

## STUDIES FROM THE HARVARD PSYCHOLOGICAL LABORATORY. (III.)

COMMUNICATED BY PROFESSOR HUGO MÜNSTERBERG.

### A. THE PLACE OF REPETITION IN MEMORY.

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The investigation of which I wish to give a short account was undertaken with the view of affording material for a further step in the experimental analysis of the processes involved in learning and recollection.<sup>1</sup> Every one knows that repetition plays an important part in the process of acquiring knowledge, but hitherto there has been no attempt experimentally to study this factor beyond the experiments of Ebbinghaus relating to the effect of repetition on the duration of memory. The aim of the following experiments has been to determine the extent and character of memory at different stages of repetition. Series of nonsense syllables formed the subject-matter which had to be learned; the reagent made no attempt to learn a series by heart, but simply reproduced as much as he could recollect after he had repeated it a certain number of times.

The experiments were carried on in the Harvard Psychological Laboratory with the kind assistance of Prof. Münsterberg in the spring and summer of 1895. I am able to present the results gained from eight subjects. In some cases the experiments are not so numerous as might be desired; on the other hand, owing to the large number of subjects, any conclusion which may be drawn can hardly be vitiated by merely individual peculiarities. Only the initial stage of the research can be presented here, but as I have no immediate prospect of making any substantial advance in the investigation, it seems best to bring forward now the results so far as they have been gained.

<sup>1</sup>This research may be regarded as a continuation of the work on memory which formed the subject of an article in *Mind*, N. S., IV., p. 47.

The following method was adopted in the experiments. Series of syllables were printed on slips of paper by means of the typewriter in such a form that the subject could easily read what was printed. In each series there were ten syllables forming one line; in each syllable there were three letters, the vowel being in the middle. Syllables which were too harsh in sound, or which might suggest too easily an intelligible word or phrase were rejected. No two successive syllables were allowed to have the same vowel, and the same consonant could recur only after several others had intervened. Modified vowels were not used, and consonants whose pronunciation was ambiguous, *e. g.*, *h*, *c*, were either not used at all, or were used only under certain conditions. The syllables were formed and arranged after a method similar in certain respects to that followed by Müller and Schumann; the object was to let chance rule as far as possible in the formation of the series. When the supply of new and unobjectionable syllables was exhausted the syllables which had been already used were rearranged to form fresh series.

In the actual experiments the slip of paper bearing the syllables was inserted in a frame which was fastened behind an oblong horizontal opening in a screen made of black cardboard. Behind this opening and before the slip of paper was a shutter which could be raised or lowered at any moment. The subject, who sat at his ease before the screen, was required to read the series aloud, one syllable after another, at a rate determined by a metronome standing near him. The rate of the metronome varied with the different individuals, that rate being chosen for each reagent which seemed to be most convenient for him. As a matter of fact the two rates chosen were 80 and 100 per minute. Only in one case was the rate changed in the course of the experiments; this was done because the subject complained that the old rate had become too slow for him. The object of introducing the metronome was to secure that the subject should, as far as possible, give the same time and attention to each syllable. Where a series had to be repeated several times the subject made a pause of two beats each time he came to the end, and then began the repetition again. The shutter cov-

ering the series was raised only after the subject had given a signal that he was ready and had accommodated himself to the rhythm; before the experiment began he was told whether one,<sup>1</sup> few, or many repetitions were required. The signal for closing was given, except when there was only one repetition, by a tap on the table which came in the pause preceding the last repetition. The subjects were asked to repeat the series with regular attention and without any special effort or strain at any point; the purpose of the closing signal was to secure that the value of the experiment should not be lowered by any accidental fluctuation of attention just before the close of the experiment. By these precautions the disturbing effects of fatigue, of variations of attention and of emotional changes were to a large extent avoided. Where, notwithstanding the precautions, there occurred a disturbance of any kind which seemed to endanger the value of the result a new experiment was made. Irregularities in the formation of the series, or in the conduct of the experiments, were made a ground of rejection of the result when the subject had been disturbed thereby, or when the character of the irregularity seemed to render the value of the experiment doubtful.

The experiments were arranged with a view to ascertaining the value of the memory at five stages in the process of learning, the series being repeated, according to the directions of the experimenter, once, thrice, six times, nine times or twelve times. As far as possible an equal number of experiments was made each day for the various stages of repetition. Owing, however, to various distractions and also to the loss of time involved in cross-questioning the subjects in regard to their state of mind during the course of the experiments, this rule could not always be carried out. In no case have the experiments of any day been accepted on which there was not at least one experiment with each stage. Preliminary experiments for practice were made with each subject both at the beginning of the investigation and at the beginning of each day's work.

