficients were calculated between the two sets of values. Five out of six coefficients are negative. Three of these are — 1.00 and the other two are between — 1.00 and — .60.

TRANSFER AND RETROACTION

According to Webb's findings there is a negative correlation between positive transfer and negative retroaction. The mazes used in the retroaction experiments had previously been used in transfer experiments. These mazes could be ranked, therefore, according to both the positive transfer and the negative retroaction shown by them. Twenty-four pairs of such variables give twenty-one negative correlations. Five of these are — 1.00, seven are between — 1.00 and — .70, and the remainder are around — .50. Webb concluded from this that the greater the assistance rendered by a first maze in the mastery of a second maze, the less disturbance there will be in relearning the first maze. The same relationship is apparent in comparing humans and rats in transfer and retroaction. The human subjects show greater susceptibility to negative retroaction and also less susceptibility to positive transfer.

PATHOLOGICAL CONDITIONS OF RETROACTION

The acceleration of the forgetting process due to organic brain diseases, epileptic attacks, hysterical attacks, convulsions, severe blows on the head, or emotional shocks is the topic of a familiar chapter in abnormal psychology. *Retrograde Amnesia* is the term usually employed to designate this group of phenomena. The literature of the subject abounds in concrete illustrations. For example: "While in an intoxicated condition a man received a blow on the head while resisting arrest. Following the injury

he was unconscious for eight or ten hours, and on regaining consciousness found that he was unable to recall any events of the week previous. The memories of the amnesic period have never spontaneously returned, although a period of several years has elapsed. His only knowledge of the events of the week comes through information gathered from friends."¹¹ Similar illustrations might be cited of the retroactive effects of other disturbing conditions.

In this connection it might be well to mention that cases of Retroactive Hypermnnesia have also been observed.¹² In such cases commonplace and relatively insignificant events taking place before some shock or emotional crisis are afterwards recalled with unusual vividness.

THEORIES OF RETROACTIVE INHIBITION¹³

(1) *The Perseveration Theory.* Müller and Pilzecker believed that the processes underlying perseveration and retroactive inhibition are the same. According to this theory memorizing is followed by a period of gradually diminishing activity of the neural elements involved in the memorizing. Evidently this after-activity is of vital importance in the setting-in of the memory pattern. Now, the introduction of any kind of strenuous mental work while this setting-in is still going on will interfere in some way with the progress of the setting-in process. Memorized material, therefore, will not be as well retained where memorizing is followed by mental work as where it is followed by comparative rest. As the after-activity diminishes gradually, the deleterious effects of interpolated work will vary inversely as the time elapsing between the end of memorizing and the beginning of the work. This theory is supported by two of the findings of Müller and Pilzecker: (1) One kind of strenuous mental work gives as great inhibitory effects as another, although they differ decidedly in their relative resemblance to the original

¹¹ Coriat, I. H., *Abnormal Psychology*, 1910, p. 183.

¹² Stratton, G. M., *Psychol. Rev.* 1919, 26.

¹³ In presenting these theories I have not in all cases attempted to use the exact language of the writers referred to.

memorizing; and (2) Interpolated work beginning 17.2 seconds after memorizing shows greater inhibitory effects than interpolated work beginning 6 minutes after memorizing. This explanation of retroactive inhibition has received rather wide acceptance, but it should be remembered that the experiments from which Müller and Pilzecker derived their most critical results are not very convincing from a quantitative point of view. Furthermore, later work, while it has disproved none of their main tenets, has yet failed to verify them.

(2) *The Transfer Theory.* DeCamp suggested that the small amounts of inhibition which he obtained might be explained by an extensively modified form of a theory commonly used to explain transfer of training. "From the neurological standpoint, in the learning of a series of syllables, we may assume that a certain group of synapses, nerve cells, nerve paths, centres, etc. are involved. Immediately after the learning process the after-discharge continues for a short time, tending to set the associations between the just learned syllables. Any mental activity engaged in during this after-discharge, involving or partially involving the same neurological group, tends, more or less, to block the after-discharge and to give rise to retroactive inhibition. Engagement in any mental activity involving a new—so far as it is new—group of synapses, neurones, etc., would allow the setting-in process of the just excited group to proceed unhindered. The effect of retroactive inhibition would vary directly as the relative identity of the neurological groups involved."¹⁴ This theory can not be taken literally, of course, because, in progressing toward greater and greater identity of neurological groups, we must reach a point where the good effects due to repetition are greater than the bad effects due to interference. It may hold, however, within certain limits.

DeCamp's theory differs from that of Müller and Pilzecker in that the inhibition is supposed by him to be a function of the relative identity of original memorizing and interpolated work, rather than of the difficulty of the interpolated work. The two

¹⁴Op. Cit. p. 62.

theories are alike in that both consider the interruption of a setting-in process as the primary cause of the disintegration or inhibition.

(3) *Other Explanations.* Webb has suggested two explanations of retroactive inhibition in terms of transfer without reference to a possible setting-in process following memorizing. In the first place, certain elements in the original learning process may become transferred from the pattern of the original learning to the pattern of the interpolation, so that the recall of the originally learned material is interfered with. In the second place, there may be a transfer of elements of the interpolation to the situation in which the original material is recalled. This introduction into the recall of certain extraneous elements may have deleterious effects. Webb points out that there is no theoretical reason why these effects should always be deleterious; they may conceivably be facilitative as well as inhibitory.

There are still other explanations which may be applied to special cases of accelerated forgetting. Where the interpolated activity is very strenuous, the general efficiency of the organism may be so low that the process of recall can not function normally. Where, as in many cases of retrograde amnesia, the interpolation supposedly causing disintegration is distinctly pathological, the impressionability of the organism may be subnormal for some time before the evident onset of the pathological state.

EVALUATION OF CURRENT THEORIES

A consideration of current theories of retroactive inhibition, or whatever one chooses to call it, in light of our empirical knowledge indicates that none of these theories has any great amount of factual support. Further observations are necessary before we can accept any one of them either as it stands or in modified form. It is quite possible, too, that no single theory may ever suffice and that radically different explanations may have to be formulated for the different conditions under which the forgetting process is positively accelerated.

THE MOST IMMEDIATE PROBLEMS

The subject of retroactive inhibition offers almost limitless opportunities for investigation. But two problems, it seems to me, especially deserve attention: (1) The relationship between retroactive inhibition where learning and interpolation are similar, and retroactive inhibition where the two are comparatively dissimilar; and (2) The influence of the temporal position of interpolated work upon the degree of retroactive inhibition. Experiments on both of these topics are included in the present study. There is also a third investigation which deals with the susceptibility to retroactive effects of materials learned with varying degrees of completeness.

CHAPTER II

EXPERIMENTS WITH INTERPOLATION SIMILAR AND DISSIMILAR TO ORIGINAL LEARNING

Three experiments were conducted to determine whether the degree of retroactive inhibition is in any way related to the similarity between the interpolation and original learning. This question, as I have pointed out, has already received both an affirmative and a negative answer. But the affirmative answer given by DeCamp has no basis in experimental fact, and Müller and Pilzecker's negative answer is based upon very limited data.

EXPERIMENT I

MATERIALS, METHODS, AND SUBJECTS

The originally memorized material consisted of series of eight four-place numbers. These series were made up by chance, with the following limitations:

- (1) No digit within one number occurs in the immediately preceding or following number.
- (2) No digit occurs twice in the same number.
- (3) No digit immediately precedes another digit one more in value.
- (4) The numbers 1357, 2468 and 3579 were never used.

Each number series was typed on a three-by-five-inch card. The presentation was simultaneous and the subject was given the following instructions:

"I have here a series of four-place numbers. You will have three minutes during which to study them. Later I shall ask you to reproduce in proper order as many of these numbers as you can."

Three minutes after presenting the number series the experimenter removed it from before the subject and directed him to engage in one of five forms of interpolated activity for a period of three minutes. An average of approximately 15 seconds

elapsed between the end of the three minutes of original memorizing and the beginning of the three minutes of interpolated activity. The interpolated activities and the directions the subject received for each were as follows:

(A) *Numbers*—Memorizing a second series of four-place numbers.

Directions: "I have here another series of four-place numbers. You will have three minutes during which to study them. Later I shall ask you to reproduce in proper order as many of these numbers as you can."

(B) *Consonants*—Memorizing a series of twenty consonants arranged in a vertical column. Each series was a chance arrangement of all the consonants except w. No consonant, however, immediately followed or preceded a consonant adjacent to it in the alphabet.

Directions: "I have here a series of consonants. You will have three minutes during which to study them. Later I shall ask you to reproduce in proper order as many of these consonants as you can."

(C) *Poetry*—Memorizing a passage of descriptive poetry. Each of the three passages used was selected from Sir Walter Scott's *Rokeby*. They were the first 18 lines of Stanza XVII, Canto Second, the first 18 lines of Canto Fifth, and the first 20 lines of Canto Sixth.

Directions: "I have here a passage of poetry. You will have three minutes during which to study it. Later I shall ask you to reproduce as much of this poetry as you can."

(D) *Multiplication*—Solving four-place by four-place multiplication problems. Three sets of twelve problems each were used. Each problem was a chance arrangement of the eight digits from 2 to 9 inclusive. Each set was typed on a sheet of paper which allowed ample space for the subject's calculations.

Directions: "I have here a series of multiplication problems. You will have three minutes during which to work on them. Work as accurately and as rapidly as you can."

(E) *Reading*—Reading simple narrative prose with no at-

tempt to memorize. The following three stories by Richard Harding Davis were used: Miss Delmar's Understudy, The Editor's Story, and The Man with One Talent.

Directions: "I have here a story. You will have three minutes during which to read in it. Read naturally and make no attempt to memorize what you read." The subject began his reading at the beginning of the story with which he was presented.

