

THE PSYCHOLOGICAL REVIEW

THE EFFECT OF TIME-INTERVAL UPON RECOGNITION MEMORY¹

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In the November issue of the PSYCHOLOGICAL REVIEW it was shown that the per cent. of advertisements that can be correctly recognized decreases as the length of the series is increased.² The plotted results showed a slight curve—almost a straight line. Increasing the difficulty of the task by adding more stimuli results then in a slow decrease in the ability to identify the previously shown advertisements. The purpose of this paper is to study the effect produced upon recognition memory when a different sort of difficulty is introduced into the operation. In this case the same number of stimuli is used throughout the study but the intervals between exposure and identification are varied. Here we find no sort of an approximation to a direct proportion between the efficiency of identification and the varying intervals of time. Instead, we find a very rapid decrease in efficiency up to about 2 hours after exposure. From that point on the decrease in efficiency becomes more and more gradual until it is apparent that there is little or no difference between the effect of an interval of 7 days and that of 42 days upon recognition memory.

It is not necessary to point out here the relationship between the results of this experiment and those of other workers.

¹ I wish here to express my sincere thanks to Dr. and Mrs. H. L. Hollingworth, to Mrs. Clara Hart, and to my wife, for having served as subjects in this experiment, and especially to the last, who also served as coexperimenter.

² E. K. Strong, Jr., 'The Effect of Length of Series upon Recognition Memory,' *PSYCH. REV.*, XIX., 6, November, 1912.

A recent monograph¹ covers this field satisfactorily in that it compares the curves of forgetting for different materials and different methods of investigation. But it is somewhat of a help to an appreciation of our results to state at the start that there is a very close parallel between these results and those given us by Ebbinghaus in his study of recall memory.²

Reference to Plate III. will show at a glance the relationship between the two studies.

THE EXPERIMENT

The experiment was as follows. From the Standard Dictionary were taken all the ordinary common words,—with few exceptions none over three syllables in length was used. Each word was written on a slip of paper. After all had been thoroughly shuffled they were divided into two boxes,—one used by subject *A* when she acted as experimenter and the other used by subject *B* when he acted as experimenter. A list of 40 words drawn at random from the box was first prepared. These 40 were then shuffled together and another list of 20 was made from these 40. Here some guidance was exercised in order that words which obviously made sense should be widely separated. But in the main, even these lists were formed by chance. This second list of 20 words was the exposure list. The first list of 40 words was given to the subject after the designated interval of time had elapsed and from it he was expected to choose those words which had been in the first list.

¹ C. H. Bean, 'The Curve of Forgetting,' *Archives of Psychol.*, No. 21, 1912. In this monograph, which appeared in the midst of our experiments, a forgetting curve, for the 'method of selection' was given. This is the same method as employed here and called 'recognition memory.' The form of Bean's curve would probably be identical with ours if his method of scoring had been adequate. But he overlooked the fact that chance selections had to be reckoned with in the scoring. In his experiments 9 consonants were exposed and later had to be selected from a total of 18 consonants. Each correct choice of the 9 consonants was scored $\frac{1}{9}$ of 100 per cent. But random chance would give a selection of $4\frac{1}{2}$ correct and $4\frac{1}{2}$ incorrect or a score of 50 per cent. according to his method of scoring. In the same way he counted up the number of substitutions but there again it would be impossible to get a lower score than 50 per cent. Just what his actual scores should be cannot be determined for lack of the detailed scores.

² H. Ebbinghaus, 'Ueber das Gedachtniss.' Leipzig, 1885.

The exposure lists of 20 words were written on slips of paper, the words appearing in a column, one under the other. The subject was instructed to read the words aloud at his leisure. He was told that he might read them slowly enough to actually grasp the meaning or content of the word, but must read them fast enough not to be able to *consciously* form associations between them. Both *A* and *B* found at the start that reading aloud was a decided help in aiding them to refrain from forming associations between the successive words. There was no intention on the part of the experimenter that the subjects should not form associations of any sort here, but merely that they should not consciously attempt to form them. Subject *D*, alone, found difficulty in inhibiting the conscious attempt to form associations between the words in the list. But this was only at the start. After a few trials he overcame the tendency to build pictures out of the words as he found it was a serious handicap when it came to recognizing the separate words later. The aim throughout was to obtain a maximum of attention upon 20 separate words, not as brute syllables but as words with meaning. A constant rate of exposure for each word would have given a uniformity of exposure when considered in terms of physical time. But this does not mean that there would have been necessarily in the exposure a uniformity in the psychological processes of perception and attention. In fact, some experiments of the writer, not yet reported, show very clearly that when a number of stimuli are being presented in succession at a constant rate, the attention devoted to each varies enormously. Process of interference of some sort probably accounts for this. To repeat then, the aim was to obtain as nearly as possible the maximum attention upon each word. From a careful study of the results—both statistical and introspective—we feel sure that the aim was obtained in the great majority of cases.

At the bottom of each of the exposure lists was a short problem in mental arithmetic. The subject was required upon finishing reading the list immediately to solve the problem. This device was necessary in order to prevent the seemingly instinctive tendency to run the eyes back up the column in

order to grasp the last four or five words and hold on to them. It was a rare exception that the subject would recall any of the 20 words within a few minutes after the exposure. Record was kept of the words that were recalled when the recognitions were made but they were so few in number and so scattered that no statistical treatment of them could be made. This seems rather surprising, but it should be borne in mind that the subjects did not read the lists with the intention of remembering the words so as to be able to recall them later. Our "mind-set" or attitude toward the task before us has seemingly everything to do with the way in which we "take-in" stimuli.¹

One objection to the use of common words as material in such a study must be recognized. Such words do vary in the ease with which they will impress any given mind. But as several thousand different stimuli had to be employed it seemed to the experimenter that words or numbers were the only possible material that could be employed. Naturally words were chosen. The different parts of speech vary also in their strength of impressing themselves on the mind. It was a mistake to employ prepositions, conjunctions, and pronouns. As it turned out they were more difficult to remember than the other parts of speech. They could have been omitted as there were only a few of them. The ideal thing would be to use only nouns, but there are not enough of them for the purposes of this study. The only effect of using these different parts of speech has been to cut down the reliability of the results.

When the second list of 40 words was given, the subject was expected to check those words in the list which he remembered as having seen in the exposure list of 20 words. The following procedure was followed in the checking. A "1" was placed after those words which the subject was *absolutely* sure were in the exposure list (100 per cent. sure); a "2" was placed after those words which he was *reasonably* sure were in the exposure list (about 75 per cent. sure); a "3" after those words which he had a faint idea were in the list (about 25 per cent. sure); and a "4" after those words which were a pure guess.

¹ For a very extreme example of this, see H. L. Hollingworth, "The Influence of Caffeine on Mental and Motor Efficiency," *Archives of Psychol.*, No. 22, 1912, p. 17.

TABLE I

SHOWING A SPECIMEN RECORD SHEET (THE FOURTH RECORD OF SUBJECT *A* FOR THE INTERVAL OF 4 DAYS)

The words with numerals before them comprised the exposure list. The numerals placed after the words indicate *A*'s recognitions and their degree of certainty.

	timid	4
6	scour	
	vanilla	
	thirty	
	wane	4
	this	
	saddle	
	tremble	
	favor	
	progress	
	thin	
	obstinate	
	persistent	4
7	industry	4
16	oblong	4
	zoölogy	
3	witch	1
13	ink	
	owl	4
19	gradation	1
	scatter	
4	founder	2
17	quinsy	1
5	then	
14	massacre	2
12	warmth	4
	scorn	
	victor	4
11	reveal	3
	week	
2	faculty	1
1	militia	3
15	permit	
	wash	
20	traitor	2
9	resume	
	quill	3
8	wharf	
10	percolate	1
18	mask	3

Summary

File No. 1, 5 correct, 0 incorrect.
 File No. 2, 3 correct, 0 incorrect.
 File No. 3, 3 correct, 1 incorrect.
 File No. 4, 3 correct, 5 incorrect.

A "4" was necessary because the subject was required to check 20 words each time. The five subjects all understood these

requirements thoroughly. The four degrees of certainty will be referred to respectively as Piles No. 1, No. 2, No. 3, and No. 4. In the scoring, Pile No. 2 is credited at $\frac{3}{4}$ of the value of Pile No. 1, Pile No. 3 at $\frac{1}{4}$ value, and Pile No. 4 at 0 value. This system of scoring is fair, because it was on the basis of such a scoring that the subjects assigned the various recognitions to the four piles.

Table I. gives a typical record sheet. This is the fourth record of subject *A* for the interval of 4 days. Before 20 of the words appear numerals from 1 to 20. They represent the order of these 20 words as they appeared in the exposure list. That is, the words with a numeral before them were in the exposure list and should have all been checked with a "1" to give a perfect recognition record. After the words in the list appear the 4 numerals referring to the four degrees of certainty of the recognitions. At the right of the list appears a summary. We see then that 5 words placed in Pile No. 1 were correct and 0 were incorrect; 3 words placed in Pile No. 2 were correct and 0 incorrect, 3 were correct and 1 incorrect in Pile No. 3, and 3 correct and 5 incorrect in Pile No. 4.