<sup>1</sup>The phrase 'one repetition' is so convenient that the inaccuracy involved in its use may be pardoned.

The results of these experiments are presented in the tables given below. In the first Table are given the numbers which represent the values of the memory at each stage of repetition, these numbers being the final averages gained by taking together the averages of the eight reagents. The object of the second Table is to show the relative frequency with which syllables in the various parts of the series are recollected. In Table III., which is printed at the end of this article, are given the individual averages which form the basis of the values given in Table I. The description of the divisions and details of Table I. applies without alteration to Table III.

The written records handed in by the subjects have been analyzed in Tables I. and III. from two points of view, and the resulting values have been arranged in two divisions. In the first division, on the left hand of the page, the records are analyzed from the point of view of the syllable. The first column gives the average number of syllables in each experiment, which are correct both in their component letters and in the position assigned to them by the subject, while in the second column are collected the syllables whose only fault is that they have been put in the wrong place. In the third and fourth columns are given the incomplete syllables, *i. e.*, those which have dropped a letter or exchanged one of their letters for a false one; in the third column appear the incomplete syllables whose place is correct, while those whose position is wrongly given are in the fourth. In the second division, where the different classes of error are marked by *Arabic* letters, the syllables are regarded as made up of separate letters; in this way several points which could not well be brought out in the first division receive recognition. In column *a* is given the average number of letters which are omitted. In the next two columns are recorded the letters which are rightly recollected, but have been put in a wrong position; those under *b* have retained their position in complete or incomplete syllables, while the syllables themselves have been wrongly placed; those under *c* have lost all trace of their original arrangement. The next column, *d*, contains the letters which have been reproduced oftener than they appeared in the original series. Column *e* is intended to

give material for a further analysis of the errors recorded under *c*, and contains the average number of *vowels* in each experiment whose original arrangement has been entirely lost. The average of all errors taken together is given under *m*; the figures in this column have been gained, not by adding the averages in the other columns, but by a separate summation of the errors in each experiment. Cases of inversion where the original order of the letters is simply reversed occurred so rarely that the column which had been set apart for their reception was left unused; errors of this kind found a place in column 3 or 4 in the first division, and in column *b* in the second division, the mode of estimation being slightly modified for them. Errors due to insertion of a wrong letter were likewise rare, and appear only in the total averages under *m*. The Roman numerals in the first vertical column represent the different stages in repetition.

In Table II. the numbers in the horizontal columns opposite the Roman numerals give the percentage of times that the syllables in the ten places in the series, whether in complete or incomplete state, are reproduced by the subject; the analysis takes into account only the original position of the syllable and neglects entirely the place assigned to it by the subject. Owing probably to the fact that the experiments were not sufficiently numerous to eliminate accidental variations, the results of the analysis regarding the original position of the recollected syllables are somewhat irregular if we look only at the individual results. The general tendency, however, is plain and since that tendency is expressed with sufficient clearness in the figures gained by taking together the averages of all the subjects I have decided to present only the final averages.

TABLE I.

	1	2	3	4	a	b	c	d	e	m
I. . .	2.2	0.35	1.1	0.6	15.5	2.5	3.0	1.0	0.7	22.2
III. . .	2.5	0.9	1.1	0.9	13.0	4.3	2.5	1.35	0.6	21.4
VI. . .	2.8	0.9	1.1	0.9	11.9	4.5	2.6	1.5	0.5	20.5
IX. . .	3.4	0.9	1.1	0.6	10.9	3.95	2.2	1.5	0.6	18.9
XII. . .	3.9	0.8	1.0	0.7	10.0	3.75	2.1	1.3	0.6	17.3

TABLE II.

	1	2	3	4	5	6	7	8	9	10
I. . .	81	52	24	16	16	24	26	26	62	84
III. . .	84	67.5	39	38	34	33	29	44	69	92
VI. . .	81	61	42	42	34	32	46	54	74	85
IX. . .	89	67	49	41	32	33	48	64	77	93
XII. . .	92	58	46	41	56	57	57	61	84	91

It will be noted on comparing the values given in Table I. with those in Table III. that, while the general features of the results are reproduced in Table I. with great distinctness, there is yet among the different individuals a considerable amount of variation. The values given by the subject St. in col. *m* are opposed to those of all the other subjects, though in the case of two others, H. and Sn., the numbers do not conform very closely to the typical curve. It is unfortunate that another subject, whose memory proved itself better than that of any other, was unable to continue his attendance long enough to give a satisfactory number of experiments. The three subjects, H., Cu. and P., who have carried out the largest number of experiments, present fairly typical examples of the different kinds of memory; in order to give some proof of the trustworthiness of the average values assigned, the probable error of the averages in col. *m* has been calculated<sup>1</sup> and the figures inserted to one place of decimals under *r*.

