

# Two Studies in Memorizing by Slow And by Rapid Repetition

## I.

### RATE OF REPETITION AND TENACITY OF IMPRESSION

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## II.

### THE RELATIVE AMOUNTS OF FATIGUE INVOLVED IN MEMORIZING BY SLOW AND BY RAPID REPETITION

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# I.

## RATE OF REPETITION AND TENACITY OF IMPRESSION

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## I.

# RATE OF REPETITION AND TENACITY OF IMPRESSION

### *Introduction*

This paper and the paper which follows are both off-shoots of the writer's "Study in Memorizing Various Materials by the Reconstruction Method."<sup>1</sup> It is unnecessary here to say much of the rough but extended series of experiments made by this method, but it is necessary to call the reader's attention to their general nature and outstanding results, since the problems of the two papers here submitted will be better understood if their historical and logical connection with the earlier work be traced in some detail. This introduction, therefore, will contain (I) a very brief account of the reconstruction experiments, (II) an enumeration of the links which connect the reconstruction work with this present work, and (III) the formulation of the problem of this paper and of the next.

I. By the term *reconstruction method* is meant the procedure in which series of objects are presented to the subject who is afterwards required to arrange them in the order in which they were originally given. This performance may be repeated until the reconstruction is both accurate and unhesitating. In the writer's experiments, the material consisted of scents, of colors, and of nonsense syllables written upon small oblong cards. The results of these experiments are in two respects in marked contradiction to the results usually obtained by the method of complete memorizing, or *Erlernungsmethode*, the method of Ebbinghaus and of Müller and Schumann.<sup>2</sup> In the first place, practice tended

<sup>1</sup> *Wellesley College Studies in Psychology*, Psychological Review, Whole Number 43. Throughout this paper, this work will be referred to as *Memorizing by the Reconstruction Method*.

<sup>2</sup> The nature of this method may be briefly indicated as follows: A series of words or syllables is repeated over and over again until it can once be recited without inaccuracy or hesitation. The first repetitions are made by the experimenter who presents the whole series to the subject. At the end

to reduce the number of repetitions necessary for memorizing by the reconstruction method to the same number for longer and longer series, so that to the practiced learner the length of the series was of surprisingly small importance. In the second place, the number of repetitions required was remarkably small, even with untrained subjects. The number of repetitions necessary for a completely accurate and unhesitating reconstruction rarely exceeded four, even with beginners who were memorizing series of eighteen members, or with practiced learners who were memorizing series of thirty-one or of forty-one. These figures are in striking contrast with the numbers of repetitions, rarely falling below ten, which were necessary for memorizing series of twelve nonsense syllables in the experiments of Müller and Schumann and with the very similar results of other experimenters who have worked with the method of complete memorizing. One should especially recall in this connection the statement of Ebbinghaus: "Whereas I am able, almost without exception, to recite series of six nonsense syllables without mistake after a single presentation, I can recite series of twelve syllables (read rapidly) only after from fourteen to sixteen repetitions, series of sixteen only after thirty, and series of thirty-six only after fifty-five."<sup>3</sup>

II. The connection between the reconstruction experiments (virtually finished in 1905) and the experiments here reported (which were begun in 1910) may be traced (*a*) through other experiments and (*b*) through a theory suggested by them.

*a.* The contrast just indicated between the results obtained by the reconstruction experiments and by the method of complete memorizing led the writer to make an experimental study of the reconstruction method itself.<sup>4</sup> This study included experiments with nonsense syllables by the method of complete memorizing

of any repetition the subject may begin to recite, but as soon as he hesitates or makes a mistake, the rest of the series is presented to him. The method is more fully described on p. III below.

<sup>3</sup>*Grundzüge der Psychologie*, Zweite Aufgabe, p. 651. Cf. *Memorizing by the Reconstruction Method*, pp. 76, 87-89 and 206.