In all cases the subjects were unable to finish with the material upon which they were working during the three-minute interpolated interval.

Immediately after the three-minute interpolated period, the experimenter placed pencil and paper before the subject and said: "Write here in proper order as many as you can of the series of numbers (or "first series of numbers" in case the interpolated activity was also memorizing a number series) which you studied. Work as accurately and rapidly as you can." These directions took about 8 seconds. By means of a stop-watch the experimenter measured the time between the end of his directions and the subject's signal that he was through with the reproduction.

As soon as the subject had completed his work on the reproduction of the original number series he was asked for a reproduction of the interpolated material where, as in (A), (B), and (C), it was of a sort to be memorized.

The plan of the experiment can be seen as a whole in the following outline:

- Step (1) Directions for original memorizing.
- Step (2) Memorizing numbers—3 minutes.
- Step (3) Directions for interpolated activity—approximately 15 seconds.
- Step (4) Memorizing numbers,
Memorizing consonants,
Memorizing poetry, —3 minutes
Multiplying, or
Reading.
- Step (5) Directions for recall of the original material—approximately 8 seconds.

Step (6) Recall of original number series.

Step (7) Directions for recall of interpolated material.

Step (8) Recall of interpolated material.

Four-place numbers were chosen for original memorizing because of the ease with which lists of fairly constant difficulty could be prepared, and because pairs of such lists selected at random seemed more apt to have, between the members of each pair, a constant degree of similarity than pairs of lists of, say, non-sense syllables.

The interpolated activities employed were selected as fairly representative of activities which may operate retroactively in similar real-life situations. Memorizing numbers was selected because of its close similarity to the original memorizing. Memorizing consonants was selected as like the original memorizing in that it is comparatively meaningless, although the two are unlike in content. Memorizing poetry is like the original memorizing in that it, too, is memorial, but it is much more meaningful. Multiplication is non-memorial, but it is similar to the original memorizing in content, *i. e.*, numbers are manipulated in both. Reading simple prose was selected as approximating the *passive* condition which other investigators have taken as *rest*. It seemed unwise to employ day-dreaming or undirected thought for two reasons: (1) Most of my subjects were inexperienced, and (2) Even with experienced subjects some objective control of *rest* was desirable.

All of the subjects stated that they never rehearsed the original number series during the interpolated interval. Now and then a subject would report that one or two of the numbers had come to mind, involuntarily as it were, during the interpolation.

Fifteen subjects served in the present experiment. There were eight women and seven men. Five men and five women were undergraduates in the University of Cincinnati, one man was an undergraduate in the University of Chicago, and three women and one man were graduate students of psychology in the University of Chicago. None of the subjects was aware in any detailed way of the purpose of the experiment.

Each of the fifteen subjects went through each of the five conditions of the experiment three times. The regular experimentation was preceded by five sittings at which the subjects obtained practice in studying and reproducing series of four-place numbers. During this practice the study period was three minutes in length, and recall came immediately after the completion of the study period. Only one series of numbers was studied at each of the practice sittings. Before the completion of the practice most of the subjects formulated a study method which they followed throughout the experiment.

A further precaution was taken to guard against effects which practice might have on the final results. The subjects were divided into three groups of five each. Each subject within a given group went through the five conditions in different order, so that each condition was favored by equal amounts of practice in the general procedure of the experiment. Table I shows the arrangement of experimental conditions for a single group during a single five-day cycle. Subsequent cycles to the first were repetitions of the same arrangement.

TABLE I

Subject		Day 1	Day 2	Day 3	Day 4	Day 5
1	Cond.	A	B	C	D	E
2	Cond.	B	C	D	E	A
3	Cond.	C	D	E	A	B
4	Cond.	D	E	A	B	C
5	Cond.	E	A	B	C	D

Experimentation, including preliminary practice, was conducted on five days (Monday to Friday) of four weeks. In the case of the first two groups the Thanksgiving recess made it necessary to suspend work during the fourth successive week. It was resumed and concluded, therefore, during the fifth week. The same conditions were adhered to in work with the third group, which was carried on a year later than the work with the other two.

On any given experiment day all subjects had the same number series for their original memorizing. This fact at least partially counteracted possible inequalities in the difficulty of different

series, for each interpolated activity was tested once with each series.

It was impossible to test all subjects at the same time of day, but, within any week, the sitting times for the individual subjects were kept practically constant. In three or four instances it was necessary, because of unpredictable circumstances, to omit a day's work during the regular week and add on a Saturday sitting, or to work with some individual from Tuesday until Saturday instead of from Monday until Friday.

The subjects were directed not to talk about the experiment to anyone until it was completed.

CRITERIA OF RECALL

In order to measure the degrees of retroactive inhibition present under the different conditions of the experiment, it was necessary to compare the efficiency of recalling the original numbers after the five kinds of interpolation. Three criteria of recall were selected: (1) Amount of Recall—the number of digits recalled irrespective of their correctness; (2) Error of Recall—the percentage of the total digits recalled which were incorrect or in incorrect position. Each four-place number which was one place removed from its correct position was counted as a single error. A four-place number more than one place removed from its correct position was counted as four errors. (3) Time of Recall—the total time taken for reproduction divided by the total number of digits given in the reproduction.

These criteria were employed in all of the experiments of this research except Experiment III.

RESULTS

The contents of Table II were obtained by averaging the records of the fifteen subjects. Each subject's record was determined by taking the average of his performance under each condition in the three cycles or weeks of the experiment.

By all criteria the interpolation of a second series of numbers has the greatest disintegrating effect upon a number series previously learned. Reading causes the least inhibition by the

TABLE II

CONDITION	AMOUNT	ERROR	TIME
Numbers	15.4 digits	27.5%	5.73 Secs.
Consonants	22.4 "	17.4%	3.07 "
Poetry	21.9 "	19.3%	3.57 "
Multiplication	22.1 "	15.7%	3.55 "
Reading	22.8 "	16.5%	3.03 "

amount and time criteria and next to least by errors. Poetry causes the next to most inhibition by all three criteria. Between consonants and multiplication there is little basis for differentiation. These two seem to lie somewhere between Poetry and Reading in the degree of inhibition shown. According to this table, then, Numbers shows the most inhibition, Poetry the next most, Consonants and Multiplication the next most, and Reading the least.

The conditions other than Numbers, however, differ from each other by amounts whose statistical certainty is questionable. Each average represents, in a sense, 45 individual measures and upon this basis it might seem profitable to evaluate these averages by the ordinary probable error method. On the other hand, the 45 measures are distributed among only 15 subjects. In other words the actual number of cases from which each average is figured is 15, too small a number about which to make any such assumptions as are required by a method reliably applicable only to normally distributed variables. It will be necessary, therefore, in further estimating the results of this experiment, to inspect the records of the individual subjects in some detail.

Tables III, IV, and V present for the three criteria the average performance of each of the fifteen subjects under each condition of interpolation. There are also entered in these tables the ranks of the different conditions according to the amounts of inhibition which they show. Where, under *Numbers*, a figure 1 appears in the column headed *Ranks*, it means that for the subject concerned recall was most disturbed after the interpolation of numbers. A rank of 5 means that a given subject, under a given condition, was disturbed least.

These tables will be examined with two main questions in

mind: (1) Does the interpolation of numbers clearly show more inhibition than the other conditions? and (2) Are there any convincing differences among those other conditions?

TABLE III
AMOUNT OF RECALL
(Total Digits)

SUBJECT	Numbers		Consonants		Poetry		Multiplication		Reading	
	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS
1	18.7	4	17.3	2	18.7	4	16.7	1	18.7	4
2	8.3	1	17.7	5	14.7	4	13.3	3	13.0	2
3	14.7	5	11.7	4	9.3	2	7.3	1	10.7	3
4	23.0	1	23.3	2	25.3	3	30.0	5	27.3	4
5	23.0	3	22.7	1.5	22.7	1.5	24.3	4	24.7	5
6	16.3	1	27.3	4	21.0	2	24.3	3	29.0	5
7	5.3	1	28.0	5	25.3	3.5	22.7	2	25.3	3.5
8	8.0	1	22.7	3	21.0	2	24.7	5	24.0	4
9	12.0	1	24.0	3	25.3	4.5	25.3	4.5	23.0	2
10	30.0	2	30.0	2	30.7	4	30.0	2	32.0	5
11	16.0	1	32.0	4	32.0	4	30.7	2	32.0	4
12	12.0	4	8.3	2	12.3	5	9.0	3	6.0	1
13	21.7	5	18.3	1	19.3	3	18.7	2	20.7	4
14	14.3	1	32.0	4	24.7	2	32.0	4	32.0	4
15	8.0	1	20.7	2	26.0	5	22.3	3	23.7	4

TABLE IV
ERROR OF RECALL
(% of Recall Erroneous)

SUBJECT	Numbers		Consonants		Poetry		Multiplication		Reading	
	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS
1	28	4	30	2.5	40	1	24	5	30	2.5
2	20	3	22	2	23	1	4	4	0	5
3	17	2	9	4	49	1	8	5	15	3
4	32	1	23	3	19	4	24	2	18	5
5	25	3	20	4	16	5	29	1.5	29	1.5
6	48	1	18	5	33	3	34	2	21	4
7	25	1	3	5	23	2	6	4	7	3
8	19	2	18	3	22	1	16	4	4	5
9	11	1.5	3	4	0	5	6	3	11	1.5
10	54	1	39	2	28	3	20	5	27	4
11	10	1	0	4.5	4	3	0	4.5	9	2
12	25	1	23	2.5	11	5	23	2.5	20	4
13	35	1	32	3	7	5	13	4	33	2
14	31	1	3	5	4	3.5	14	2	4	3.5
15	33	1	18	3	11	5	15	4	20	2

TABLE V
TIME OF RECALL
(*Av. Time in Secs. per Digit*)