Thirteen different intervals of time were regularly used in the experiment. They were "immediately after exposure" or 15 seconds, 5 minutes, 15 minutes, 30 minutes, 1 hour, 2 hours, 4 hours, 8 hours, 12 hours, 1 day, 2 days, 4 days, and 7 days. One complete record consists of an experiment with each one of these intervals. As it turned out fewer intervals could have been used just as well. But in view of the Ebbinghaus curve, it was thought that it would be well to have records for short intervals after the exposure. In addition to the above thirteen intervals, two records were obtained, one each from *C* and *D*, for an interval of 42 days. The order of experimenting on the thirteen intervals was determined the first time by chance. Thereafter, the order was arranged so that any one interval would come equally often at the commencement, in the middle, and at the end of the orders. In this way the advantage due to practice effect was evenly divided among the thirteen intervals. Only one experiment was carried on at a time on any one subject. When that was completed, the

TABLE II

SHOWING THE PER CENT. OF CORRECT RECOGNITIONS FOR EACH OF THE THIRTEEN INTERVALS STUDIED
 (The four degrees of certainty of the recognitions are separately noted for each of the five subjects and their summary)

Interval Studied	A (Av. 5 Records)				B (Av. 5 Records)				C (Av. 2 Records)				D (Av. 2 Records)				E (1 Record)				Summary (Av. 15 Records)			
	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4
15 sec...	92	0	3	0	71	12	6	0	93	0	0	0	93	0	2	0	80	0	0	0	84.3	4.0	3.3	0
5 min..	73	6	7	0	68	9	7	1	88	5	0	2	75	8	2	0	65	0	5	5	73.0	6.7	5.3	1.0
15 min..	76	5	5	0	61	9	8	2	58	13	10	0	40	15	5	15	45	15	5	0	61.7	9.3	6.7	2.7
30 min..	68	6	8	0	53	6	17	5	53	5	5	15	63	8	7	2	40	0	10	5	58.3	5.7	10.7	4.3
1 hr. . .	69	5	9	0	48	11	15	3	58	26	0	2	43	10	7	2	50	5	5	10	55.7	10.3	9.3	2.3
2 hrs. . .	62	4	8	1	43	12	19	3	53	5	0	5	43	18	7	5	40	10	5	0	50.3	9.0	10.3	2.7
4 hrs. . .	61	5	15	1	34	19	20	0	40	10	13	5	45	15	10	8	55	15	5	0	46.7	12.3	15.0	2.0
8 hrs. . .	52	6	18	0	34	11	19	5	35	18	13	10	35	20	8	8	35	0	10	20	40.3	10.7	15.7	5.3
12 hrs. .	48	14	17	0	24	17	17	6	43	21	5	5	50	5	13	7	30	5	15	15	38.3	14.0	14.7	4.7
1 day. . .	25	18	23	0	25	11	18	6	55	10	8	10	25	15	2	13	25	5	5	20	29.0	13.3	15.3	6.3
2 days	25	15	25	1	19	13	24	8	35	25	2	2	28	10	7	18	15	0	35	15	24.0	14.0	20.0	6.7
4 days	21	11	34	3	14	10	36	1	18	18	12	12	15	5	23	15	40	5	0	15	18.7	10.3	28.0	6.0
7 days	16	11	30	6	9	10	26	8	0	30	10	10	5	12	7	33	20	15	10	15	10.3	13.7	21.7	11.3
42 days	—	—	—	—	—	—	—	—	0	15	10	35	0	0	20	35	—	—	—	—	0	7.5	15.0	35.0

RECOGNITION MEMORY

TABLE III

SHOWING THE PER CENT. OF INCORRECT RECOGNITIONS FOR EACH OF THE THIRTEEN INTERVALS STUDIED
(The four degrees of certainty of the recognitions are separately noted for each of the five subjects and their summary)

Interval Studied	A (Av. 5 Records)				B (Av. 5 Records)				C (Av. 2 Records)				D (Av. 2 Records)				E (1 Record)				Summary (Av. 15 Records)			
	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4	Pile 1	Pile 2	Pile 3	Pile 4
15 sec...	0	1	4	0	0	3	8	0	0	2	0	5	3	0	0	2	0	5	10	5	0.3	2.0	4.7	1.3
5 min..	1	1	11	1	4	1	9	1	0	0	5	0	2	0	5	8	5	0	5	15	2.3	0.7	8.3	2.7
15 min..	1	2	11	0	1	1	17	1	2	10	2	5	0	7	5	13	0	5	25	5	1.0	3.7	12.0	3.0
30 min..	5	3	9	1	0	2	13	4	2	2	8	10	0	8	7	5	5	20	15	5	2.3	4.3	10.3	4.0
1 hr. . .	4	4	8	1	1	0	16	6	2	2	2	8	0	7	18	13	0	5	5	20	2.0	3.0	11.0	6.3
2 hrs. . .	2	3	18	2	5	5	19	4	0	15	12	10	0	7	10	10	10	10	5	20	3.0	6.3	12.3	6.0
4 hrs...	1	1	15	1	0	9	18	0	5	10	10	7	0	0	2	20	5	0	10	10	1.3	4.7	13.3	4.7
8 hrs...	1	3	20	0	3	6	17	5	2	7	5	10	2	2	10	15	5	10	5	15	2.3	5.0	14.7	6.0
12 hrs...	3	5	13	0	2	4	24	6	2	10	7	7	0	2	8	23	0	5	10	20	2.0	5.0	14.0	7.3
1 day..	4	3	27	0	4	7	27	2	0	7	8	2	0	5	7	33	5	20	5	15	3.0	6.3	20.3	6.3
2 days.	5	9	17	3	3	6	18	9	5	23	0	8	2	5	18	12	0	0	20	15	3.7	8.7	15.3	7.7
4 days.	3	5	18	5	2	6	26	5	2	15	8	15	0	7	15	20	10	0	15	15	2.7	6.7	18.7	9.0
7 days.	3	6	24	4	2	11	30	4	0	23	20	7	0	10	15	18	5	5	10	20	2.0	10.3	23.3	7.3
42 days.	—	—	—	—	—	—	—	—	0	0	20	20	0	0	5	40	—	—	—	—	0	0	12.5	30.0

TABLE IV

VALIDITY OF THE RECOGNITIONS FOR EACH OF THE FOUR DEGREES OF CERTAINTY

Interval	Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 4
15 sec.....	99.6	66.7	41.3	0
5 min.....	96.9	90.6	38.9	27.0
15 min.....	98.4	71.5	35.8	47.4
30 min.....	96.2	57.0	51.0	51.8
1 hr.	96.5	77.4	45.8	26.7
2 hrs.....	94.4	58.8	45.6	31.0
4 hrs.....	97.0	72.4	53.0	29.9
8 hrs.....	94.6	68.1	51.6	46.9
12 hrs.....	95.0	73.7	51.2	39.2
1 day.....	90.6	67.8	42.9	50.0
2 days.....	86.6	61.7	56.6	46.5
4 days.....	87.4	60.6	59.9	40.0
7 days.....	83.7	57.1	48.2	60.8

experiment on the next interval was commenced. The period of experimentation lasted from the first of January to the twenty-third of August, 1912. Because of the difficulty of fitting in several of the intervals and also because of the inability to complete the experiment due to interruptions or the failure on the part of the experimenter to remember to test the subject at the given hour, many of the tests which were planned for one interval had to be completed for a different interval. This in no way injured the experiment. On the other hand, it entirely prevented any unconscious behavior on the part of the experimenter from being communicated to the subject as to the length of interval then being tested, for not even the experimenter was sure that the interval he was planning to test would really be the interval that was eventually tested.

Five subjects were employed in this experiment, respectively, *A*, *B*, *C*, *D*, and *E*. The first four were experienced subjects, the fifth, the mother of *A*, was a novice. Five complete records were obtained from *A* and *B*, two complete records from *C* and *D*, and one record from *E*. Thus fifteen complete records for each interval were obtained. *A* and *B* were the experimenters: *A* experimented upon *B* and *C*, while *B* experimented upon *A*, *D*, and *E*.

THE RESULTS

1. *Correct Recognitions.*—Table II. presents the data concerning the correct recognitions. The average results for each

TABLE V

SHOWING THE EFFECT OF VARIOUS INTERVALS OF TIME BETWEEN EXPOSURE AND IDENTIFICATION UPON RECOGNITION MEMORY

The records for the five subjects are given separately and then a summary of the five. (Under each of the six divisions the results from each of the three degrees of certainty are noted together with a summary of the three different degrees of certainty. These summaries represent the score from Pile No. 1 plus $\frac{2}{3}$ the score in Pile No. 2. plus $\frac{1}{3}$ the score in Pile No. 3.)