<sup>4</sup>*Memorizing by the Reconstruction Method*, Chapter VI.

and led, by numerical and introspective evidence, to the following conclusions: (1) The small number of repetitions necessary for memorizing series of any practicable length by the reconstruction method was due in large measure (a) to the fact that the subjects were allowed unlimited time for reconstruction and were thus enabled to work with emotional composure and (b) to the fact that the rate of presentation was very slow. The nonsense syllables and colors were presented at intervals of from three and a half to four seconds and the smells at intervals of five seconds. Thus, the rate at which the nonsense syllables were presented was, roughly speaking, only one tenth as fast as the rate used by Ebbinghaus in his classical experiments, and only about one-fifth as fast as the rates ordinarily employed in the method of complete memorizing. (2) Even in this method of complete memorizing itself, the number of necessary repetitions can be very greatly reduced by reducing the rate at which the series is repeated, although this saving of repetitions is ordinarily accomplished at the cost of some waste in the total learning time. The subject learns more in a single slow repetition than in a single rapid repetition but learns more in the rapid repetition in proportion to the time spent upon it.<sup>5</sup> (3) In the method of complete memorizing, also, reducing the rate at which the series is repeated greatly reduces the importance of series length. It would seem on introspective grounds that this fact is due to the lessening of the mutual interference of the associations, the crowding out of one part of the series from the learner's mind by another.<sup>6</sup> (4) Learning by slow repetition under the con-

<sup>5</sup>This result is entirely in agreement with the findings of other experimenters. See the references given on page 157 below.

<sup>6</sup>Ebbinghaus says (if translated): "Many persons can never, in a reasonable time, achieve a perfectly correct recitation of the longer series of nonsense syllables. Some parts are continually thrown into confusion by others. . . . The readings which follow the first readings of the series often seem to bring about only a slight increase in the subject's power to reproduce it. The mutual disturbance of the series members by one another, which is distinctly manifest to immediate consciousness, brings the process of learning to a standstill and only when the whole series has become somewhat more familiar through numerous readings, does a further increase in the number of retained elements take place." *Grundzüge*, p. 651.

ditions of either the reconstruction method or the method of complete memorizing fosters the development of a technique in learning, which could not readily be acquired through learning by fast repetition, but which, once acquired, can be transferred to learning by rapid repetition.<sup>7</sup>

b. The repetition-saving advantage of slow repetition is somewhat parallel to the repetition-saving advantage of distributed repetitions (*Verteilung der Wiederholungen*), an advantage which was demonstrated by Jost. This parallel led the writer to compound out of the doctrines of Professor G. E. Müller and his disciples, (1) a physiological theory of the repetition-saving advantage of slow repetition with (2) a complementary theory of the time-saving advantage of fast repetition. Such a physiological theory is, of course, purely speculative, whereas the tendency of slow repetition to foster the development of technique is a fact of clear introspection. But, however small the value of the writer's theory may be, it is necessary to mention it here because it led directly to the experiments reported in this paper and the next. The theory is set forth in full in the last pages of "Memorizing by the Reconstruction Method." Here it may be summarized in the following statements: (1) An association, in the physiological sense, consists of such a modification of the nerve-path connecting two cortical areas that excitation tends ever afterward to run from one to the other, or, to put the matter still more vaguely, of such a modification of the cortex that the excitatory process of one idea tends ever afterward to involve that of the other. The formation of such a modification,—say, by the attentive repetition of two nonsense syllables—requires cortical energy, whatever the nature of this energy may be. If the modification is at all lasting, some process of consolidation

<sup>7</sup> G., the present writer and the principal subject in all these experiments, was able at maximum practice, to learn, by the method of complete memorizing, series of eighty-one syllables in one hour when the syllables were presented at intervals of five seconds, and in three quarters of an hour when they were presented at intervals of one second. The time required for learning syllable series of the same length by the reconstruction method was one hour and a half, but this time included the considerable periods necessary for recording the results of each trial.