	Numbers		Consonants		Poetry		Multiplication		Reading	
SUBJECT	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS
1	7.6	2	6.7	3	6.4	5	6.5	4	7.7	1
2	7.1	1	2.0	4	2.5	3	3.1	2	1.8	5
3	1.9	5	2.8	3	4.9	2	5.6	1	2.7	4
4	4.4	1	2.6	5	3.0	2	2.8	3.5	2.8	3.5
5	4.8	1	2.4	5	4.5	2	3.4	4	4.3	3
6	4.1	1	3.0	3	3.3	2	2.6	4	1.9	5
7	6.1	1	1.9	5	2.4	4	4.5	2	3.1	3
8	13.5	1	3.8	3	4.4	2	2.3	5	2.4	4
9	2.9	1	0.9	5	1.2	3	1.1	4	1.5	2
10	7.5	2	6.5	3	6.4	4	8.4	1	4.2	5
11	5.5	1	1.4	4	1.2	5	1.6	3	2.1	2
12	1.0	5	1.8	3	1.3	4	4.4	2	5.1	1
13	3.2	3	3.4	2	4.1	1	2.3	4	2.2	5
14	12.5	1	3.3	3	6.5	2	2.8	4	2.1	5
15	3.8	1	3.5	2	1.4	5	1.8	3	1.6	4

Considering Table III, it appears that nine out of fifteen subjects show the highest degrees of inhibition under the Numbers condition. One subject shows the greatest inhibition under Consonants, two under Multiplication, and one under Reading. With one subject there is a tie for greatest inhibition between Consonants and Poetry and with another a tie between Numbers, Consonants and Multiplication. The group as a whole, then, suffers the greatest inhibition after memorizing a second number series. Among those subjects who are not most affected by Numbers, the greatest inhibition is caused by now one and now another of the other conditions, with no quantitative emphasis upon any one condition in particular.

The lack of differentiation among the conditions other than Numbers is also seen upon considering the tendency of each of those conditions to cause least inhibition—to rank fifth. Reading shows least inhibition with three subjects, and Numbers, Consonants, Poetry and Multiplication with two each. The remaining subjects show ties for least inhibition among various conditions. These differences are no greater than might be expected by chance.

Table IV shows nine subjects in whom retroactive inhibition is greatest under the Numbers condition and a tenth is most affected by Numbers and Reading, the two being tied. With four subjects there is greatest inhibition under Poetry, and with one a tie for greatest between Multiplication and Reading. This would seem to indicate that Poetry stands somewhere between Numbers and the other conditions in the amount of inhibition which it causes. Such a conclusion is contradicted, however, by the fact that in this same table five subjects have least inhibition under the poetry condition, while only three subjects show the least inhibition in each of the conditions, Consonants, Multiplication and Reading.

From Tables III and IV, then, one can safely conclude only this much; that memorizing numbers causes a greater degree of retroactive inhibition than the other conditions, and that among those other conditions there are no significant differences.

Table V tells about the same story. Ten subjects suffer most in their recall after the interpolation of numbers. Of the other five subjects, two suffer most after Multiplication, two after Reading and one after Poetry, a result which shows no decided preference for any one condition. Reading is the best condition for five subjects, Consonants for four, Poetry for three, Numbers for two, and Multiplication for one. There is some evidence here that Reading is more favored than certain of the other conditions.

SUMMARY

By the criteria of amount, errors and time, memorizing a number series between the memorizing and recall of another number series causes marked disintegration of the first series. Memorizing consonants or poetry, or solving multiplication problems have approximately equal effects upon the retention of a number series. There is a slight chance that Reading causes interpolated period, as under the Multiplication condition, but this fact is not statistically certain. In other words, the experiment indicates *retroactive inhibition* where *original learning and interpolation* are highly similar, and little or none where they are

comparatively dissimilar. It is interesting to note that similar material (four-place numbers) may be dealt with during the interpolated period, as under Multiplication condition, but this fact alone does not insure any more retroactive inhibition than is obtained in certain cases where the interpolated material is quite dissimilar to the original memorizing.

EXPERIMENT II

MATERIALS, METHODS, AND SUBJECTS

The originally memorized material again consisted of series of four-place numbers. Series employed in Experiment I were also used in this experiment, since no subject served in both experiments. The method of presenting this material, the directions given the subject, and the length of time devoted to memorizing and to the interpolated activities (3 minutes for each) were the same as in the previous experiment.

Experiment II differs from Experiment I mainly in the interpolated activities used. The five interpolated activities and the directions given for each were as follows:

(A) *Four-Place Numbers*—This condition and the directions for it were the same as (A), Experiment I.

(B) *Digits*—Memorizing a series of 32 digits, the same number as contained in Condition (A), arranged in a single vertical column.

Directions: "I have here a series of digits. You will have three minutes during which to study them. Later I shall ask you to reproduce, in proper order, as many of these digits as you can."

(C) *Mental Multiplication*—Performing two-place by two-place multiplications. Each problem was made by a chance drawing of the digits from 2 to 9 inclusive.

Directions: "I am going to give you a multiplication problem. You work it in your head and give me the answer as soon as you are through. Then I shall give you another problem." This work was stopped as soon as the three minute period was up, whether the subject was in the midst of a problem or had just begun or finished one.

(D) *Pictures*—Observing attentively pictures of nudes. Two pictures were used, one for each of the two cycles of the experiment. They were colored reproductions (approximately 9 x 15 inches) of *Das Erwachen* by Anders Zorn and *Ruhende Nymphe* by Anselm Feuerbach.

Directions: "I have here a picture. You will have three minutes during which to look at it. Confine your attention to the picture during the entire three minutes."

(E) *Reading*—Reading in current editions of the *New York Times*.

Directions: "I have here a newspaper. You will have three minutes during which to read it. Read naturally and make no attempt to memorize what you read."

As in Experiment I, the interpolated period was followed by the reproduction of the original number series, and after that came the reproduction of the interpolated material, where it was of a sort to be memorized.

The interpolated activities of Experiment II were selected for various reasons. Four-place Numbers and Reading were selected for the purpose of making possible a comparison of the results of this with the results of the previous experiment. Less grounds were provided for comparing the results under Reading, of course, because the materials read differed in the two experiments, but Experiments IV and V, which had already been conducted showed that newspaper reading, like reading in short stories, causes comparatively little inhibition. The memorizing of a column of digits supplied a basis for comparing the influence of similarity of form with that of similarity of content upon retroactive inhibition. Mental Multiplication introduced a new factor into the interpolation of non-memorial numerical activity. Where the problems were done "in the head" rather than on paper, a certain sort of memorizing was required. That is, the results of completed operations had to be retained while other operations were in progress. The observation of pictures furnished an activity with some affective tone. (Most of the subjects showed some evidence of embarrassment during this

interpolation, which was probably due not alone to the nature of the pictures, but also to the fact that the experimenter was a comparative stranger.)

Ten subjects served in this experiment. All were men. Nine were juniors and seniors and one a graduate student in Yale University. None was aware of the purpose of the experiment.

Each subject went through each of the five conditions twice. The experiment proper was preceded by five sittings at which the subjects obtained practice in memorizing and reproducing four-place numbers. During this practice the study period was 3 minutes in length and recall was preceded by a 3-minute period of newspaper reading.

The subjects were arranged in groups of five after the manner of Experiment I.

The criteria of recall were the same as in the previous experiment, *i. e.* (1) Amount, (2) Error, and (3) Time.

RESULTS

Table VI gives the average amount, error, and time of recall after the five different interpolations. The table was made up by averaging the individual averages for each condition. Just as in Experiment I, memorizing a second series of four-place numbers shows the most inhibition by all three criteria. Reading again shows the least inhibition by two out of three criteria and next to least by the third criterion. The actual difference, however, between Reading, Pictures, and Mental Multiplication are slight. By all three criteria, Digits is next to Four-Place Numbers in the amount of inhibition shown.

That the results of this experiment and those of the first experiment are comparable is seen in the degrees of retroaction caused by four-place numbers in the two cases. Considering Reading as a norm, the percentages of retroaction caused by Four-Place Numbers, according to the criteria of amount, error, and time, are, in the first experiment, 32, 73, and 89 respectively, and in the second 29, 77 and 63. The agreement is close, especially for amount and error.

TABLE VI

CONDITION	AMOUNT	ERROR	TIME
Four-Place Numbers	15.3 digits	33.8%	5.50 Secs.
Digits	18.2 "	22.4%	4.30 "
Multiplication	20.6 "	21.5%	4.08 "
Pictures	20.6 "	22.3%	3.15 "
Reading	21.4 "	19.1%	3.38 "

In order to estimate the reliability of these results it will be necessary, as in the previous experiment, to turn to the individual records. These are presented in Tables VII, VIII, and IX. These tables were made up in the same way as Tables III, IV, and V.