	A (Av. 5 Records)					B (Av. 5 Records)					C (Av. 2 Records)				
	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P.E.	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P.E.	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P.E.
15 sec.....	92.0	-1.0	-1.5	90.9	3.2	71.0	8.6	-2.3	76.9	2.1	92.5	-2.5	0	90.6	.4
5 min.....	71.2	5.0	-4.0	73.9	5.2	60.8	7.7	-1.3	66.3	5.4	87.5	5.0	-5.0	90.0	5.6
15 min.....	74.1	2.7	-4.2	75.1	1.8	59.2	7.4	-6.3	63.1	3.7	53.1	1.7	7.5	56.2	12.8
30 min.....	60.1	3.0	-1.4	62.1	5.8	53.0	3.6	4.4	56.8	6.7	47.9	2.5	-2.5	49.1	3.5
1 hr.....	62.0	1.0	1.2	63.0	3.4	46.1	11.0	1.5	54.8	1.8	52.9	21.0	-2.5	68.0	2.4
2 hrs.....	58.3	1.0	-7.9	57.1	4.7	36.3	6.6	8.0	43.3	6.5	52.0	-8.3	-12.5	42.6	4.9
4 hrs.....	59.2	4.0	.2	62.3	6.6	34.0	10.1	1.0	41.8	5.9	32.2	0	2.3	32.8	6.9
8 hrs.....	50.2	2.5	-1.2	51.8	4.2	29.6	4.1	1.5	33.1	5.9	31.3	10.0	6.5	40.4	19.3
12 hrs.....	42.6	8.1	4.5	49.8	6.6	20.9	11.4	-4.8	28.3	3.6	38.0	7.4	-1.7	43.1	0
1 day.....	19.1	13.8	-2.5	28.9	4.6	19.6	4.3	-5.8	21.4	5.6	55.0	1.5	0	56.1	.8
2 days.....	17.5	4.2	6.3	22.3	3.5	15.6	5.7	4.8	21.1	2.6	27.9	1.4	2.5	29.5	10.0
4 days.....	16.2	5.2	11.1	22.9	3.4	11.6	3.2	7.9	16.0	2.0	13.8	2.9	3.8	16.9	.2
7 days.....	11.3	3.9	3.4	15.1	2.7	6.4	.5	-3.3	6.0	3.2	0	11.6	-8.0	6.7	6.4
42 days.....	—	—	—	—	—	—	—	—	—	—	0	15.0	-6.6	9.6	1

	D (Av. 2 Records)					E (1 Record)					Totals (Av. 15 Records)				
	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P.E.	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P.E.	Pile No. 1	Pile No. 2	Pile No. 3	Summary	P.E.
15 sec.....	87.8	0	2.5	88.4	4.7	80.0	-5.0	-10.0	73.8	-1	83.7	1.9	-1.6	84.6	1.9
5 min.....	70.3	7.5	-1.7	75.5	4.6	55.7	0	0	55.7	—	68.8	5.9	-2.7	72.7	3.0
15 min.....	40.0	7.5	-.8	45.4	4.0	45.0	7.5	-16.6	46.5	—	59.8	5.1	-3.7	62.7	3.0
30 min.....	62.5	0	0	62.5	4.5	31.1	-20.0	-3.0	15.4	—	54.5	1.3	.5	55.5	3.4
1 hr.....	42.5	2.1	-7.1	42.3	5.0	50.0	0	0	50.0	—	52.1	7.1	-.4	57.3	2.0
2 hrs.....	42.5	8.1	-1.5	48.2	8.6	24.0	0	0	24.0	—	45.8	2.5	-1.8	47.2	3.1
4 hrs.....	45.0	15.0	7.5	58.1	4.9	45.9	15.0	-3.4	56.3	—	44.4	7.7	1.5	50.6	3.4
8 hrs.....	30.6	16.3	-1.5	42.5	6.3	26.3	-10.0	3.4	19.6	—	36.6	5.0	1.0	40.6	3.6
12 hrs.....	50.0	1.5	12.5	54.2	1.1	30.0	0	3.0	30.8	—	34.9	7.7	1.6	41.1	2.7
1 day.....	25.0	8.3	-3.8	30.3	1.3	16.7	-12.0	0	7.7	—	24.7	6.6	-3.3	28.8	3.2
2 days.....	23.0	5.0	-8.1	24.7	.8	15.0	0	9.6	17.4	—	18.8	4.2	3.6	22.9	1.8
4 days.....	15.0	-2.5	5.0	14.4	2.6	32.0	5.0	-15.0	32.0	—	15.2	3.2	6.5	19.3	1.6
7 days.....	5.0	1.5	-8.5	4.0	1.1	12.0	7.5	0	17.7	—	7.4	3.7	-2.2	9.6	2.0
42 days.....	0	0	12.0	3.0	-1	—	—	—	—	—	0	7.5	2.7	6.3	2.0

¹Only one record.

TABLE VI

SHOWING PRACTICE EFFECT

The results of subject A are given in detail together with summaries of the five subjects

	First Record					Second Record					Third Record				
	Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 4	Score	Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 4	Score	Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 4	Score
15 sec. .	15-0	0-1	3-1		73.2	18-0	0-0	0-2		87.5	19-0	0-0	0-1		93.8
5 min. .	12-0	2-0	3-3		67.5	11-1	0-0	4-4		45.9	17-0	1-0	0-1	0-1	87.5
15 min. .	15-0	0-0	2-3		74.3	14-0	2-0	1-3		75.6	17-1	0-1	1-0		73.0
30 min. .	12-4	2-0	1-1		37.5	13-1	1-0	2-3		58.7	10-0	1-1	5-3		51.6
1 hr. . .	14-2	2-0	1-1		60.0	13-2	0-1	2-2		43.7	14-0	0-0	2-4		68.4
2 hrs. . .	14-1	0-2	0-3		49.4	11-1	0-0	2-6		42.1	10-0	1-1	3-5		48.5
4 hrs. . .	8-1	1-1	6-3		33.6	10-0	0-0	5-5		50.0	15-0	2-0	1-0	1-1	83.8
8 hrs. . .	9-1	2-0	3-5		42.0	8-0	0-0	9-3		45.7	9-0	0-1	4-6		39.8
12 hrs. .	7-1	3-2	4-3		32.1	8-1	1-1	6-3		33.6	8-0	1-1	5-5		40.0
1 day . .	5-2	4-2	3-4		15.0	6-2	3-1	4-4		20.7	2-0	3-0	7-8		20.6
2 days .	7-2	2-2	3-4		18.7	4-2	1-1	9-3		12.3	2-0	3-2	7-6		13.0
4 days .	4-1	2-2	7-4		14.4	3-1	1-1	8-6		8.9	4-0	2-1	10-3		29.2
7 days .	5-1	3-1	6-4		23.8	3-0	0-4	7-6		0.7	3-1	1-0	8-7	0-0	11.9
Av. A . .	9.8-1.2	1.8-1.0	3.2-3.0		41.6	9.4-0.8	0.7-0.7	4.5-3.9		40.4	10.0-0.2	1.2-0.6	4.1-3.8	0.1-0.2	50.9
Av. B . .	6.9-1.4	3.2-2.1	2.6-3.8		27.3	6.0-0.1	2.5-0.9	4.8-6.0		33.5	6.8-0.2	2.1-0.6	4.9-3.5	0.8-1.1	40.8
Av. C . .	9.8-0.4	2.8-1.0	1.2-1.2	1.4-2.2	52.1	9.5-0.4	2.8-2.9	1.2-1.5	1.1-0.8	43.7					
Av. D . .	8.5-0.1	2.5-1.1	1.4-1.0	1.8-2.7	45.7	8.7-0.2	1.8-0.8	1.8-1.5	2.0-3.2	45.2					
Av. E . .	8.3-0.8	1.2-1.3	1.7-2.2	1.8-2.8	44.2										

	Fourth Record					Fifth Record				
	Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 4	Score	Pile No. 1	Pile No. 2	Pile No. 3	Pile No. 4	Score
15 sec. .	20-0	0-0	0-0	0-0	100.0	20-0	0-0	0-0	0-0	100.0
5 min. .	15-0	2-0	0-3	0-0	78.8	18-0	1-1	0-0	0-0	90.0
15 min. .	17-0	1-0	0-2	0-0	86.3	13-0	2-1	1-3	0-0	66.1
30 min. .	18-0	0-0	0-1	0-1	88.8	15-0	2-2	0-1	0-0	73.8
1 hr. . .	13-0	3-3	1-0	0-0	66.3	15-0	0-0	3-1	0-1	76.9
2 hrs. . .	12-0	2-0	1-2	1-2	66.7	15-0	1-0	2-2	0-0	78.8
4 hrs. . .	16-0	1-0	1-2	0-0	83.0	12-0	1-0	2-5	0-0	61.1
8 hrs. . .	12-0	1-1	1-5	0-0	55.9	14-0	3-1	1-1	0-0	75.7
12 hrs. .	13-1	3-0	1-2	0-0	66.0	12-0	6-1	1-0	0-0	77.3
1 day . .	7-0	2-0	6-5	0-0	43.2	5-0	6-0	3-6	0-0	45.0
2 days .	5-1	4-1	4-1	1-3	28.7	7-0	5-3	2-3	0-0	39.0
4 days .	5-0	3-0	3-1	3-5	38.2	5-1	3-1	6-4	0-0	23.8
7 days .	2-0	3-0	4-3	4-4	22.0	3-1	4-1	5-4	2-0	17.2
Av. A . .	11.9-0.2	1.9-0.4	1.7-2.1	0.7-1.2	63.4	11.8-0.2	2.6-0.8	2.0-2.3	0.2-0.1	63.4
Av. B . .	9.3-0.2	1.4-0.5	2.9-2.6	1.6-1.5	49.1	9.7-0.2	2.3-0.6	2.8-2.1	1.2-1.1	52.9

of the five subjects are shown. These results are stated in terms of per cent. of the total number of recognitions. That is, for subject *A*, out of 100 recognitions made immediately after exposure 92 were correct in Pile No. 1 and 3 were correct in Pile No. 3, while there was 1 incorrect recognition in Pile No. 2 and 4 in Pile No. 3 (see Table III.). (The details from which the records of Subject *A* in this table are made up appear in Table VI.) In the sixth division of the table is similarly presented a summary of the 15 complete records. The sum-