Before going on to draw any conclusion from the results we may note shortly the limitations of the research. The results obviously can only be taken as representative of the process of learning series of syllables of a certain length, repeated aloud in a more or less artificial manner. The only test of the value of the memory at the different stages lay in the accuracy with which the subject recollected the syllables immediately after the learning was finished. Without doubt the results would be different if we allowed some time to elapse between learning and recol-

<sup>1</sup> In experiments such as those of Ebbinghaus, as has been remarked, the probable error is an unsatisfactory test, because while the number of repetitions may become indefinitely large it can never fall below 1. Here, on the other hand, the total number of errors may be zero, but it can never rise above a certain point.

lection. Probably in this case the errors in the first stages would increase much faster than those in the later stages of repetition. Finally, in these as in other memory experiments, we have a very mixed result in which factors, such as the memory images of sight and hearing, are inextricably mingled together.

The results given in the tables confirm in general the accepted fact of the efficacy of continued repetition in impressing any kind of subject-matter on the memory. That even with the reagents who remember best its effect is so small is somewhat surprising. Probably the explanation of this feature is to be found partly in the artificiality of the experimental conditions; partly, also, in the fact that the subjects were directed not to try and learn as much as possible, but simply to repeat, with all possible regularity, what was presented to them. The advantage of this rule was that there was very seldom any complaint made of fatigue due to the experiments. A comparison of the average values in the earlier and later halves of the series of experiments carried out by the subjects who have furnished the largest number of experiments shows that in the majority of cases there is a slight increase in the value of the memory in the second half, a result probably due to practice.

It is interesting to observe a confirmation here of another fact which meets us in common life. In any pursuit or competition the candidates start fairly equal; it is towards the end that they begin to separate from each other. Here we are met by the fact that on the whole the different individuals do not differ very greatly in the number of errors which they commit after one repetition, while as we go on to twelve repetitions the difference increases markedly. The difference between the best and the worst memory after twelve repetitions is very much greater than after one repetition. A better way of proving the same fact consists in giving the mean variation of the final averages (Table I. *m*) at each stage:—

I.	III.	IV.	IX.	XII.
mv. 1.8	3.0	3.8	3.7	5.1

The first repetition is undoubtedly the best; *i. e.*, more is learned by it than by any other repetition, or, in fact, by all the other repetitions put together. There seems to be a slight increase in

the value of a repetition as we pass from the third to the twelfth; this result shows itself in cols. 1 and *m*, but not in col. *a*, where errors of omission alone appear; in fact the change in col. *a* is in the opposite direction, the increase in the number of letters recollected, caused by the successive repetitions, appearing to grow smaller as the number of repetitions increases.

If we look more closely into the figures for each stage we find certain regularities which hold for almost every subject. The number of syllables which are correctly remembered (col. 1) increases regularly with the increase in number of repetitions, while the total of errors (col. *m*) and also the errors of omission (col. *a*) decrease as regularly. The other classes in both divisions comprising the errors of disorder show values which remain pretty constant throughout; *i. e.*, the number of errors, while remaining absolutely constant, decreases relatively to the total number of syllables and letters remembered. It is one of the limitations of this investigation that it does not enable us to analyze exactly the errors due to the various kinds of confusion and disorder and separate them from errors of omission. To do this it would be necessary to employ a method which was followed by Bigham in his research on memory.<sup>1</sup> According to this method the subject would be supplied with a list of the syllables, arranged in chance order, which were being used in an experiment and would be required to rearrange them after the repetitions were finished. What we seem to have in the present experiments is a continual process of promotion during the learning; a syllable or letter, at first forgotten, appears by and by in one of the classes which represent failure to remember the right order and then passes into the classes of syllables or letters correctly remembered; in this way the figures representing errors of disorder might be expected to remain fairly steady.