or "setting" must take place and this process also requires cortical energy. The amount of nervous energy available in the cortex at any one time is limited. Therefore, when a number of associations, which we may symbolize by letters, are formed in quick succession, the initiation, say, of  $e - f$  draws energy away from the consolidation of  $d - e$ . Thus,  $d - e$  will be less firmly stamped the more quickly, at each repetition of the series, its impression is followed by the impression of  $e - f$ , and in so far as  $d - e$  is being consolidated, it will weaken the impression of  $e - f$ . Thus, a single rapid repetition of a series accomplishes little. Slow repetition has a physiological advantage. *Only multiplication of repetitions can make up for rapidity of repetition.* (2) Rapid repetition greatly increases the perseverative tendencies of the series members. Therefore, a *short* series, if rapidly repeated can be learned for purposes of *prompt recitation* in a relatively short time, since in the case of a short series, the perseverative tendencies of the members may more than make up for the comparative weakness of the associations between them. But the number of words or syllables which tend to persevere at any one time is very limited. Moreover, rapid repetition tends to increase not only the perseverative tendencies but also the mutual interference of the members—that interference which is so clearly manifest to introspection and which is doubtless the psychic index to the draughting of cortical energy in too many directions at once. Therefore, *long* series cannot be learned by rapid repetition within a "reasonable time" unless the learner has acquired a most unusual technique. (This statement holds, of course, only for the learning of meaningless material.) Moreover, perseverative tendencies,—as (or if) manifested in the "mental echo" of the series—fall away rapidly with lapse of time, running down noticeably in the first thirty seconds and becoming after three minutes negligible as an aid in repeating even a twelve-syllable series. Hence, if a series is to be recited largely in virtue of the perseveration of its members, it must be recited at once and rapidly.

At the time this theory was propounded, the writer held a view of recall, which was afterwards more clearly formulated by

Titchener, who indeed is far from espousing it but sets it forth only to reject it. According to this view three different tendencies may come into play when the word or syllable *e* has been strongly associated with the word or syllable *f* and soon afterward recurs: (1) The impressional tendency of *f*, that is, its readiness to emerge (as an image), "the distance below the conscious limen at which its excitory process is now going on"; (2) the associative tendency, which indexes the strength of the connection between the excitory processes of *e* and *f*; and (3) the perseverative tendency of *f*, which is "a sort of rhythm impressed upon the impressional tendency," such that *f* may "now and again emerge without the aid of the associative tendency." It is this rhythmical, non-associative recurrence which Titchener rejects as unproved.<sup>8</sup> In the theory of the present writer, impressional and perseverative tendencies were not distinguished from each other, but the rhythmical character of something which might well have been called the "impressional tendency" was suggested. In most cases in which the term *perseverative tendency* is used in this paper, *impressional tendency* might be substituted. The writer did indeed (and does still faintly) believe that a *recent*, *vivid* and *oft-repeated* percept might recur as an image without the aid of association, but has never supposed that a whole series of syllables could be recited *in order* in virtue of perseveration alone. For if equal attention were given to all members of the series, the perseverative tendencies of the last repeated would be the strongest, so that if the series emerged in virtue of perseveration it would be likely to emerge in reverse order—"wrong-end-to." But in the rapid recitation of a much and quickly repeated series, one is conscious of no rearrangement, except in so far as one is conscious of the mental echo of the last few syllables in a sort of polysyllabic nonsense word and is conscious of putting this aside in order to "begin at the beginning." In beginning the series and in reciting it in proper order, perseveration, if operative, must simply facilitate association. One has different feelings or "attitudes" (*Bewusstseinslagen*) when one is reciting a series rapidly repeated many times and

<sup>8</sup> Cf. Titchener, *Text-Book of Psychology*, pp. 400-401.

when one is reciting a series slowly repeated two or three times, even when one does not hesitate in either instance. In the one case, one feels as if one were speaking automatically; in the other, as if recitation really involved "voluntary" recall. Do these different feelings, however they may be analyzed in organic and kinaesthetic terms, indicate a difference of kind in the nervous conditions of recall? The question is surely worth asking and trying to answer.<sup>9</sup>