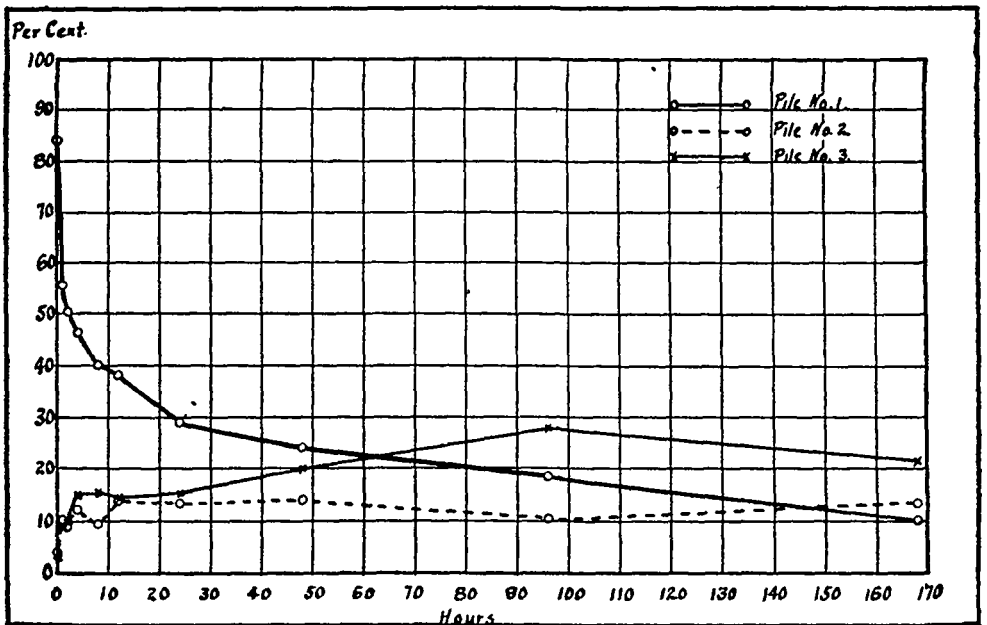


PLATE I. Showing the Effect Made upon the Per Cent. of Correct Recognitions by Lengthening the Interval between Exposure and Identification.

maries of Piles No. 1, No. 2, and No. 3 are shown in Plate I. From the table and plate it is very apparent that the per cent. of correct recognitions in Pile No. 1 drops very rapidly from "immediately after exposure" until an interval of 1 day. From there on the decrease is very much more gradual. The number of recognitions, which one is "reasonably sure" are correct, remains fairly constant. On the other hand, the per cent. of correct recognitions that are made in Pile No. 3 in-

creases from "immediately after exposure" to an interval of 7 days. This is due primarily to the fact that there are very few or no recognitions of the certainty of which the subject doubts, for the very short intervals of time. But as the interval of time increases the feeling of certainty accompanying the recognitions changes, becoming less and less positive. Only the first 3 degrees of certainty were employed with subjects *A* and *B* until the middle of the third series of experiments. Up to that time these subjects were forced to pick out words

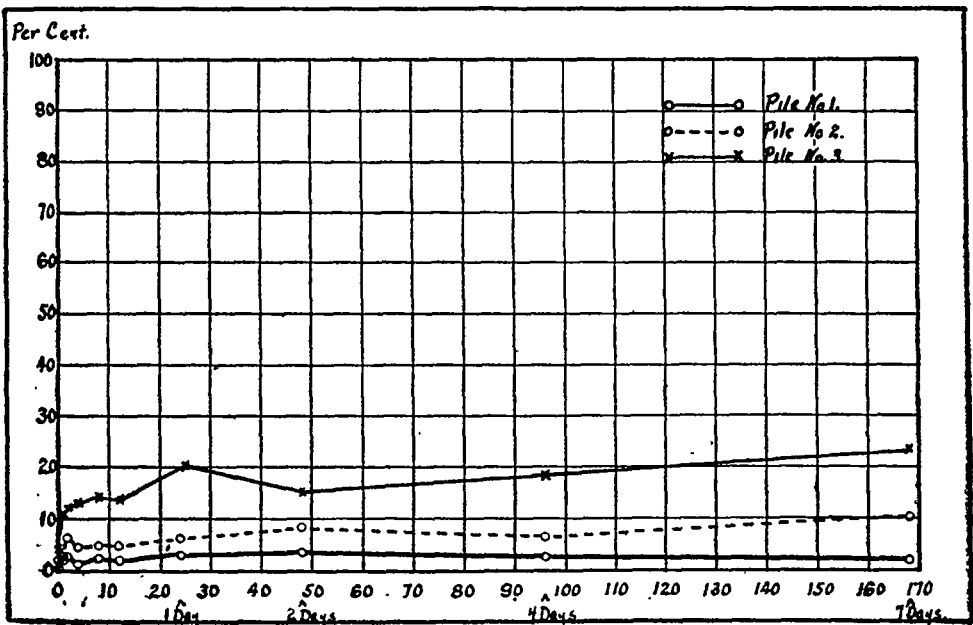


PLATE II. Showing the Effect Made upon the Per Cent. of Incorrect Recognitions by Lengthening the Interval between Exposure and Identification.

and put them in the third pile even when they felt that they were mere guesses. (As a matter of fact, very few such cases appeared.) After the change, such guesses were, of course, put in Pile No. 4. But neither of these subjects ever felt much need for this pile anyway. Subjects *C*, *D*, and *E*, however, used this fourth pile a great deal, as is shown in the table, and especially is this so in the case of the longer intervals.

Seemingly, some recognitions, which would have been put

in Pile No. 1 with a short interval, are put in Pile No. 2 with a somewhat longer interval, and with a very much longer interval of time between exposure and identification they are put in Pile No. 3. A study of the introspections apparently confirms this tendency. Pile No. 2 then constantly gained from Pile No. 1 and lost to Pile No. 3. The total number in the pile in this way remained practically constant.

Increase of difficulty in recognition, whether produced by increasing the number of stimuli presented at exposure or by increasing the interval between exposure and identification, causes first of all a pronounced decrease in the certainty with which the recognitions are made.

2. *Incorrect Recognitions.*—Table III. and Plate II. present the data with regard to the incorrect recognitions that were made in these experiments. Here we find that there is only a slight tendency to increase the total number of incorrect recognitions as the difficulty of the task is increased. There is actually an increase in this respect in all the three degrees of certainty. But the surprising thing is that it is so slight. It is evident here just as it was in the study of recognition memory with varying lengths of series that *an increase in the difficulty of the task does not cause one to make many more incorrect recognitions.* There is a limit, however, to the accuracy of this statement, as has been shown by R. H. Paynter, 3d, of Columbia University. In an unpublished study, he exposed pages of quarter-page advertisements at the rate of 1 page per 2 seconds. In this case there was a noticeable number of mistaken recognitions, especially with his subjects under 16 years of age. Nevertheless, within seemingly quite extended bounds, an increase in the difficulty of the task does not cause one to make many more incorrect recognitions.

The very much larger per cent. of incorrect recognitions in Pile No. 3 in the cases of subjects *A* and *B* than with the other three subjects is due largely to the fact, previously pointed out, that they did not have the use of a fourth pile, in which to put their mere guesses until half way through the entire experiment. If the experiment had been conducted with them at the start as it was at the end it is quite reasonable to suppose that

they would not have recorded against them such a large number of both correct and incorrect recognitions in Pile No. 3. Many of these would have been placed in Pile No. 4. This would have resulted in a lower per cent. of correct and incorrect recognitions in the summaries for the group.

3. *The Validity of the Recognitions.*—We have seen now that the correct recognitions in Pile No. 1 decrease very surprisingly in number as the interval of time is increased and that the correct recognitions in Pile No. 2 remain about constant in number, while those in Pile No. 3 increase in number as the interval is increased. We have also traced the tendency of the incorrect recognitions to increase in number with the increase of difficulty of the task, although this increase is comparatively slight. It is worth while to stop a moment to study the general validity of the recognitions for each pile under the varying conditions of the experiment. In other words, what per cent. of all the recognitions placed in Pile No. 1 were correct for the different intervals under study?