Cases of inversion of syllables practically did not occur at all; inversions of letters and insertion of false letters occurred rarely, as before remarked. What the precise explanation of these facts may be I have no means of saying. With Ca. and R. the figures in col. 3 are much larger than in cols. 2 or 4 at each stage, while with H. and St. the figures in col. 4 are regularly the largest. Sn., on the other hand, shows the

<sup>1</sup> PSYCHOLOGICAL REVIEW, I. pp. 34, 453.



largest numbers in cols. 2, *b* and *c*. Such results point to the need for purposes of explanation of a more exact knowledge of the psychical processes of each individual. Observations were made in the course of the experiments on the nature of the memory and its variations at the different stages, but I have not been able to any great extent to correlate these observations with the numerical values given in the tables. The memory in every case seemed to be of a mixed character, now visual, now auditory and now motor images being more prominent. A comparison of the figures in cols. *c* and *e* seems both interesting and significant. If consonants retained their hold on memory to the same extent as vowels the figures in the last column ought to range about a third of those in col. *c*; as a matter of fact they range somewhere about a fourth, the figures tending to approach nearer to a third in the later stages. The conclusion seems justified that vowels impress themselves better on the memory than consonants. There was a tendency in most subjects to associate foreign ideas with the syllables or make the syllables into intelligible phrases, though towards the end this tendency was lessened. With one individual, Ca., this was a very troublesome feature from beginning to end, and there was hardly an experiment where I had not one or more instances of this associating tendency. I have summed up the associations made at each stage by this subject, and without any great stress being laid on the figures they may be presented as an illustration of the fact, which was otherwise confirmed, that this associative tendency grows with the number of repetitions.

	I.	III.	VI.	IX.	XII.
No. of Assns.	6	9	23	34	33

It was decided that an experiment should be rejected only where connecting associations were formed, *i. e.*, associations which connected two syllables in the series into a single intelligible phrase.<sup>1</sup> This rule proved in the end too severe, as the associations very often occurred in the more laborious experiments of the later stages, and in the end it was decided to ac-

<sup>1</sup> Examples: *div nur*—divine nurture; *mon sud*—Monday Sunday. The range of these associations will be understood when it is mentioned that they included English, Scotch, German, French, Russian, Latin, Greek and Hebrew words.

cept the experiment when an association was formed between the first two or last two syllables at any stage, or between syllables in any part of the series when the number of repetitions was twelve; in all these cases there was a considerable probability that the syllables would have been remembered in the absence of the association.

There does not seem to be any definite connection traceable here between excellence of memory and the mode of reproduction. The subject with the best memory and the subject with the worst both wrote from the beginning straight on, the syllables at the end of the series being thus written last. In the great majority of cases the first two syllables are reproduced first; often the last two come next; this is specially marked in the case of the reagent P. However, although the last syllable does not come first in the reproduction, it is in most cases best remembered.

The subjects were left free throughout the experiments to introduce a rhythm into the repetition if they pleased. In most cases there was a slight rhythm present. In a few instances its effect is visible in the detailed results which form the basis of the second table; in these cases there is a greater difference between the figures in the second and third and also the eighth and ninth places than between those in the first two and last two places. On the whole, however, its effect is less than might have been expected. It appears from Table II. that a syllable in the second half of a series has a somewhat greater chance of being remembered than one in the first half; the best places are at the beginning and the end, the chance of being recollected lessening at first rapidly, then more slowly as the middle of the series is approached. During the pause of two beats between the repetitions the subjects waited without trying to memorize; in most cases their eyes were fixed inattentively on the beginning or end of the series which was being presented. Two of them complained that in this way an undue advantage seemed to be given to the first and last syllables. One of the two adopted the device of shutting the eyes during the pause; in spite of this, the first and last pairs of syllables are in this case specially well remembered. There does not seem any reason to suppose that looking at the syllables in this inattentive way has any very marked effect upon the memory.