III. The problem of this paper and that of the next are questions which test the theory just outlined,—questions whose answers must buttress or in some degree undermine the theory. The questions are these:

a. If learning by fast repetition involves a severer demand upon cortical energy than learning by slow repetition, then *learning by fast repetition should be the more fatiguing to the subject. Is this the case?* This is the problem of the second paper.

b. If the reason that fast repetition saves time is that a series can, in virtue of the perseveration tendencies of its members, be recited before the associations between the members are firmly stamped, then series learned by fast repetition should not be so

<sup>9</sup> The *locus classicus* for the doctrine of perseveration in normal psychology is Müller and Pilzecker, *Beiträge zur Lehre vom Gedächtniss*, Zeitschrift f. Psych. und Physiol. der Sinnesorgane, Ergänzungsband 1 (1900), pp. 58-78. According to this passage, the term *Perseverationstendenz* means the tendency of a recent, vivid and repeated experience to return to consciousness spontaneously (*frei*), i.e., not in virtue of an associative connection. This is the meaning attached to the term *perseverative tendency* by the present writer, except that she would prefer to say, "not or not wholly in virtue of association." For a destructive study of the doctrine of perseveration as thus construed see Foster, *On the Perseverative Tendency*, American Journal of Psychology, 25, pp. 393-426. For the theory of consolidation processes, see Müller and Pilzecker, *op. cit.*, pp. 195-198. See also Müller's paper on *Wiedererkennung und rückwirkende Hemmung*, with the discussion following, in the Bericht über den V. Kongress für experimentelle Psychologie (1912), pp. 216 f. Jost's work is found in the Zeitschrift f. Psych. und Physiol. der Sinnesorgane, 14 (1897), pp. 436, f. His title is *Assoziationsfertigkeit in ihrer Abhängigkeit von der Verteilung der Wiederholungen*. For the suggestion that perseveration tendencies are heightened by rapid repetition, see Ephrussi, *Experimentelle Beiträge zur Lehre vom Gedächtniss*, same Zeitschrift, 37 (1905), p. 202.

well remembered as series learned by slow repetition, series which must be recited wholly in virtue of association and not partly by the aid of perseveration. *Are series learned by fast repetition as well remembered as series learned by slow repetition?* This question constitutes the primary problem of this present paper. A secondary interest lies in securing evidence for a consolidation process in the case of slow repetition. The experimental conditions and data may now be presented.

### *Materials*

Throughout the experiments, the material consisted of "normal" series of "English" nonsense syllables, made in imitation of the normal "German" series of Müller and Schumann.<sup>10</sup> A full description of the English series will be found in the writer's study of the reconstruction method.<sup>11</sup> Series of twenty-four

<sup>10</sup> Müller and Schumann, *Experimentelle Beiträge zur Untersuchung des Gedächtnisses*, Zeitschrift f. Psych. und Physiol. der Sinnesorgane, 6, pp. 99-106.

<sup>11</sup> *Memorizing by the Reconstruction Method*, pp. 20-23. In the series used in 1910-1911, i.e., in the earlier experiments covered by this paper, the combination *qu* was introduced among the initial consonants. In the series used in 1911-1912, i.e., in the last experiments covered by this paper and in all the experiments covered by the following paper, two additional changes were made. The digraph *th* was stricken from the list of initial consonants, because in aural presentation the sound was too easily mistaken for that of *f*. Further, before the terminal silent *e*, which was used to indicate a long sound for the central vowel, *c* was used to give the hard sound of *s*. *S* cannot be used before the silent *e* on account of its phonetic ambiguity and, therefore, in the earlier series the hard sound of *s* had not been used after a long vowel, although the soft sound had been given by *z*. (One could not tell from the spelling whether *bise* should rhyme with *wise* or with *mice* but *bice* is unambiguous.)