Table IV. expresses these relationships. Each figure in the table gives the percentage of correct recognitions from the total number of correct and incorrect recognitions in that situation. For example, 99.6 per cent. of all recognitions "immediately after exposure" which are felt to be absolutely correct are actually correct. This per cent. drops to 83.7 per cent. when the interval has been lengthened to 7 days. Evidently, there is a very gradual decrease in the reliability of recognitions placed in the category of "absolute certainty" as the interval between exposure and identification is increased. But it is well to emphasize that this decrease, as has already been pointed out, is due not to an actual increase in incorrect recognitions as the intervals are lengthened but to a decrease in the number of correct recognitions. Either tendency would produce the same effect of a gradual drop in the validity of the recognitions, but they give totally different interpretations to the situation. As it actually is here, *the drop in the validity is due to the fading out of impressions received at the exposure, not to the rise of new and false impressions.*

The validity of the recognitions in Pile No. 2 remains

practically constant, approximating 67 per cent. The third pile shows a validity of about 50 per cent. As was pointed out in the study of the effect of length of series upon recognition memory the validity of the third pile is no better than a random guess. For a random selection of 20 from 40 would give us 50 per cent. of validity. This is likewise true here—the validity of the third pile is no better than what chance would warrant. It is interesting to note here in addition, however, that the validity of the third pile is actually higher than that of the fourth pile. Recognitions representing pure guesses are then lower actually in validity than are those when we feel there is a chance of their being correct. (The reason that there are consistently lower per cents. in Pile No. 4 than 50 per cent. is due to the fact that after all the recognitions in which the subject has any confidence have been made we have more incorrect than correct words to choose from in making a selection. The per cents. in Pile No. 4 are probably pretty close¹ to what chance would warrant, and these per cents. for the different intervals probably indicate the relationship between correct and incorrect words that are left to be chosen from after Piles No. 1, No. 2, and No. 3 have been determined.

4. *Results Combining (1) the Number of Correct Recognitions and (2) the Validity of the Recognitions.*—In order now to measure the total amount of correct recognition possible for the different intervals under study it is necessary to combine the results from the first three piles. This is done, as has already been pointed out, by adding to the score in the first pile, $\frac{3}{4}$ of that in the second and $\frac{1}{4}$ in the third pile. As the fourth pile only meant a guess it manifestly has no value whatever in this connection. But it is not enough to simply add together the scores obtained from the correct recognitions. The number

¹ G. S. Fullerton and J. McK. Cattell ('On the Perception of Small Differences,' p. 151, 1892) have shown that "the observer is more apt to be right than wrong even when he feels little or no confidence in his decision." This point cannot be determined in this experiment due to the complexity of the situation. To the extent that it holds true here it would modify the statement in the text. However, in experiments where the stimuli to be recognized in the test are presented in order and a judgment as to one's confidence in the recognition is registered before proceeding to the next stimulus, the chance remains throughout 1 to 1 that one is correct. And even in such cases, the recognitions assigned to the doubtful class (Pile No. 3) are no better than chance would warrant for the great majority of subjects.

of incorrect recognitions must also be taken into account. Unless this is done an interval which is credited with 8 correct and 3 incorrect recognitions would be scored higher than an interval with 7 correct and 0 incorrect recognitions, which would be, of course, wrong.

Now perfect memory would in this case consist of selecting the 20 correct words and placing them in Pile No. 1. Zero memory would be any score equal to pure chance as 6 correct and 6 incorrect or 2 correct and 2 incorrect. The following formula¹ gives 100 per cent. for perfect memory, 0 per cent. for zero memory and an orderly progression of steps between the two extremes.²

$$\frac{\text{correct recognitions}}{\text{total number presented}} \times \frac{\text{correct} - \text{incorrect recognitions}}{\text{correct} + \text{incorrect recognitions}} \times 100.$$

For example, consider the score given in Table I.

Pile No. 1, 5 correct and 0 incorrect,.....	$\frac{5}{20} \times \frac{5-0}{5+0} \times \frac{100}{1} = 25$ per cent.
Pile No. 2, 3 correct and 0 incorrect.....	$\frac{3}{20} \times \frac{3-0}{3+0} \times \frac{100}{1} \times \frac{3}{4} = 11.3$ per cent.
Pile No. 3, 3 correct and 1 incorrect,.....	$\frac{3}{20} \times \frac{3-1}{3+1} \times \frac{100}{1} \times \frac{1}{4} = 1.9$ per cent.
Total	<u>38.2</u> per cent.

The calculations involved in the above example seem very complicated but after a little use the totals are readily obtained, since the several steps above can be reduced to just one in most cases.³

¹ For further information regarding this formula, see Strong, *op. cit.*

² I wish to correct here a statement in my previous article. It was there stated that the steps were *equal*. They are not, and that was known at the time. For example, the score for 10 correct and 1 incorrect out of a possible 20 is 40.9 per cent. while for 11 correct and 1 incorrect it is 45.8 per cent.—a difference of 4.9 per cent. The score for 10 correct and 9 incorrect is 2.6 per cent. while for 11 correct and 9 incorrect it is 5.5 per cent.—a difference of 2.9 per cent. An extra correct recognition should count more according as it is more unlikely to happen according to chance and this is just what our formula does. *

³ Any formula used in this connection, that I have been able to devise, has some objection to it, although several that I have used give within a few per cent. of the same final scores. The present formula penalizes mistakes a little more than is warranted on a basis of chance. If on the other hand, we subtract the incorrect from the correct

Using this formula a score was determined for each record obtained. A summary of these records is given in Table V. We have there summaries of the 5 subjects and then a final summary of the 15 records. Under each one of these six headings are given the average scores for the first three piles and then a summary of the three. (The details from which the averages are obtained for subject *A* appear in Table VI.) Many records appear with a minus sign attached. The negative score is due to the fact that more incorrect than correct recognitions were made in those records. Now practically there can not be such a thing as negative memory but statistically there can be and should be here. In order to offset the correct recognitions which were made by chance it is necessary to subtract the score where incorrect recognitions are made equally by chance,—hence the negative scores. And also, we must have some way of penalizing the subject who places, for example, 19 correct words in Pile No. 1 and 1 incorrect word in Pile No. 2. Such a score is not so good as if the 1 incorrect word had been placed in Pile No. 4. The two scores actually, in these cases, would be 91.3 per cent. and 95 per cent., respectively.

The probable errors given here are probable errors of the averages. They indicate a lower reliability to the figures than actually exists. This is true because of the presence of a very noticeable practice effect. If the different scores for each record were stated in ratios of the score for recognition “immediately after exposure” the probable errors from these ratios would be very much smaller. It is because of this that probable errors have not been given to the other tables. However, it might be added here, that they are approximately the same in Tables II., III., and IV. as shown here.

recognitions (as was done by B. R. Simpson in his ‘Correlations of Mental Abilities,’ Col. Contributions to Education, No. 53) and score on the basis of such differences we have a formula which does not penalize mistakes enough. For example, 10 correct and 0 incorrect in this experiment will be scored 50 per cent. by either of these two methods. But 12 correct and 2 incorrect will be scored 35.7 per cent. and 50 per cent. by the two methods respectively. The former possibly, as has been said, penalizes the mistakes too heavily, the latter does not penalize them enough. For 10 correct and 0 incorrect is certainly preferable in any sense to 12 correct and 2 incorrect.

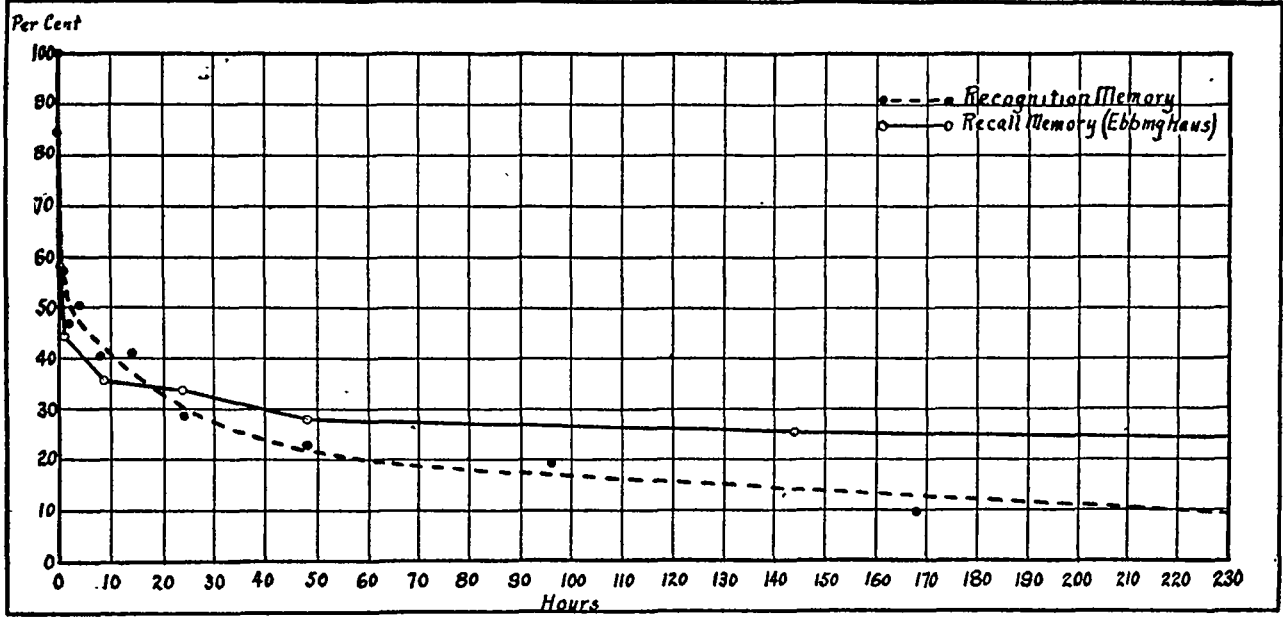


PLATE III. Showing the Relationship between Length of Interval between Exposure and Identification and Recognition Memory (when amount and accuracy of recognition are both considered).