TABLE VII
AMOUNT OF RECALL
(Total Digits)

SUBJECT	Four-Place Numbers		Digits		Multiplication		Pictures		Reading	
	AVER-		AVER-		AVER-		AVER-		AVER-	
	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS
1	16.0	1	20.0	2	24.0	3.5	24.0	3.5	24.5	5
2	16.0	3.5	15.5	2	14.5	1	16.0	3.5	21.5	5
3	9.5	1	13.5	2	20.0	5	10.5	3.5	19.5	3.5
4	6.0	1	8.0	2	12.0	3	18.0	5	16.0	4
5	14.0	1	18.5	2	22.0	3.5	26.0	5	22.0	3.5
6	29.5	3.5	27.5	2	29.5	3.5	19.0	1	30.0	5
7	19.5	2.5	19.5	2.5	16.5	1	20.0	4.5	20.0	4.5
8	10.0	1	24.0	5	22.0	3.5	22.0	3.5	20.0	2
9	18.0	1.5	18.0	1.5	26.0	5	21.5	4	20.0	3
10	14.5	1	18.0	2	20.0	3.5	20.0	3.5	20.4	5

TABLE VIII
ERROR IN RECALL
(% of Recall Erroneous)

SUBJECT	Four-Place Numbers		Digits		Multiplication		Pictures		Reading	
	AVER-		AVER-		AVER-		AVER-		AVER-	
	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS
1	56	1	24	3	28	2	18	4.5	18	4.5
2	49	5	58	3.5	58	3.5	64	2	70	1
3	58	1	28	2	0	4.5	8	3	0	4.5
4	6	5	44	1	28	3	33	2	22	4
5	28	1	3	5	16	3	25	2	13	4
6	12	3	6	4	14	2	19	1	3	5
7	40	1	31	2	19	3	15	4	10	5
8	35	1	22	3	25	2	5	5	16	4
9	28	2	0	5	5	4	31	1	19	3
10	26	1	8	4	22	2	5	5	20	3

TABLE IX
TIME OF RECALL
(*Av. Time in Secs. per Digit*)

SUBJECT	Four-Place Numbers		Digits		Multiplication		Pictures		Reading	
	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS	AVER- AGES	RANKS
1	6.6	1	6.2	2	5.9	3	2.6	4	2.4	5
2	0.7	5	2.8	1	2.5	2	2.2	3	1.3	4
3	18.4	1	9.7	3	7.0	5	8.3	4	11.8	2
4	1.6	2	0.8	4.5	0.8	4.5	1.2	3	2.0	1
5	2.8	1	2.7	2	1.4	5	1.8	4	2.0	3
6	3.2	2	2.4	3	5.8	1	1.7	5	2.3	4
7	5.4	3	8.0	2	8.6	1	4.7	4	2.5	5
8	2.4	4	2.8	2.5	2.8	2.5	2.0	5	3.4	1
9	6.1	1	3.2	5	3.6	4	4.2	2	3.9	3
10	7.8	1	4.4	2	2.4	4	2.8	3	2.2	5

Beginning with Table VII, we find six out of ten subjects suffering most under the Four-Place Numbers condition and another subject who is equally disturbed by Four-Place Numbers and Digits. Two suffer most after Mental Multiplication and one after Pictures. In other words, there is plain evidence of a greater amount of inhibition after Four-Place Numbers, but no marked differences are apparent among the other conditions. Four subjects are least affected by Reading, two each by Mental Multiplication and Pictures, and one by digits. Although Reading shows least inhibition, from a consideration of this table alone, there is little basis for differentiating among the conditions other than Four-Place Numbers.

According to Table VIII, six individuals out of ten are most affected by Four-Place Numbers, two by Pictures, and one each by Digits and Reading. Two each are least affected by Four-Place Numbers, Digits, Pictures, and Reading. One subject recalled with equal accuracy after Mental Multiplication and Reading, and another with equal accuracy after Reading and Pictures. Here again Four-Place Numbers cause appreciably more retroactive inhibition than the other conditions and again there are few or no apparent differences among those other conditions.

Table IX shows five subjects most inhibited by Four-Place

Numbers, two each by Mental Multiplication and Reading and one by Digits. Three subjects are least inhibited by Reading, two each by Mental Multiplication and Pictures, and one each by the other two conditions. One subject is equally little affected by Digits and Multiplication.

Digits show some tendency to rank second in degree of inhibition caused. This is especially marked in Table VII.

SUMMARY

Experiment II, like Experiment I, shows that there is decided retroactive inhibition where a second series of four-place numbers is memorized between the memorizing and recall of a similar original series. Among the other conditions, Reading shows the least inhibition. Although the odds in its favor are not great, the fact that it is the most advantageous condition in both experiments indicates that its superiority is probably real and not a matter of chance.

Memorizing columns of thirty-two digits causes more inhibition than observing pictures or engaging in mental multiplication. But it causes decidedly less than memorizing a second series of four-place numbers. The first experiment, in its comparison of the retroactive effects of memorizing numbers with those of multiplication, brought out the fact that the degree of retroactive inhibition is a function of similarity of process as well as similarity of content—that similar content in original memorizing and interpolation does not in itself guarantee any more inhibition than is obtained where these contents are comparatively dissimilar. The present experiment also shows but a small degree of inhibition for multiplication, even though, in this instance, the multiplication is to some extent a memorial process. The results of interpolating the memorization of vertical columns of digits add the further important fact that the degree of retroactive inhibition is markedly influenced by similarity in the forms of interpolated and originally memorized materials, as well as by similarity in their contents or in the processes involved. This finding is the more surprising when one recalls that nothing was said to prevent the subjects from learning the digits in groups of fours, if they wished to do so.

EXPERIMENT III

In the experiments so far reported there was plain evidence of retroactive inhibition where original memorizing and interpolation were very similar, and slight evidence of such inhibition for certain conditions where original memorizing and interpolation were comparatively dissimilar. The present experiment was planned to subject these findings to further test.

The writer planned and supervised this investigation. The actual experimentation was carried on by Mr. L. W. Muntz, a graduate student in psychology in Yale University.

The general procedure was suggested by DeCamp's Experiment XIII.¹⁵ He, as the reader will remember, was concerned only with the retroaction caused by dissimilar interpolation. In the experiment to which I refer he studied the effect of addition and other simple arithmetical operations upon the retention of a particular setting or form of chess men. Five men were used: a pawn, a knight, a bishop, a rook, and a queen. These men were placed in a chance arrangement upon a chess board and the subject was allowed fifteen seconds to study them. There followed a three-minute interval given over to (1) Rest (doing nothing) or to (2) Work (solving arithmetical problems for two minutes and resting for one minute). At the expiration of this interval the subject tried to reconstruct the form which he had previously studied. Time for this reconstruction was taken with a stop-watch. To quote DeCamp, "The error value for any chessman, in the reconstructed form, was obtained, speaking mathematically, by adding the differences between the ordinates and abscissae in the two cases, chess-board squares considered as units." DeCamp failed to find any evidence for retroaction in this experiment.

MATERIALS, METHODS AND SUBJECTS

Six chess-men were used in our experiment: king, queen, knight, rook, castle, and pawn. Half of the subjects worked with a chess-board 14 x 14 inches and half with a board 18 x 18 inches, but in each case the men used were proportionate in size

¹⁵ Op. Cit. pp. 57-60.

to the board. An ordinary focusing cloth was so arranged that, by pulling a string, it could be made to hide the board or uncover it. A stop-watch was used for all timing.

The men were given a chance arrangement on the board and then the subject was given one minute during which to study them. As soon as the minute was up the experimenter directed the subject (these directions took from five to seven seconds) to engage in one of the following interpolated activities for one minute:

(A) *Chess*—Studying another setting of chess-men, or as in the majority of cases, reconstructing a setting learned in a previous experiment of the same day.

(B) *Multiplication*—Performing mentally two-place by two-place multiplications.

(C) *Reading*—Reading selected passages from *American Government and Politics* by Robinson and Beard.

Immediately after the interpolated period the subject was again presented with the chess board and directed to place the men on the board in their proper places as quickly as possible.

Six subjects, four men and two women, served in the regular experiment. All were university students. The men were graduates and the women undergraduates. They were informed that tests were being made on their memories. Aside from this, they had no knowledge of the purpose of the work.

The subjects served every day for nine successive days. On each day each subject went through all three conditions of the experiment. Between tests for different conditions there were rest periods of about ten minutes, usually devoted to random conversation. Practically all of the experimentation was carried on between six and ten P. M.

The subjects were divided into two groups of three each. The arrangement of the experimental conditions for each subject on each day are shown in Table X. Since the arrangement was the same for each group of subjects, only one group is included in the table.

This arrangement was designed to eliminate inequalities in the

TABLE X
ARRANGEMENT OF EXPERIMENTAL CONDITIONS
EXPERIMENT III

Subject	Order	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9	
		Cond.	A	Cond.	B	Cond.	C	Cond.	B	Cond.	C	Cond.	A	Cond.	C	Cond.	A	Cond.	B
1	1																		
	2		" B		" C		" A		" C		" A		" B		" A		" B		" C
	3		" C		" A		" B		" A		" B		" C		" B		" C		" A
2	1		" B		" C		" A		" C		" A		" B		" A		" B		" C
	2		" C		" A		" B		" A		" B		" C		" B		" C		" A
	3		" A		" B		" C		" B		" C		" A		" C		" A		" B
3	1		" C		" A		" B		" A		" B		" C		" B		" C		" A
	2		" A		" B		" C		" B		" C		" A		" C		" A		" B
	3		" B		" C		" A		" C		" A		" B		" A		" B		" C

practice to which the various conditions or sequences of conditions were subjected. It may be said here, however, that our results show that there was, in reality, little need for this precaution. The records for the individual subjects seem practically independent of the positions which they occupied in their groups. Besides the arrangement of subjects and conditions as shown in Table X, there was also a methodical arrangement of the particular chance settings given the chess-men, so that each interpolation acted an equal number of times upon each setting.

RESULTS

Table XI gives the accuracy of each subject's reconstruction after the different kinds of interpolation. Each reconstruction is entered simply as C, if correct, and as E, if erroneous. Four subjects out of six give most correct reconstructions after Reading, one shows greatest accuracy after Multiplication, and one shows equal accuracy after Reading and Multiplication. Five out of six subjects give fewest correct reconstructions after Chess and one is equally inaccurate after Chess and Multiplication. Three out of six subjects show an accuracy after Multiplication lower than after Reading and higher than after Chess. Considering the data as a whole, *forty-nine out of fifty-four reconstructions are correct after Reading, forty-one out of fifty-four after Multiplication, and twenty-three out of fifty-four after Chess*. Retroactive inhibition is plainly at work under both the Chess and the Multiplication conditions, but a greater effect is evident in the case of Chess.