TABLE III.<sup>1</sup>

		1	2	3	4	a	b	c	d	e	m	r
H. 21	I. . .	0.7	0.1	1.1	1.0	16.9	2.6	5.1	2.0	1.4	27.1	0.5
	III. . .	0.7	0.5	1.3	1.5	15.3	5.0	4.6	1.6	1.4	27.2	0.4
	VI. . .	1.0	0.5	1.0	1.7	14.2	4.9	4.6	1.4	1.0	25.7	0.4
	IX. . .	1.4	0.4	1.3	0.9	14.5	3.2	4.8	1.8	1.3	24.5	0.5
	XII. . .	1.0	0.4	1.7	1.3	13.7	4.0	5.3	1.1	1.2	24.2	0.5
Cu. 21	I. . .	2.0	0.3	1.3	0.4	16.7	1.8	2.7	0.6	0.5	21.8	0.3
	III. . .	2.6	0.6	1.7	0.6	13.2	2.7	2.2	1.0	0.4	19.2	0.5
	VI. . .	3.2	0.5	1.7	0.8	11.3	3.0	2.0	1.3	0.3	17.7	0.6
	IX. . .	4.6	0.3	1.4	0.5	9.2	2.0	1.7	2.8	0.4	16.0	0.9
	XII. . .	4.9	0.6	1.3	0.4	8.1	2.7	1.4	2.0	0.4	14.3	0.7
P. 20	I. . .	2.6	0.2	1.25	0.5	15.3	2.15	2.1	0.35	0.5	20.05	0.5
	III. . .	3.0	0.9	1.1	0.6	13.6	3.5	1.1	0.9	0.3	19.2	0.6
	VI. . .	4.0	0.35	0.95	0.65	11.3	2.5	1.85	0.7	0.5	16.4	0.6
	IX. . .	4.25	0.6	1.0	0.5	10.45	2.95	1.35	0.8	0.35	15.6	0.7
	XII. . .	4.75	0.65	1.0	0.25	9.1	2.5	1.55	0.55	0.4	13.7	0.7
Ca. 18	I. . .	3.3	0.5	1.0	0.6	13.8	2.6	2.1	0.7	0.7	19.3	
	III. . .	3.7	0.7	0.9	0.8	11.4	3.4	1.6	1.1	0.4	17.7	
	VI. . .	3.9	1.3	1.25	0.6	8.0	5.3	2.6	1.4	0.9	17.0	
	IX. . .	4.4	0.8	1.0	0.7	7.2	3.7	1.8	0.8	0.6	13.7	
	XII. . .	6.2	0.7	0.8	0.3	6.0	2.8	0.7	1.2	0.3	11.0	
L. 16	I. . .	2.3	0.6	0.6	0.4	17.5	2.6	1.8	0.25	0.4	22.1	
	III. . .	2.4	1.1	0.75	0.5	14.5	4.4	2.0	0.6	0.4	21.6	
	VI. . .	2.3	0.6	0.9	0.8	15.6	3.5	1.7	0.6	0.1	21.4	
	IX. . .	3.5	0.9	0.9	0.2	13.4	3.25	1.4	0.3	0.2	17.9	
	XII. . .	3.1	0.7	0.5	0.5	15.1	2.9	1.5	0.25	0.4	19.9	
St. 12	I. . .	2.75	0.2	1.6	0.8	10.6	2.3	4.9	3.6	1.2	21.9	
	III. . .	2.25	0.4	1.7	1.7	9.5	5.0	4.5	4.7	1.2	23.8	
	VI. . .	2.1	1.1	1.1	1.1	10.5	5.4	4.5	4.1	1.5	24.9	
	IX. . .	2.1	1.4	1.4	1.3	9.0	7.1	4.1	3.9	1.5	24.75	
	XII. . .	2.8	0.7	1.3	1.7	9.2	5.5	3.9	3.6	1.2	22.5	
Sn. 12	I. . .	1.4	0.9	0.5	0.7	18.5	4.25	1.6	0.25	0.3	24.6	
	III. . .	1.5	2.25	0.25	0.6	15.1	7.9	1.75	0.2	0.5	25.1	
	VI. . .	1.6	2.3	0.4	0.9	13.2	9.0	2.1	0.8	0.4	25.2	
	IX. . .	2.6	2.1	0.5	0.4	13.0	7.8	1.2	0.25	0.2	22.25	
	XII. . .	2.25	2.2	0.4	0.9	12.7	8.3	1.3	0.4	0.3	22.75	
R. 12	I. . .	2.2	0.0	1.4	0.75	14.7	1.5	3.75	0.9	0.7	20.8	
	III. . .	3.75	0.4	1.25	0.6	11.7	2.7	1.9	0.7	0.4	17.2	
	VI. . .	4.25	0.3	1.3	0.6	10.75	2.2	1.3	1.5	0.25	15.9	
	IX. . .	4.3	0.4	1.25	0.2	11.0	1.6	1.8	1.4	0.25	16.2	
	XII. . .	6.1	0.2	1.3	0.4	6.1	1.3	1.2	1.3	0.3	9.9	

<sup>1</sup> The letters in the first vertical column represent the names of the reagents, while the figures give the total number of experiments made at each stage. It may be mentioned that Ca. made 16 instead of 18 experiments with stage VI.