Plate III. presents the totals for the 15 records in the shape of a curve. The dotted line is a "smoothed" curve from the results. The other curve represents the results secured by Ebbinghaus¹ in his study of recall memory. Ebbinghaus' first record was after 20 minutes—hence the very low first record on his curve (58.2 per cent.). Our 15 minute record was 62.7 per cent. and our 30 minute record was 55.5 per cent. Evidently there is no difference between his initial record and what would have been found here in this study of recognition memory for an interval of 20 minutes. The two curves are very similar in shape and almost agree as to actual amounts until after the 4 day interval. It seems possible that from there on Ebbinghaus' curve represents a greater amount retained than does our curve. It is certainly higher than ours at this point as well as at 31 days. It is also considerably higher than the individual record of *A*—our best subject. But still two records of *A* and one of *B* are higher than Ebbinghaus' average and two more records, one of *A* and one of *C*, approximate it pretty closely. After all, then, it may represent nothing more than an extreme individual difference.

In Plate IV. are presented similar curves to those in Plate III. but for the two subjects *A* and *B* separately and the three other subjects, *C*, *D*, and *E*, together. Each of the three curves is based on an average of 5 records for each interval studied, except the 42 day interval. The relative relationship between the three curves remains constant, barring irregularities due to the few cases. Subject *A* is evidently superior and *B* inferior to the group of the three subjects.

We should conclude that *there is no difference in the form of the curves for retention in recall and recognition memory.* The amount retained at any particular point in such curves depends, of course, upon the material used and the method employed.

One more point in Table V. might be mentioned. The individual records as well as the summary show a steady decrease in the score in Pile No. 1 as the interval studied is lengthened. The score in Pile No. 2, on the other hand, increases slightly but very irregularly. The score in Pile No. 3 approximates

¹ Ebbinghaus, *op. cit.*, p. 103.

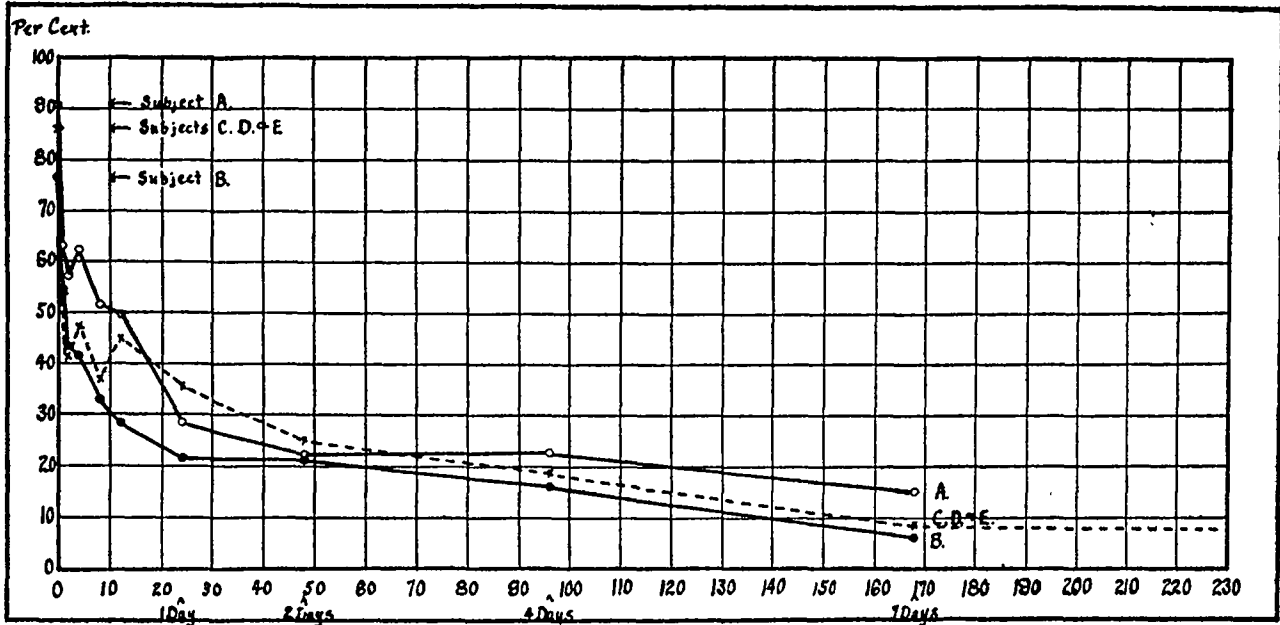


PLATE IV. Showing the Records of Subjects A and B separately and C, D, and E together.

zero. This is the same situation as was found in studying the effect of length of series upon recognition memory. In both cases the score in Pile No. 1 decreased as the difficulty of the task was increased, the score in Pile No. 2 remained practically constant, and that in Pile No. 3 was practically zero. As stated there, "*evidently then recognitions that are not accompanied with a feeling of "absolute certainty" are practically no better than random guesses.*" In this study also they are no better in Pile No. 3, and in Pile No. 2, though they do amount to something, it is very little when compared with Pile No. 1.

5. *The Effect of Practice on Recognition Memory.*—Table VI. presents a complete detailed record of all the experiments on subject *A*. The records for each pile (or degree of certainty) are given for each separate experiment and then the score that is obtained from each of the experiments is shown in the fifth column. Under each pile appear two columns of figures—the first column refers to the total number of correct recognitions and the second column refers to the total number of incorrect recognitions which were assigned to that pile in each separate experiment. For example, opposite the 15 second interval we have the numbers respectively, 15—0, 0—1, 3—1, blank, 73.2. These figures indicate that in the first experiment on this interval 15 correct and 0 incorrect recognitions were assigned to the first pile (absolute certainty), 0 correct and 1 incorrect were assigned to the second pile (reasonable certainty), 3 correct and 1 incorrect to the third pile (doubtful certainty), and no recognitions were assigned to the fourth pile (not then being used). The score for these results is 73.2 per cent. of a perfect record. Below the averages for subject *A* are given the corresponding averages of subjects *B*, *C*, *D*, and *E*. (It must be remembered in this connection that Pile No. 4 was not introduced with subjects *A* and *B* until they were half way through the third record.)

A study of the average scores in the bottom rows of this table gives us some idea of the way improvement took place with these subjects. These figures are plotted in Plate V. The records of *A* and *B* show a very noticeable improvement,—an improvement from 42 per cent. to 63 per cent. with the

first and an improvement from 27 per cent. to 53 per cent. with the second. Such improvement in memory should be explained if possible.

Throughout this experiment it has been considered that we were studying a memory function. And in the generally accepted use of the term that is correct. But it must be remembered that in this experiment we have not separated the pure memory function, whatever that is, from many other functions which have entered into the total process. And now in

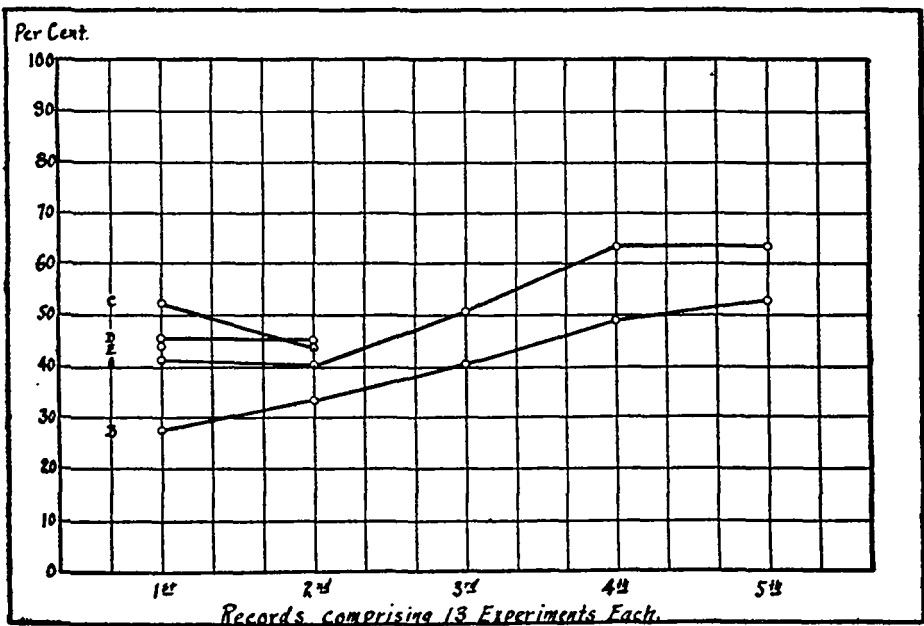


PLATE V. Showing Practice Effect. Each record represents the average of the scores for the thirteen different intervals studied.

attempting any explanation of the improvement which *A* and *B* have shown we must take into consideration all of the possible processes which have influenced the work. Roughly speaking, we have the three divisions,—the sensory reception of the stimuli, their retention, and the expression of them at the appropriate time. The question is, was the total improvement due to an improvement in one of these three general divisions, or to two of them, or to all three of them?