Table XII gives the same results as Table XI, but in even clearer terms. Under the day columns are entered the rankings of the three conditions according to the amount of retroactive inhibition shown by the time criterion. Where a given condition is entered as 3, it showed the least inhibition of the three conditions on that day; where it is entered as 1, it showed the most. Again one can make the generalization that Chess causes the greatest, Multiplication the next greatest, and Reading the least amount of retroactive inhibition. Every subject, without exception, gives

TABLE XI
CORRECT AND ERRONEOUS RECONSTRUCTIONS
C = Correct E = Erroneous

Condition	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Total Correct Reconstructions
<i>Subject 1</i>										
Reading	E	C	C	C	C	C	C	C	C	8
Multiplication	C	E	E	C	C	C	C	E	C	6
Chess	E	E	E	E	E	E	E	C	C	2
<i>Subject 2</i>										
Reading	C	C	C	C	C	C	C	C	C	9
Multiplication	C	E	C	C	E	C	C	C	C	7
Chess	C	C	C	E	C	C	C	E	C	7
<i>Subject 3</i>										
Reading	C	C	C	C	C	C	C	C	C	9
Multiplication	C	C	C	C	C	C	C	C	C	9
Chess	E	E	C	E	C	E	C	E	C	4
<i>Subject 4</i>										
Reading	C	E	C	C	C	C	E	C	C	7
Multiplication	E	C	C	C	C	C	C	E	E	6
Chess	E	C	E	C	E	C	E	C	E	4
<i>Subject 5</i>										
Reading	C	C	C	C	E	C	C	E	C	7
Multiplication	C	C	C	C	C	C	C	C	C	9
Chess	C	C	C	E	C	E	E	C	E	5
<i>Subject 6</i>										
Reading	C	C	C	C	C	C	C	C	C	9
Multiplication	C	E	E	E	E	C	C	E	C	4
Chess	E	E	E	E	E	C	E	E	E	1

the conditions this order. In terms of composite results, it may be said that:

Chess shows most inhibition in 49 out of 54 comparisons.

Multiplication shows next most in 41 out of 54 comparisons.

Reading shows least in 42 out of 54 comparisons.

RESULTS WITH A CHESS PLAYER

The subjects of our regular experiment were not chess players. We obtained three measurements under each condition, however, for a subject who was an enthusiastic and fairly skilled follower of the game. Of the nine reconstructions made by this subject, all were correct—none of the interpolations disturbed the accuracy of his recall. He also completed his reconstructions very

TABLE XII
RELATIVE AMOUNTS OF INHIBITION ACCORDING TO THE
TIME CRITERION

Condition	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	DAY 8	DAY 9	Summary
<i>Subject 1</i>										
Reading	2	3	3	2	3	3	3	3	3	3d 7 times
Multiplication	3	2	2	3	2	1	2	2	2	2d 6 "
Chess	1	1	1	1	1	2	1	1	1	1st 8 "
<i>Subject 2</i>										
Reading	3	3	3	3	3	3	2	3	3	3d 8 "
Multiplication	2	2	2	2	1	2	3	2	2	2d 7 "
Chess	1	1	1	1	2	1	1	1	1	1st 8 "
<i>Subject 3</i>										
Reading	3	3	3	3	2	3	2	3	3	3d 7 "
Multiplication	1	2	2	2	3	2	3	2	2	2d 6 "
Chess	2	1	1	1	1	1	1	1	1	1st 8 "
<i>Subject 4</i>										
Reading	3	1	3	3	2	3	3	3	3	3d 7 "
Multiplication	2	2	2	2	3	2	2	2	2	2d 8 "
Chess	1	3	1	1	1	1	1	1	1	1st 8 "
<i>Subject 5</i>										
Reading	3	3	3	3	1	3	3	2	3	3d 7 "
Multiplication	2	2	2	2	2	2	2	3	2	2d 8 "
Chess	1	1	1	1	3	1	1	1	1	1st 8 "
<i>Subject 6</i>										
Reading	3	3	3	2	3	2	2	3	3	3d 6 "
Multiplication	2	2	2	3	2	3	3	2	2	2d 6 "
Chess	1	1	1	1	1	1	1	1	1	1st 9 "

quickly. His times range from 6 to 11 seconds, while those of the inexperienced group range from 5 to 312 seconds. His average reconstruction time is considerably below that of the best member of the group. There is some evidence that his reconstruction time was prolonged most by the interpolation of Chess and next to most by Multiplication. Table XIII shows the rankings of the three conditions according to the inhibition which they showed by the time criterion, with this subject.

TABLE XIII

CONDITION	DAY 1	DAY 2	DAY 3
Chess	1.5	1.0	2.0
Multiplication	1.5	2.5	1.0
Reading	3.0	2.5	3.0

On the whole, the signs of inhibition are not as clear in the case of this subject, accustomed to chess situations, as they are in the case of the inexperienced group.

This fact may be due to the subject's practice with the material involved, or the same native peculiarity which made him take up chess may here have operated to prevent inhibition. From a slightly different point of view, the low susceptibility to retroaction may be due to the comparative isolation of memorizing and interpolated activities in this subject, or he may simply have mastered the original material with unusual thoroughness and thus reduced its likelihood of being disintegrated. All of these factors may have entered into the situation.

In as much as there is only one skilled player to compare with the unskilled group, these findings should be accepted with some reservation.

SUMMARY

The results of Experiment III throw interesting light upon those which have gone before it. Experiments I and II showed that interpolation similar to the original memorizing causes pronounced inhibition, but they did not give any certain evidence of significant retroaction where the interpolation is comparatively dissimilar to the original learning. Experiment III has again demonstrated the greater inhibitory effects of very similar interpolation. It has demonstrated further that there may be (as in the Multiplication condition) marked inhibition where interpolation and original memorizing are comparatively dissimilar. Our results with a practiced chess player give some indication that materials with which one is accustomed to deal are less susceptible to retroactive effects than unfamiliar materials.

CHAPTER III

THE TEMPORAL POSITION OF RETROACTIVE INTERPOLATION

EXPERIMENT IV

Those theories of retroactive inhibition which postulate the interruption of a setting-in process, are based upon the alleged fact that the more closely a retroactive interpolation follows the original learning, the greater is the resulting inhibition. Experiment IV was conducted in order to ascertain whether this fact could be verified or, if not, what relationship there might be between the temporal position of retroactive interpolation and the degree of inhibition caused by it.

MATERIALS, METHODS AND SUBJECTS

Lists of ten three-place numbers were used for the original memorizing. These lists were constructed according to the rules followed for the four-place numbers of the first and second experiments. The following numbers were not used: 135, 357, 579, 246, and 468.

The numbers were displayed on a hand-operated drum which the experimenter controlled with reference to the swings of a pendulum hung on the wall behind the subject. Each number was exposed for a period of two seconds. Twenty seconds elapsed between the disappearance of the last number of one complete exposure of the list and the appearance of the first number of the next complete exposure. Each list was given eight complete exposures. Between the disappearance of the last number of the last complete exposure and the test for recall there was an interpolated period twenty minutes and twenty seconds in length. The subject's activity during the first twenty seconds of this period was uncontrolled. The following twenty minutes were spent in one of five ways:

(A) The whole period was devoted to reading, with no at-

tempt to memorize, in current editions of the *Chicago Tribune*.

(B) The first five minutes were devoted to studying a second list of ten three-place numbers (the list was exposed eight times under the same conditions as the original list), and the following fifteen minutes to newspaper reading.

(C) The first five minutes were devoted to newspaper reading, the next five minutes to studying a second list of numbers, and the remaining ten minutes to newspaper reading.

(D) The first ten minutes were devoted to newspaper reading, the next five minutes to studying a second list of numbers, and the remaining five minutes to newspaper reading.

(E) The first fifteen minutes were devoted to newspaper reading, and the remaining five minutes to studying a second list of numbers.

For the sake of brevity these conditions will be referred to in subsequent discussion simply as A, B, C, D, and E.

Immediately after the interpolated period the subject was directed to reproduce the original list of numbers. This reproduction, as in the first two experiments, was written. Following the reproduction of the original list, the subject, under the B, C, D, and E conditions undertook the reproduction of the interpolated list. The directions for reproduction were the same as in Experiments I and II.

Five subjects served in Experiment IV. All were men. Four were graduate students in psychology at the University of Chicago. One was an undergraduate in the same institution. None of the subjects of this experiment had served in my earlier experiments and none knew the purpose of this work, aside from what might have been inferred from the general procedure.

Five practice sittings for each subject preceded the experiment proper. At these sittings the subject studied a list of ten three-place numbers under the same exposure conditions as those used in the regular experiment. Recall came immediately after the last exposure of the list.

Each subject had thirty-five sittings during the experiment proper—seven under each of the five conditions. A subject went through but one condition on any single experiment day.

The experiment was made up of seven five-day cycles, during each of which all the subjects went through all the conditions once. The experiment was conducted from Monday to Friday inclusive of eight successive weeks, the first week being devoted to the practice sittings.

Each subject went through the five experimental conditions in different order. This arrangement was exactly analogous to that employed in Experiments I and II. Within each cycle the subjects had regular sitting times which were kept as nearly constant as possible.

The criteria of recall were the same as those employed in Experiments I and II, *i. e.*, (1) Amount, (2) Error, and (3) Time.

RESULTS

Table XIV gives the average amount, error, and time of recall after the different interpolated conditions. The table was made up by averaging the average performances of the five subjects under the different conditions.