These series contain English words. So also do the normal series of Müller and Schumann contain German words. English series made by our rules have, however, at least this one merit, that a learner at all versed in the rules of English phonetics knows how to pronounce them when he sees them and can very easily learn how to spell them when he hears them. (The writer has seen in other laboratories such syllables as *qiv*, which seem unsuitable for most purposes.) It must be confessed, nevertheless, that not all laboratory workers are able readily to apply the laws of English phonetics and that nonsense syllables are in the case of English-speaking subjects by no means so satisfactory a material as they are in the case of German subjects. The German language is phonetic; English phonetic rules have

members were made by joining two series of twelve, end to end, with care that no one sound should occur both in the twelfth and in the thirteenth syllables. The following may be given as a specimen series of twenty-four members: *quoke, pule, bouj, roin, jiv, lame, tene, mite, kug, wox, vesh, haz, moce, quag, poul, vube, hud, raje, shet, lif, keze, toim, wine, yosh.*

### *Method*

Briefly described, our experiments consisted in learning and in relearning series of nonsense syllables by the method of complete memorizing, with aural presentation and with a variety of rates both of presentation and of recitation. In this section, it is necessary (I) to recall the details of the method to the reader's mind, (II) to state the exact manner in which the method was used in our own experiments, and (III) to set forth the procedures by which we strove to test the tenacity of the associations formed in learning the series.

I. The method of complete memorizing or *Erlernungsmethode* is the pioneer method for memory investigation which was devised by Ebbinghaus more than thirty years ago and was elaborated by Müller and Schumann in the early nineties. The writer has taken the term *method of complete memorizing* from Bergström.

The standard features of this method are as follows: A series of words or syllables is presented over and over again, either to the eye or to the ear of the learner, until he can once (or twice) recite the whole in order, without mistakes and without hesitation. At the end of any presentation,

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countless exceptions. Persons who have worked with the writer have persisted to the last in pronouncing certain syllables by analogy with English words not phonetically pronounced, *e.g.*, on making *pove* rhyme with *love* and *dove* instead of with *clove* and *stove*. Another unfortunate tendency is toward pronouncing the strange combinations of letters by analogy with French or German words. Thus, *bouj* may be made to rhyme with *rouge* and *jiv* may be called *yiv*. The writer can see no way of using a large number of different syllables without entailing these disadvantages upon the material.

the subject may begin to recite the series from the beginning, but as soon as he hesitates or makes a mistake, the rest of the series is presented to him. Thus, every repetition or traversing of the series, except the first and the last, may consist partly of presentation and partly of recitation. The first, which, strictly speaking, is not a repetition at all, is necessarily a complete presentation and the last consists in the unerring and unhesitating recitation. In all the publications of this laboratory, the term repetition is used (like the German word *Wiederholung*) to stand for any traversing of the series, whether made up wholly of presentation or wholly of recitation or partly of the one and partly of the other. In reading this paper, it is necessary to keep the distinction between presentation and recitation clearly in mind, since the rates of presentation and of recitation were varied independently of one another.

In the case of visual presentation, a recitation is counted as "unhesitating" when each syllable is named before it can be read by the subject from the revolving drum or other apparatus which is used to bring the syllables singly into view. When the presentation is aural, the distinction between hesitating and unhesitating recitation is harder to draw. The only general statement which can be made is that recitation is called unhesitating when the syllables are recited at the definite rate (however slow) at which the learner is required to recite them. In fact, "unhesitating" recitation is not an indispensable feature of the method. The essential points are rather (a) that the series should be repeated from beginning to end until the learner can recite the members in order, without mistakes and within a reasonable time, and (b) that when he has once made a mistake or abandoned the attempt to recite, the rest of the series should be presented to him without break. *Prompting* is foreign to the method of complete memorizing proper.