Let us study the details of the improvement first and then return to our general question.

From the data from subject *A* it is evident that there was a slight drop in the second record as compared with the first. Introspection furnishes a possible explanation of this. The first few experiments were new and interesting. The subject found no difficulty in applying herself to the exposure lists. But after a short time the experiment became a matter of course, and the enthusiasm died out. That is, spontaneous attention failed or at most came only in spurts. The first record is to be considered somewhat in the light, then, of an initial spurt—a time when the newness of the experiment kept one interested in it. The second record of *C* likewise shows a drop. The experimenting in her case with the second record dragged on for nearly two months. The experimenter was very much bored with the experiment at that time and although introspections of *C* throw no light on the subject, she at least took very little interest in the work at that time. The results of *D*'s two records show no gain or loss. The average scores of *B*, on the other hand, show no drop in efficiency but instead a steady rise. Introspections by him show that at no time did he lose, at least consciously, any of the freshness with which he first attacked the work. It seems then very reasonable to suppose that the drop in efficiency in the second record with subject *A*, and probably with *C*, and the no-gain with *D* are due partly at least to a loss of spontaneous attention. If this was the only factor operating we should expect a steady drop in efficiency from record to record. But there were other factors.

First, subject *A* reports that she consciously attempted to improve the accuracy with which she assigned recognitions to Pile No. 2. Her first introspection showing such a need occurred when she was half way through the first record. As is shown later, many words seem to the subjects to have been in the exposure list when they were not there at all. They wavered between placing them in the first or second pile. But it was soon realized that the recognition of these words had a different feeling-tone from many of the other recognitions.

When this was learned the subject ceased to consider them for either Pile No. 1 or No. 2. This tendency is reflected in the averages under Pile No. 2 in the table. These averages show a decided drop in the use of Pile No. 2 during the second record as compared with the first record for subjects *A* and *B*. From there on there is a steady increase in the number of correct recognitions coupled with about a constant number of incorrect recognitions with *A*, while with *B* there is a similar tendency to improve the proportion of correct to incorrect recognitions but here shown by a decrease in the number of incorrect recognitions. After the first tendency not to use the second pile there came the more intelligent use of it. Subjects *C* and *D*, who could not scrutinize another's records, as could *A* and *B*, did not learn about the tendency to make mistakes in Pile No. 2, as the records show.

Another factor which operated to raise the scores was the more careful use of Pile No. 1. The averages for both subjects *A* and *B* at the bottom of Table VI. show a very decided improvement in this respect. *B* learned quicker than *A* here for he has practically no mistakes in Pile No. 1 in his second record, while it was not until the third record that *A* attained this same degree of perfection. Yet *A* was conscious of the need for such improvement by the time she was half way through the first record according to the date of her first introspection on this subject.

It is quite evident, then, that both subjects *A* and *B* learned to distinguish better between correct recognitions and incorrect ones. (Some of the points brought forth from introspections on this point will be given later.) But not only improvement in the quality of the work took place but also a decided improvement in the quantity. Consider the scores from the third and fourth records for both subjects *A* and *B*. Here there was no improvement in decreasing mistaken recognitions in Piles No. 1 and No. 2. But there was a decided gain in the number of correct recognitions assigned to the two piles by both the subjects. How shall we explain this improvement? Was it an improvement in the processes of 'taking-in' the impressions or in the processes of retention? The data at our disposal do

not permit us to answer; they throw no light on this point beyond merely recording the fact that there was such improvement. Introspection throws some light on the subject, however. Over and over again after the first few experiments the introspections record the fact that both *A* and *B* were consciously forcing themselves to 'grasp' each word in the exposure list,—not to be content with merely automatically looking at the word and pronouncing it but to actually comprehend what it meant.

This process of comprehending seems analogous to the flow of electric current. If the current does not flow somewhere there is no current in the wire. In the same way it seemed that if the stimulus word did not cause a thought current to flow somewhere there was really no current at all—there was no comprehension of the word. Comprehension of nouns with subject *B* was very often accompanied by localizing the object which the word stood for. This localizing was accompanied many times by a nod of the head in the direction of the place. Whether he always nodded his head or not *B* does not know but whenever he watched himself carefully he found himself doing it. For example, to the word 'kettle' there was not an association with 'kitchen' in the sense of definitely thinking 'kitchen' nor an incipient pronunciation of the word, as far as *B* could determine, but a general feeling of 'kettle in kitchen' and a nodding of the head in the direction of the kitchen. Later, on recognizing 'kettle' 'kitchen' came to mind. But the characteristic thing about the association was the emphasis upon the direction of the object rather than the object itself. Adjectives were similarly very often localized by assigning them to appropriate objects whose location was known. Verbs and adverbs were very often applied to the subject, himself, as though he was going through the action. For subject *B*, then, comprehension involved in a great many cases the holding of the word long enough in the mind for it to result in an incipient movement of the subject's body. This was not an easy task for many words. Such words did not readily provoke a response and it required voluntary attention to hold them in the mind until they would do so.

From the introspections of *B* it would seem that the improvement shown in this study in recognizing more and more words correctly was due to conscious effort in the reception of them.

The process of comprehension was slightly different in the case of *A*. She was not conscious of any tendency to localize but in attempting to realize the full meaning of each word she inevitably formed certain associations with it. These associations were all of the simple and obvious type as they were entirely spontaneous. They increased in number with practice. In the early part of the experiment there would be words in each list with which *A* formed superficial associations as of sound or of similarity of appearance of the word. By the time of the fifth record however, practically every word was comprehended clearly and all associations were obvious. "For instance, whereas, 'kettle,' if it had been used in the first record, might have called up 'kittle cattle,' by the time of the fifth, it would certainly have been associated with 'kitchen' or 'cooking'" (introspection of *A*). Reference to the next section will indicate how this change materially aided in the identification of the previously shown words.

Returning to our question, How shall we explain the improvement? We must answer it by the simple statement that introspection clearly indicates a change in the method of receiving the original impressions while the improvement was taking place. That the two are related seems most probable. That *A* and *B* were able to improve the accuracy of their recognitions through watching the mistakes of their subjects and that the means of accomplishing this improvement depended upon a better analysis of the feelings accompanying the recognitions seems to imply that there was a change in the control of the response to the experiment. Whereas, at first recognitions were made with little or no guidance, they later were made under careful scrutiny and according to standards justified by experience. We should conclude, then, that *the improvement in quantity is due very largely to improvement in methods of 'taking in' the exposure words, and that improvement in the quality of the work is due very largely to the better control of the response to the tests.* But as to whether there was any change in the process of retention, we cannot say.

6. *Some Information Concerning the Process of Recognizing Words as Revealed by Introspection.*¹—A word, first of all, should be said as to the general reaction to the lists. Once the list had been read and the problem in mental arithmetic solved it seemed to both *A* and *B* that the list was gone forever. There seemed in many cases that there was no string (figuratively speaking) which by pulling could bring back the list nor any of its contents. The words were gone. For example, one remark of *A* immediately after finishing the problem was, "I haven't a single word carried away." This was not strictly true of all of the lists. In many cases the subjects felt that they might recall the words if they would, especially did they feel this way immediately after reading the list. But after the list had been retained some time, the feeling would come that the whole thing was gone. Not only was this so but it was found very difficult to keep track whether one was in the midst of an experiment or not. A rather favorite expression of both *A* and *B* was, "Have I a list down me?" and when told they had to reply, "I have? I don't remember it." Similar remarks were noted from subjects *C* and *D*. This 'lostness' of feeling was quite characteristic.

No attempt was made to study those feelings which generally give one an idea as to whether they have done well or not. But on two very definite occasions when *A* reported that she knew she had not done so well as usual her work was fully up to average. On one of these occasions she had a headache and on the other she had just been wakened from a nap and did the work although insisting that she was still too sleepy to do it right. On another occasion *B* was sure he had done poorly and actually had not. Moreover, he felt no different from his usual state, on the two occasions when he made proportionately the two poorest records.

In order to give a better idea of the information obtained from the introspections a characteristic record is given here. It is the first test on *D* for 1 hour. Those words of the 40 in the second list are given here which were in the exposure list

¹This section is added as simply a statement of what was found in this study, not as an attempt to prove or disprove current theories as to recognition memory. The writer hopes, however, to take this subject up at some future time.

together with those words which were wrongly identified. The others have been omitted. The first column of figures gives the position of the 20 correct words as they appeared in the exposure list. The second column gives the degree of certainty which *D* attached to his recognitions. Then follow the words and the introspections.