TABLE XIV

CONDITION	AMOUNT	ERROR	TIME
A	29.1 digits	6.1%	1.6 Secs.
B	18.6 "	31.9%	5.9 "
C	19.7 "	29.0%	5.5 "
D	19.2 "	32.6%	6.4 "
E	18.4 "	30.3%	6.9 "

Condition A, in which the entire interpolated period was spent in newspaper reading, shows, by all criteria of recall, the greatest efficiency, and this by unambiguous amounts. The values under consideration give no indication that inhibition is greatest where the retroactive interpolation follows most closely after memorizing. By amount and error of recall, efficiency is practically equal for the B condition, where the retroactive interpolation occurs earliest in the interpolated period, and for the E condition, where it occurs latest. By the time criterion, recall is more efficient under the B condition than it is under E. Among the conditions other than A, the highest efficiency is under C, where the second number list was studied toward the middle of

the interpolated period. That this superiority of C is anything more than accident, however, seems doubtful in light of the small margin of its superiority and the fact that the other condition, namely D, where the retroactive interpolation lies toward the middle of the interpolated period, shows no clear evidence of being better than B and E.

Tables XV, XVI, and XVII, made up in the same way as Tables III, IV, V, VII, VIII, and IX of Chapter II, present the records of the individual subjects.

TABLE XV
AMOUNT OF RECALL
(Total Digits)

	Condition A		Condition B		Condition C		Condition D		Condition E	
	AVER-		AVER-		AVER-		AVER-		AVER-	
SUBJECT	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS
1	27.1	5	15.7	4	15.0	2	15.4	3	14.6	1
2	29.6	5	18.4	4	17.6	2	17.2	1	18.1	3
3	30.0	5	25.3	1	27.4	2.5	27.4	2.5	29.1	4
4	30.0	5	26.9	2	29.7	4	28.8	3	23.4	1
5	28.7	5	6.9	1.5	9.0	4	7.3	3	6.9	1.5

TABLE XVI
ERROR IN RECALL
(% of Recall Erroneous)

	Condition A		Condition B		Condition C		Condition D		Condition E	
	AVER-		AVER-		AVER-		AVER-		AVER-	
SUBJECT	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS
1	18.4	5	45.9	4	48.1	3	57.3	1	51.1	2
2	2.0	5	48.7	1	37.6	3	41.1	2	34.9	4
3	0	5	23.6	3	16.7	4	28.9	1	24.7	2
4	7.1	5	35.6	1	28.7	2	20.0	3	19.3	4
5	2.9	5	5.6	4	13.7	3	15.7	2	21.6	1

TABLE XVII
TIME OF RECALL
(Av. Time in Secs. per Digit)

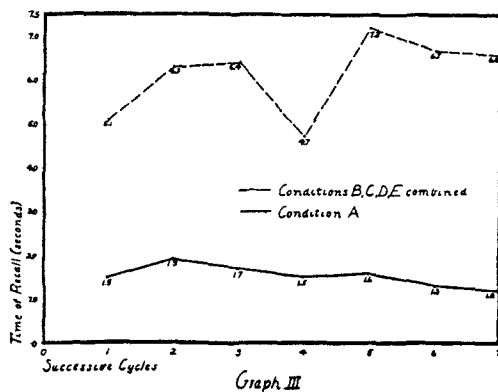
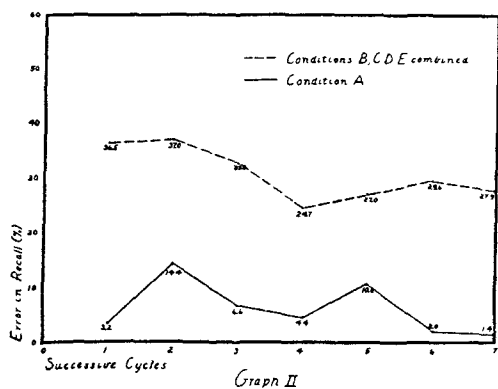
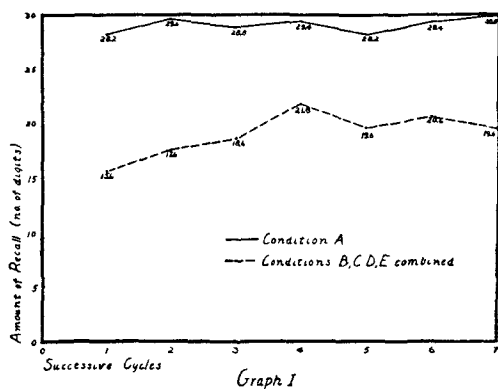
	Condition A		Condition B		Condition C		Condition D		Condition E	
	AVER-		AVER-		AVER-		AVER-		AVER-	
SUBJECT	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS	AGES	RANKS
1	1.5	5	1.9	4	3.0	1	2.6	3	2.8	2
2	1.9	5	4.9	2	5.3	1	4.7	3.5	4.7	3.5
3	1.6	5	8.6	3	6.8	4	10.5	2	11.6	1
4	1.7	5	9.4	2.5	8.9	4	9.4	2.5	9.8	1
5	1.3	5	4.9	2	3.5	4	4.6	3	5.4	1

According to amount of recall (Table XV), Condition A shows the least inhibition for all five subjects. Among the other conditions there is no more differentiation than might be looked for from chance. The same things are true according to error and time of recall (Tables XVI and XVII). From these results the degree of retroactive inhibition seems to be independent of the temporal position of retroactive interpolation.

THE INFLUENCE OF PRACTICE UPON RETROACTIVE INHIBITION

The results secured with a practiced chess player in Experiment III indicated that one who is accustomed to dealing with a given material may not be as susceptible to retroactive effects, so far as that material is concerned, as one who has not had such past experience. The present experiment furnishes additional evidence on this point. The average performance of the group under Condition A was calculated for each successive cycle. The average performance under B, C, D, and E combined was calculated in the same way. Graphs I, II, and III show by the three criteria of recall the progress made by the group during the seven cycles of the experiment in memorizing and recalling three-place numbers where (1) retroactive interpolation was used and (2) retroactive interpolation was not used. The amount of inhibition for any cycle is equal to the distance between the curves at that cycle.

Graphs I and II show a slight tendency for inhibition to decrease as the subjects become more familiar with their task of memorizing. Graph III indicates just the opposite. The lack of clear evidence for decreasing inhibition with increasing practice may be explained in several ways: (1) It may be that no lowering of susceptibility to retroactive inhibition is possible with material of this kind learned under these conditions and subjected to this sort of interpolation. (2) The flatness of the curves suggests that the limit of progress in this function may have been so nearly reached before the beginning of the experiment that no changes in susceptibility to inhibition are present.



(3) Perhaps five cycles are not enough to make apparent changes in susceptibility which are, nevertheless, taking place.

SUMMARY

Under the conditions of this experiment, at least, the degree of retroactive inhibition is independent of the temporal position of retroactive interpolation.

During the seven cycles of the experiment, the five subjects employed give but little evidence of becoming more or less susceptible to retroactive inhibition. The odds are slightly in favor of a lowering of susceptibility with increasing practice.

CHAPTER IV

THE DEGREE OF LEARNING AND SUSCEPTIBILITY TO RETROACTIVE INHIBITION

EXPERIMENT V

The work of Heine, reviewed in the opening chapter of this paper, gave evidence that susceptibility of material to retroactive inhibition stands in an inverse relationship to the amount of study given that material—amount of study being measured in terms of number of exposures. Further study of this question seemed desirable for two reasons: (1) Heine's interpolated work was comparatively dissimilar to her original learning, a condition which my experiments have shown does not give the most striking instance of retroactive inhibition, and (2) In any single experiment she worked with but two degrees of learning, so that no continuous relationship could be shown between varying degrees of learning and varying degrees of retroactive inhibition.

MATERIALS, METHODS AND SUBJECTS

The material for original learning again consisted of lists of ten three-place numbers. These lists were exposed four, six, eight, ten, or twelve times by means of the apparatus used in Experiment IV. The subject was always informed beforehand how many exposures were to be given. Each number was exposed for two seconds. Twenty seconds elapsed between successive exposures of the whole list.

An interpolated period of five minutes and thirty-five seconds occurred between the last exposure of the original list and its recall. This interval was spent in either of two ways which, for convenience, will be designated as Rest and Work. Under the Rest condition the subject's activity was uncontrolled for the first thirty-five seconds; during the remaining five minutes he read, with no attempt to memorize, in current editions of the

Chicago Tribune. Under the Work condition activity during the first thirty-five seconds was again uncontrolled; during the remaining five minutes the subject studied a second list of ten three-place numbers, the list being exposed eight times under the same conditions as the original list.

Immediately after the interpolated period, the experimenter directed the subject to recall the original list of numbers. These directions and the mode of reproduction were the same as in the other experiments with numerical memory material. Under the Work condition the subject recalled the interpolated list following the recall of the original list.

Five subjects, three men and two women, served in the experiment. Two of the men were graduate students in psychology at the University of Chicago. One man was an undergraduate there. The two women were graduate students in psychology at the same institution. The subjects were not informed as to the purpose of the experiment and they were asked not to discuss the work among themselves.

Five practice sittings preceded the regular experiment. At each of these each subject studied a list of ten three-place numbers exposed eight times. This list was recalled after a five-minute period of newspaper reading.

The experiment was made up of two cycles of ten experiment days each. The second cycle was a repetition of the first. The experiment proper was conducted from Monday to Friday, inclusive, of four successive weeks. On each experiment day each subject was tested under both Rest and Work conditions for a single degree of learning or number of repetitions of the original list. Between the tests under Rest and Work conditions there was a period of ten minutes devoted to casual conversation or newspaper reading. Table XVIII gives the arrangement of subjects and experimental conditions for a single ten-day cycle.