II. In our own experiments presentation was aural. The important details as to rate are as follows: (a) In presentation, the experimenter read the series (from the pages of her notebook) in time with the beats of a metronome. (b) The rate of

recitation was in some of the experiments restricted and in others unrestricted. When the rate was unrestricted, the subject was allowed to recite the series at any rate she pleased, provided that she named the syllables correctly and in order. The total time occupied in the final recitation was taken with a stop-watch. (See p. 120 below.) (c) When the rate of recitation was restricted, it was the same for every series as the rate of presentation for that series. The subject was required to name the syllables upon certain beats of the metronome. (d) Altogether five different presentation rates were used. These rates may be called *very slow*, *slow*, *moderately slow*, *fast* and *very fast*. When the very slow, slow, moderately slow, and fast rates were used, the metronome was set at sixty, and the syllables were named respectively upon every fourth, every third, every second and each successive beat. When the very fast rate was used, the metronome was set at seventy-five and the syllables were named one to a beat. When the recitation rate was restricted, the syllables, as already implied, were recited as well as presented at four-second, three-second, two-second, one-second and four-fifths-of-a-second intervals. For the sake of brevity, the following symbols will often be used: *VSP* and *VSR* for *very slow presentation* and *recitation*; *SP* and *SR* for *slow*; *MSP* and *MSR* for *moderately slow*; *FP* and *FR* for *fast*; and *VFP* and *VFR* for *very fast presentation* and *recitation*. *UR* will be used for *recitation at an unrestricted rate*. (e) Whatever the rate of repetition might be, the following rules were followed: (1) At the beginning of work with each series, the experimenter said "Now" upon a given metronome beat and named the first syllable on the next beat but one. (2) At the end of any presentation, after naming the last syllable, she allowed one beat to pass and on the next beat said "Now." On the next beat but one after this signal, if the recitation rate was restricted, the subject was expected to name the first syllable and if she failed, the experimenter named it on the next beat after and then presented all the rest of the syllables at the proper intervals. (3) If, in any attempt at recitation, the subject made a mistake or failed to name a syllable on the proper beat or if, in the case of "unre-

stricted recitation," she said "I don't know," then the experimenter took up on the next beat the presentation of the rest of the series.

In all experiments made by the method of complete memorizing in this laboratory, the records have been kept in the following way: The series is written in a column at the extreme left of the page. A dot or cross is put to the right of each syllable as the subject names it correctly. A dash or "check" is put opposite the first syllable which the subject fails to name—a dash if no syllable is named and a check if the syllable given is wrong. The experimenter always begins with the next repetition a new and parallel column to the right. The number and character of the repetitions can thus be seen almost at a glance. In counting the number of repetitions, the first presentation is always excluded.

III. The tenacity or firmness of the associations formed in learning series at different repetition rates was gauged by the number of repetitions necessary for relearning. In interpreting this general statement, it is necessary to give certain details in regard to the intervals which elapsed before relearning and to note the two procedures which were used in measuring tenacity by the number of repetitions necessary.

a. Throughout the experiments, except in the case of the supplementary sets, the series were, as a rule, relearned two weeks from the day and approximately from the hour at which they were learned, each sitting being given entirely to learning new series or to relearning old ones. If, for example, series were learned on a given Tuesday, the work beginning at 2:30 p. m., the same series were relearned in the same order on the next Tuesday but one, the work beginning at the same hour. If the subject served twice a week, she had in the mean time learned about three times as many other series, one set, say, on the Friday of the first week, and two more sets on the Tuesday and Friday of the second week. Even if she worked only once a week, she had learned or relearned at least one other set of series between the learning and the relearning of any given set. It is important to



note this fact for it is evident that the associations, whose firmness was tested, were weakened not merely by lapse of time but also by retroactive inhibition (*rückwirkende Hemmung*). This circumstance was a most undesirable complication but could not be avoided, if a reasonable time were to be allowed for the subject to forget the series learned and if a reasonable number of results were to be secured. As a matter of fact, the chief subject G. can remember a few series of nonsense syllables (without private review) pretty well for two weeks if no other series have been learned in the mean time, not well enough for perfect recitation without any fresh presentation but quite well enough for a perfect recitation after a single presentation. In a few instances, series were relearned three weeks from the time they were learned. This longer interval, which occurred only when entailed by inconvenient college holidays, was, of course, made to affect alike all sets of series which were brought into comparison. In the supplementary experiments in which the subjects were almost altogether untrained, the forgetting interval was one week, each subject serving three or four times a week.