- 11 1 champagne— mistook it for campaign (T. R. and Taft) which I remembered doing before.
- 20 1 rogue— at end of list, noticed it particularly and chuckled over it, feeling remembered.
- 19 1 firm— either an adjective or firm (company), thought of that when first reading list through.
- 18 1 crocodile— visual image of leather on grip.
- 13 2 haunted— quite sure I had that word, don't often think of haunted things but I know I have had a thought of such recently.
- 16 — song
- 3 divorce— mere guess.
- 17 1 penny— association of woman who dropped a cent and made some ado picking it up.
- 2 marvel— have thought of 'marvel' recently, can't think of any possible connection except the list.
- 10 — breath
- 6 1 fable— association of book just read in which a fellow makes a pedantic talk about telling fables to children to teach them.
- 2 echo— like haunted above.
- 4 puddle
- 3 4 handkerchief
- 5 1 corner— read it first as 'comer.'
- 3 den— have thought of 'den' recently, can't think of any possible connection except the list.
- 7 3 continent— had this word in a previous list, quite sure it was not in last list.
- 1 — ugly
- 2 — pass
- 3 cab— mere guess
- 4 — bill
- 12 1 insect— not quite sure it wasn't 'insert,' that seemed to vivify the word.
- 9 — cheat
- 15 1 pressure— associated with tank. Did it now and then remembered doing it before.
- 14 1 fifty— associated it with sixty in previous list.
- 8 1 period— know it was in list.

Summary.—Pile No. 1, 11 correct and 0 incorrect, score 55.00 per cent.
 Pile No. 2, 1 correct and 2 incorrect, score —2.50
 Pile No. 3, 1 correct and 3 incorrect, score —1.90
 Pile No. 4, 1 correct and 1 incorrect,
 Total..... 50.60 per cent.

A possible objection to the validity of these introspections might be made on the ground that they were merely retrospections,—that they were merely reasons trumped up afterwards to explain the recognitions. Very likely some of them are no more than such ‘after-thoughts.’ But in the great majority of cases the subjects were just as sure that these various associations, that are given in the introspections, were actually present at the time the words were first read in the exposure lists as they were sure of the recognitions of the words themselves; in fact, even more so. The introspections had the same relation to the words as the occasion of meeting someone has to the recognition of that one again. The recognition is confirmed as the occasion comes to mind.

From such records as that given above the following points have been noted concerning recognitions of which the subject is absolutely certain. Recognitions are made:

1. When the word was recognized by itself without any other association of any sort coming to mind. For example, ‘tarry—I know it was there’ (*A*), or ‘period—know it was in the list’ (*D*), ‘pride—don’t know why’ (*C*). Such introspections were comparatively rare for words assigned to Pile No. 1. Recognitions with such introspections were at first most frequently assigned to Pile No. 2 and later to Pile No. 3. Many words with such introspections were wrong, they had not been seen in the exposure list. It was the questioning of these recognitions that contributed to raising the accuracy of Pile No. 2 for *A* and *B*, referred to above.

2. Recognitions are made when at sight of the word in the second list an association with it came into consciousness. The association was then recognized as having been met with before—very often directly connected with the exposure list—and then the word was identified as having been in the exposure list. Generally speaking, as soon as the association came to mind the subject was sure of the recognition. Some recognitions, however, appeared actually to come as the result of a train of thought as outlined above. Whether this train of thought was necessary or not cannot be determined. But it does seem certain in many cases that in some way recogni-

tion of the brute word would not take place until after the previously formed association with it came into mind. The associations were of great variety. Several distinct types may be mentioned. (a) An association between the word and some idea or object. (b) An association between the word and some feeling or emotion. For example, 'waft—wäft or wäft, remembered the quandry, not the word' (*D*); 'rid—last word in the list, good riddance' (*E*); 'insect—have such a horror of them, would remember, (*E*). (c) An association between the word and a visual impression. For example, misspelled words, words with 'q's' in them, as quarry, or double 'oo's,' as in footstool, or again as 'button—at first not recognized, later remembered difficulty of reading handwriting of this word the first time and then identified it' (*B*). (d) An association between the word and a motor response. For example, 'whelp—hard to pronounce, and then recognized' (*A*). (e) An association between the word and an auditory impression. For example, 'throb—sound, I think' (*A*), 'hustle—the sound of it' (*A*), 'ant—because I corrected myself to say aunt before' (*D*).

3. Recognitions were made on the basis seemingly of associations that did not themselves come to consciousness, at least until after the recognition had been made, but which were felt to be there when the recognition was made. For example, "gastric—made some unpleasant association before—the unpleasant feeling comes up now but I can't recall the association. I know I saw the word because I recognize the feeling" (*A*); 'night—forgotten association—think it was with nightingale' (*A*); 'moon—didn't recall previous visual image until after word had been checked' (*A*); 'primitive—some association connected with this, can't recall.' Same with 'chance.' Later remembered it was 'primitive queen by chance,' thus connecting three words in the list together (*B*); 'trinket—feeling as though I had an association with it' (*B*); 'moisture—faint idea of association with rain' (*B*); etc.

Recognitions with the accompanying feeling of absolute certainty seem to depend upon the fact that the same mental process has accompanied the word the second time that did

the first time. In other words, when a new association came up on the second presentation the word was not recognized. In support of this point we have many introspections made after the checking of the list was finished and the subject was told the mistakes he had made. Then the first associations with many of the words would come to mind and the subject would realize that if it had come at the time of checking the list the word would have been recognized. It is right along this line where *A* made one of her conscious attempts to improve. She realized that when trifling associations, as of sound, came on reading the exposure list, that very often they did not appear the second time and so the word was not recognized. It was in this way that she learned to inhibit such associations or in other words not to be content in reading the list with "grasping" simply visual or sound peculiarities of the word.

It is possible that the recognition takes place as soon as the word is seen but all our introspections suggest that the recognition is more likely made while the accompanying associations are coming to consciousness the second time. Whether this is due to the mere fact that a larger content—the word + its associations—is more easily identified than a smaller one—the mere word—or whether recognitions take place when only the association centers are aroused is an interesting question to speculate over.

Let us now note a few differences in attitude that appeared which directed the use of the various grades of certainty. *D* said at one time: "With Pile No. 1 I let myself go just as my feelings direct; with Pile No. 2 I hunt up some reason for my choice and when I get it I feel justified in checking the word; and with Pile No. 3 I again let myself go as my feelings direct." None of the other subjects gave such a summary of their attitude toward the three piles. But *A*, *B*, and *E* all made such remarks as this one of *D* on referring to several words he had placed in Pile No. 2: "I think I saw those words in the list, but I have no way of justifying it. I shouldn't be surprised to find that they were less correct than those placed in Pile No. 3." As already pointed out *A* and *B* early realized

that they were making many mistakes in the recognitions assigned to Pile No. 2 and deliberately attempted to rectify the tendency. *E* also expressed herself quite emphatically that she had very little confidence in those recognitions she assigned to Pile No. 2. Her record (see Table VI.) shows that she made as many incorrect as correct recognitions. The situation with regard to this second pile was very curious. While checking the list Pile No. 2 meant a degree of certainty between No. 1 and No. 3 but afterwards on thinking it over, one felt that Pile No. 2 was less reliable than No. 3. The reason for this was in the case of *D*, as already pointed out, that guidance toward Piles No. 1 and No. 3 was on the basis of feelings of acquaintance with the word, while toward No. 2 it was on some other basis. *B* felt in somewhat the same way that there was a difference in quality between the recognitions in Pile No. 2 and the other two piles but he could not express what the difference was.

Pile No. 3 was made up largely of words which were recognized on little or no more basis than what is meant by the word 'guessing.' On many occasions the word seemed familiar and no other cause for its familiarity could be given than that it was in the previous exposure list and so it was checked. Another example of the feeling basis for these recognitions is illustrated by this introspection of *A*,—'marshall—no associations, nor reasons for checking come to mind. I just feel that it was there more than the other words. More a negative feeling toward the others than a positive feeling toward this word.'

CONCLUSION

1. When recognition is allowed immediately after presenting a list of 20 words 84 per cent. of them will be identified correctly and with a feeling of absolute certainty, while only 10 per cent. can be so recognized after an interval of 7 days.

2. The per cent. of such correct recognitions decreases very rapidly at first and then more and more gradually as the interval between exposure and identification is lengthened.

3. As the interval is increased between exposure and recognition the certainty with which the recognition is made steadily decreases.

4. Actually, very few incorrect recognitions are made as compared with the total number of correct recognitions. Nor does the per cent. of incorrect recognitions materially increase as the interval between exposure and recognition is lengthened. "It seems then that the ability to know we have not seen an object is much more firmly fixed than the ability to pick out what we have seen."

5. When the two factors of the per cent. of correct recognitions from the total number possible and their validity (comparing correct with incorrect recognitions) are taken into account, we obtain a relationship between recognition memory and the length of time between exposure and identification practically identical to the relationship found by Ebbinghaus in his study of recall memory.

6. Recognitions not accompanied with a feeling of 'absolute certainty' are little better than random guesses.

7. A very noticeable improvement in recognizing words previously exposed is shown. This improvement is shown in two ways: (1) by a decrease in the number of incorrect recognitions made, and (2) by an increase in the total number identified correctly. The former is due primarily to a better analysis on the part of the subject of the feelings accompanying recognition. The latter is due to an improvement in the methods of perception of the stimuli as they are exposed.

8. Recognition seems to depend upon the fact that the same mental process has accompanied the word the second time that did the first time.

9. Recognition ordinarily seems to take place as the associations, which were formed when the word was first seen, come up again into consciousness.

10. Increasing the difficulty of recognition by increasing the length of series exposed results in a slow but almost constant decrease in the ability to recognize correctly. But increasing the difficulty of the task by lengthening the interval between exposure and recognition results in a very rapid decrease in the ability to recognize up to about an interval of two hours and from there on a less and less rapid decrease in this ability.