One point in this procedure may seem questionable, *i. e.* the fact that all subjects were tested first under the Work condition during the first half of each cycle and first under the Rest condition during the second half of each cycle. Obviously the pro-

TABLE XVIII
ARRANGEMENT OF EXPERIMENTAL CONDITIONS
EXPERIMENT V

Exs. = Exposures

Subject	Order	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
1	1	4 Exs. Work	6 Exs. Work	8 Exs. Work	10 Exs. Work	12 Exs. Work	4 Exs. Rest	6 Exs. Rest	8 Exs. Rest	10 Exs. Rest	12 Exs. Rest
	2	4 Exs. Rest	6 Exs. Rest	8 Exs. Rest	10 Exs. Rest	12 Exs. Rest	4 Exs. Work	6 Exs. Work	8 Exs. Work	10 Exs. Work	12 Exs. Work
2	1	6 Exs. Work	8 Exs. Work	10 Exs. Work	12 Exs. Work	4 Exs. Work	6 Exs. Rest	8 Exs. Rest	10 Exs. Rest	12 Exs. Rest	4 Exs. Rest
	2	6 Exs. Rest	8 Exs. Rest	10 Exs. Rest	12 Exs. Rest	4 Exs. Rest	6 Exs. Work	8 Exs. Work	10 Exs. Work	12 Exs. Work	4 Exs. Work
3	1	8 Exs. Work	10 Exs. Work	12 Exs. Work	4 Exs. Work	6 Exs. Work	8 Exs. Rest	10 Exs. Rest	12 Exs. Rest	4 Exs. Rest	6 Exs. Rest
	2	8 Exs. Rest	10 Exs. Rest	12 Exs. Rest	4 Exs. Rest	6 Exs. Rest	8 Exs. Work	10 Exs. Work	12 Exs. Work	4 Exs. Work	6 Exs. Work
4	1	10 Exs. Work	12 Exs. Work	4 Exs. Work	6 Exs. Work	8 Exs. Work	10 Exs. Rest	12 Exs. Rest	4 Exs. Rest	6 Exs. Rest	8 Exs. Rest
	2	10 Exs. Rest	12 Exs. Rest	4 Exs. Rest	6 Exs. Rest	8 Exs. Rest	10 Exs. Work	12 Exs. Work	4 Exs. Work	6 Exs. Work	8 Exs. Work
5	1	12 Exs. Work	4 Exs. Work	6 Exs. Work	8 Exs. Work	10 Exs. Work	12 Exs. Rest	4 Exs. Rest	6 Exs. Rest	8 Exs. Rest	10 Exs. Rest
	2	12 Exs. Rest	4 Exs. Rest	6 Exs. Rest	8 Exs. Rest	10 Exs. Rest	12 Exs. Work	4 Exs. Work	6 Exs. Work	8 Exs. Work	10 Exs. Work

cedure would have been better balanced if there had been a second group of subjects for whom the order of Rest and Work conditions was reversed. The comparative flatness of the practice curves for learning three-place numbers, however, (see Graphs I, II, and III) suggests that the apparent discrepancy is logical rather than actual.

The criteria of recall were: (1) Amount, (2) Error, and (3) Time.

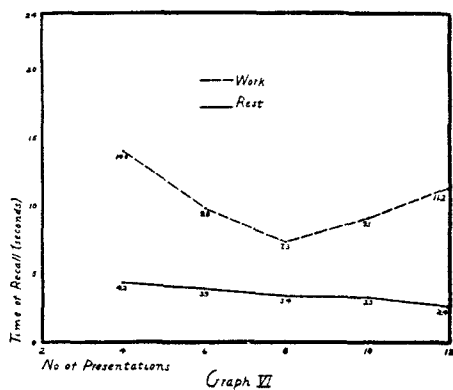
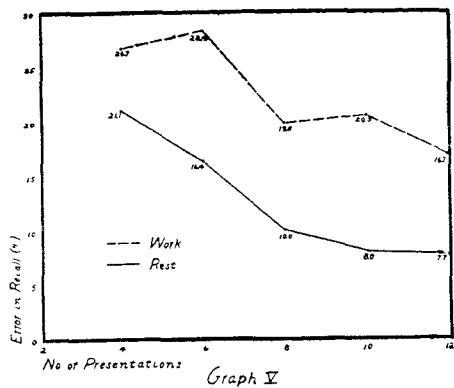
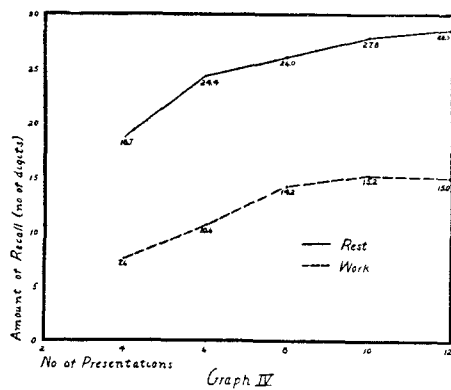
RESULTS

Graphs IV, V, and VI are curves showing amount, accuracy, and time of recall for the different degrees of learning where (1) Rest—newspaper reading—and (2) Work—memorizing numbers—were interpolated. These curves were made up from the averages of the entire group of subjects for the different conditions.

By amount of recall (Graph IV) both Rest and Work curves show a regular, negatively accelerated rise with increases in the number of exposures of the original list. And the distance between the curves, which is a measure of the degree of retroactive inhibition, remains practically constant. If the better learned lists are less susceptible to retroactive effects, this is not evident within the limits studied which, so far as amount of recall is concerned, extend almost to a point of complete learning.

The error curves (Graph V) are more difficult to interpret. Accuracy of recall after Work changes very irregularly with changes in the number of presentations. It is possible that the memorized material's susceptibility to disintegration actually varies in the manner suggested by the curve, but it seems more probable that the variability of efficiency under the Work condition is a matter of the limited sampling which it represents. In the latter event, since the Rest and Work curves show no continuous tendency to converge or diverge, it may be concluded that, as in the case of amount of recall, there is a practically constant susceptibility to inhibition for the different degrees of learning employed in this experiment.

According to the time curves (Graph VI) progress under the



Rest Condition is regular and almost linear. Under the Work condition, however, the curve falls abruptly to the eight presentations point and then rises with almost equal abruptness to twelve presentations. Here again the irregularity of the Work curve may be interpreted as due to the real nature of the function represented or to the limited sampling. In either case one can say that, from four up to twelve presentations of the memorized material, there is but little evidence for a single continuous change in susceptibility to inhibition.

Perhaps the safest generalization to be made upon the basis of the three pairs of curves is the rather negative one, that, although there are sporadic increases and decreases in susceptibility to inhibition with varying numbers of presentations, there is no continuous tendency in one direction or the other. From a theoretical standpoint it would be futile to accept such a statement as characterizing retroactive inhibition for all degrees of learning. In doing so we should fly in the face of a respectable body of empirical facts concerning the isolation, through practice, of interfering processes. We should have to deny the validity of Heine's findings, a thing which the general character of her work would hardly justify. My results here do indicate, however, that within fairly wide limits a complex set of associations may show no uniform variation in susceptibility to disintegration.

According to two out of three criteria, progress in efficiency with increasing presentations is much more regular under the Rest than under the Work condition. This in itself is important. Evidently retroactive inhibition, as observed in this experiment, is a highly variable phenomenon.

So far I have been speaking of absolute amounts of inhibition. Table XIX gives the relative amounts of loss due to the interpolation of Work. Each value was obtained by dividing the difference in efficiency between Rest and Work by the efficiency under the Rest condition. Two sets of values are given for errors: (1) relative inhibition according to percentages of error, and (2) relative inhibition according to gross errors. Up to this

point percentages of error alone have been considered. Since a more or less valid objection can be raised, however, to the procedure of figuring one set of relatives from another set of relatives, I have included in this table the set of relative error values based upon gross errors, *i. e.*, the actual number of errors made under the different conditions.

TABLE XIX
RELATIVE INHIBITION

PRESENTATIONS	AMOUNT	TIME	% ERROR	GROSS ERROR
4	59.3	233	26	—51
6	56.6	151	73	—25
8	45.4	115	98	+ 8
10	45.3	176	156	+41
12	47.3	367	117	+14

The general tendency, according to amount of recall, is toward relatively less inhibition with increasing numbers of presentations. True, there is more inhibition at twelve presentations than at ten or eight, but the difference is hardly great enough to be significant. In the main, there is a rapid decrease in relative inhibition at first and then a period where neither increase nor decrease is clearly marked.

The time criterion indicates no single continuous variation in the degree of relative inhibition. The values decrease rapidly from the four to eight presentations point and then increase rapidly up to the twelve presentations point.

Both sets of error values show, in general, an increase in relative inhibition with increasing presentations. In both cases there is less inhibition at twelve than at ten presentations, but this might fairly be interpreted as an accidental irregularity.

It is interesting to note the two minus values under gross errors. They indicate that the actual number of errors made at four and six presentations was less under the Work than under the Rest condition. In this sense, there is retroactive facilitation rather than inhibition at these points.

On the whole there is little agreement among the criteria as to any continuous correlation between the degrees of learning examined and relative inhibition. This may be due in part to

the fact that the methods of determining relative inhibition must by the nature of the case, be quite arbitrary. From the same data as those employed in calculating relative inhibition according to error of recall, one could calculate relative inhibition according to accuracy of recall. Such a procedure would change appreciably the relative values for different numbers of presentations and also the relationship between these relative values. In fact, it would tend, at least, to invert the relationship. The same can be said for the amount criterion. If the perfectly legitimate procedure were adopted of scoring amount of recall in terms of the number of digits recalled less than the total possible number, then the present relationship between the number of presentations and relative inhibition according to amount of recall would tend to be inverted.

SUMMARY

In light of the fact that relative degrees of inhibition are functions of arbitrary scoring methods, it seems to me that my most significant findings are: (1) The lack of any single continuous change in absolute susceptibility to inhibition within the limits studied, and (2) The comparative irregularity, under the Work condition, of the progress in efficiency of recall derived from given increments of presentations. It is evident that much further experimentation must be carried out in connection with this problem before any very definite generalizations can be made.

CHAPTER V

SUMMARY AND DISCUSSION OF RESULTS

The results of the experiments reported in this paper stand in rather sharp disagreement with much of what has previously been said on the subject of retroactive inhibition. This may be due to the fact that my methods and materials were, for the most part, quite unlike those of other investigators in this field. Such differences in method, however, should increase rather than decrease the value of these new results for the formulation of a conception of retroactive inhibition which is to have applicability beyond the activity of memorizing some particular material, such as nonsense syllables.

My results may be briefly summarized as follows:

(1) The degree of retroactive inhibition present in a given situation is a function of the similarity between interpolated activity and original learning. This relationship cannot, of course, be thought of as linear. That is, if an exact measure of similarity were available and the degrees of retroactive inhibition were plotted against varying values of this similarity, we should not find a steady increase in inhibition values with increases in similarity. Such an assumption would require the expectation of greatest inhibition where similarity is greatest, *i. e.*, where the interpolation and original learning are the same. But we know that in such cases there is facilitation due to practice, which excludes by definition any detectable inhibition. Under the conditions of these experiments, except in the cases of isolated individuals, the greatest inhibition was always caused by the interpolations most similar to the original learning, but further work will have to decide at just what point in the variation of similarity interpolation turns from a disintegrating into an integrating agency.

There is also the possibility that similarity is not a one-dimensional affair. Indeed my results bring out the fact that there

may be effective similarity of contents, of forms of presentation, or of processes involved, and variations in any one of these may independently modify the degree of retroactive inhibition. A further complicating factor may be present in the quantitative character of these variations. Certain of them may be serial and continuous, each change in that type of similarity being accompanied by a change in the degree of inhibition. Others may be of the *all or none* variety. For example, the processes involved may be identical or disparate. A certain amount of inhibition may be present with such identity, while, without it, there may be no inhibition caused by process similarity. That is to say, there need be no intermediate stages of similarity, so far as retroactive inhibition is concerned, between identical and plainly dissimilar processes. If the interpolated activity is memorial there may be, by virtue of this fact alone, appreciable inhibition. All other factors being ineffective, the fact that the interpolated activity is not memorial, in the ordinary sense of that term, may exclude the possibility of inhibition.

Of course this discussion is of a highly hypothetical sort. Exact knowledge of the relationship between retroactive inhibition and similarity or similarities between interpolation and original learning will have to wait upon future researches. The positive contribution of my results in connection with this point lies in their clear indication of the simple fact that similarities of contents, of processes, and of forms of presentation all play a part in determining the degree of retroactive inhibition.

(2) Where, on the face of things, interpolation and original learning are comparatively dissimilar there may still be an appreciable degree of retroactive inhibition. Engaging in certain fairly strenuous activities between memorizing and recall results in a lower efficiency of recall than where the subject occupies himself with a comparatively light task, such as newspaper reading with no attempt to memorize. This fact might possibly be interpreted as another instance of the relationship between the similarity of activities and retroactive inhibition. It might be argued, for example, that two activities are similar to the extent

to which they approach intensity equality. It might also be argued that some other unapparent differences in similarity exist between those conditions where there is more or less retroactive inhibition.

(3) While the results of the first three experiments show the greatest inhibition where there is unquestionably the greatest similarity between interpolation and original learning, they also point out the extreme difficulty of predicting the degree of inhibition which an apparent degree of similarity will bring about. The contents of both memorizing and interpolation may be numbers (four-place numbers, indeed), but unless the two are memorized there may be no more inhibition than where one is numbers and the other, say, poetry. Further, the contents of both may be numerical and the process of both memorial, but unless the two sets of material are presented in highly similar form there may be no high degree of inhibition.

(4) The degree of retroactive inhibition is independent of the temporal position of the retroactive interpolation. For the materials used this generalization holds in respect to an interval of twenty minutes between memorizing and recall.

(5) Practice in memorizing a particular kind of material may alter one's susceptibility to retroactive inhibition. A single experienced chess player was less susceptible to retroactive inhibition than a group of less experienced individuals. This may easily have been an accident, or the same factors which made this man a good chess player may have been the cause of his resistance to retroactive inhibition. A group of five subjects who memorized four-place numbers five days a week for eight successive weeks showed slight indications of becoming less susceptible to retroactive inhibition so far as their memory for that kind of material was concerned.

(6) Within the limits studied there is no single, continuous relationship between the number of presentations of a memorized material and its absolute susceptibility to retroactive inhibition. It seems improbable to suppose that this will hold for all possible degrees of learning, and it may not hold where material is

learned in simpler units. In fact, the work of Heine suggests that, where simple units of a complex material are learned in pairs, the degree of inhibition is an inverse function of the degree of learning. My results with the experienced chess player, if they are due to his more perfect mastery of the memorized material within the allotted time, also indicate an inverse relationship between retroactive inhibition and the degree of learning.

There is little or no agreement among the criteria employed as to the relationship between the degree of learning and the relative amount of inhibition.

(7) The increases in efficiency of recall incident upon adding constant increments of exposures is less predictable, according to two out of three criteria, where memorizing is followed by some constant disintegrating activity of great effectiveness than where it is followed by an activity of low disintegrating effects. If the efficiency of recall is plotted against the number of exposures given a material, a comparatively irregular curve will result where the material is subjected to retroactive inhibition, and a comparatively smooth curve for material not so subjected.

THEORETICAL CONSIDERATIONS

The above results, where they apply at all, seem to me to favor a transfer theory of retroactive inhibition. Such a theory, as we saw in the second chapter, usually implies that some elements of the original learning and interpolation are common. The activity of these elements during interpolation may weaken their position in the original pattern, or their activity during interpolation may so modify their associative potentialities that, in recall, they will have a tendency to bring up items irrelevant to the original learning or items which are conflicting and mutually inhibitory. All of these things may happen. Support is given this theory by the fact that, in my experiments, the greatest inhibition always was caused by the interpolation which apparently had the most elements in common with the original learning.

Such a conception gives retroactive inhibition an intelligible setting among the other phenomena of learning. Two facts, however, may seem to stand in the way of its acceptance. In the

first place, Müller and Pilzecker found as great inhibition where interpolation was dissimilar to original learning as where it was similar. In the second place, the experiments of Heine and Tolman, as well as those reported here, give ample evidence that retroactive inhibition may occur where two activities are comparatively dissimilar. As far as the results of Müller and Pilzecker are concerned, they may be dismissed as quantitatively inconclusive on this point. While Heine and Tolman found retroactive inhibition where interpolation and original learning were dissimilar, they present no comparisons between the retroactive effects under conditions of greater and less similarity. The facts brought out by the present investigation, in the course of which just such comparisons were made, indicate that retroactive inhibition is decidedly a function of the similarity of two activities and, therefore, probably a matter of transfer.

Still, one can not dismiss the fact that inhibition of plain degree can be caused by interpolated activities having apparently few elements in common with original learning. Here one faces two alternatives: (1) There may be two ways (or more, perhaps) in which interpolated activity positively accelerates the process of forgetting. In certain instances retroactive inhibition may be a kind of transfer. In certain other instances it may be something entirely different. (2) All retroactive inhibition may be a matter of transfer.

Taking the alternative of explaining only certain instances of retroactive inhibition in terms of transfer it is fair to ask what acceptable explanation can be given in other terms. A perseveration theory such as that of Müller and Pilzecker would undoubtedly be advanced from some quarters. Such a theory would explain retroactive inhibition as the effect of interrupting some consolidating or setting-in process going on after conscious memorizing. One test of such a theory is a comparison of the results of interpolation placed in different temporal positions between memorizing and recall. Müller and Pilzecker have some rather meagre evidence (one experiment with one subject) that, if such a supposed process is allowed time to mature, the memo-

alized material will be less easily disintegrated. My Experiment IV showed no such relationship between retroactive inhibition and the temporal position of the retroactive interpolation. It might be said in answer to this that the inhibition I obtained was of the transfer variety, while that of Müller and Pilzecker was not. But transfer or no transfer, if a setting-in process is open to interruption by a dissimilar activity, is there any reason to believe that it is not just as likely to be disturbed by a similar activity?

Another argument against a perseveration theory of this kind is the difficulty of conceiving of it in neurological terms. Of course, it is possible that one group of active nervous elements tends to drain off energy from other simultaneously active elements and so reduces the activity of the latter. But that such a drainage, if it exists at all, is independent of the degree of identity of the groups of elements involved seems quite unlikely.

There remains a consideration of the theory which would explain all retroactive inhibition in terms of transfer. This theory easily explains retroaction where original memorizing and interpolation are plainly similar, but, where they are not, a slight difficulty arises. One must admit that it would be stretching a point to accept the transfer theory, if all similarity were, like the superficially most evident sort, a matter of contents, and if all transfer were a matter of elements active in original memorizing being active, and therefore getting new associative potentialities, during interpolation. There is no need, however, for so limiting one's conceptions of similarity and transfer. The present experiments bring out the effectiveness of other kinds of similarity than that of content, and, as Webb has suggested, transfer is not as restricted a phenomenon as is sometimes supposed. The transfer causing retroaction, for instance, may in one case be a transfer from memorizing to interpolation and in another a transfer from interpolation to recall. All that one need assume, in order to explain any retroaction in terms of transfer, is that the situations, memorizing, interpolation, and recall, have enough in common, through content, form, process, or even

temporal contiguity, to insure the reinstatement of a part of one of the situations in intimate connection with another.

Thus it appears that, while many desirable facts are still outstanding, all positive acceleration of the forgetting process due to interpolated mental activity can be explained in terms of transfer. The writer does not feel in a position to say how profitably this theory can be used in connection with retrograde amnesia—the pathological instance of positively accelerated forgetting.