Both in learning and in relearning, a compensating program, designed to equalize the effects of practice and fatigue for the different repetition rates, was carried out from week to week and as far as possible at each sitting.

b. If we take the number of repetitions necessary for relearning as the gauge of the firmness of the associations formed in learning series at different repetition rates, we yet may proceed in two different ways. (1) The series may all be relearned at the same rate at which they were learned. This procedure has the advantage of making it possible to measure in terms of the percentage of the original number of repetitions which is saved in relearning. The method, however, has serious disadvantages. If in experiments of this type the recitation rate is restricted, and especially if a rapid rate be prescribed, the subject is likely to break down in a certain number of recitations simply from fright. Thus to the repetitions, really necessary for memorizing, a certain fright-increment is added; and this increment, which is likely to be quite as large in relearning as in learning,

obscures the saving in repetitions. Let us suppose that the subject, if emotionally calm, could learn the series with ten repetitions and relearn it with six. Suppose now that two extra repetitions are entailed in each case by stage-fright. This at once changes the proportion 6:10 to 8:12 and the percentage of saving from 40 to 33. If on the other hand, the rate of recitation is unrestricted, even the best of subjects is likely to take advantage of this fact and to allow his attention to slacken. This sagging of attention differs at different sittings and at different moments in the same experimental period. The question of recitation rate is a puzzling matter in experiments of the type under discussion. We shall encounter it again. Another certain objection to this first method of gauging tenacity will appear in the discussion of results. (2) The series learned at different rates may be relearned all at the same rate. In this case, some of them may be relearned at the same rate at which they were learned but some can not. It will, therefore, be impossible to measure tenacity by the percentage of repetitions saved but it will be possible to compare the numbers of repetitions necessary for relearning with one another as they stand. This method has no more serious objection than the fact that it multiplies the sets of experiments which it is proper to make—since all the rates used in learning should, theoretically, be used in relearning—and thus reduces the number of series which it is possible to have in each set.

The experiments fall into three main groups, beside a few supplementary experiments which were made on untrained subjects and need not be taken very seriously. The first and third main groups were made by the first method of procedure; the second group by a combination of the two. Our reason for returning in the third group to the first procedure was simply that we had obtained by it fairly definite results which we desired to test. The various combinations of rates in learning and relearning are shown in the following scheme, in which the abbreviations *Mem. 1* and *Mem. 2* stand for the *first* and *second* memorizings, and the letters *P*, *R* and *U* respectively for *presentation*, *recitation* and *unrestricted*.

Group I		Intervals in Seconds								Group III	
		Group II									
		Subgroup 1		Subgroup 2							
Mem. 1	Mem. 2	Mem. 1	Mem. 2	Mem. 1	Mem. 2	Mem. 1	Mem. 2	Mem. 1	Mem. 2	Mem. 1	Mem. 2
P. R.	P. R.	P. R.	P. R.	P. R.	P. R.	P. R.	P. R.	P. R.	P. R.	P. R.	P. R.
4	U	4	U	4	U	4	4	4	4	3	3
1	U	1	U	4	U	1	1	4	4	2	2
		4	U	1	U	4	4	1	1	1	1
		1	U	1	U	1	1	1	1	0.8	0.8

A glance at the scheme will show that in Group II, two rates were used in the learning and relearning in all possible combinations, making four sets of experiments in all. Comparing two of these sets with each other, *viz.*, the slow-slow set with the fast-fast, one can measure retention by the first procedure. On the other hand, if one compares the slow-slow set with the fast-slow and the slow-fast set with the fast-fast, one can measure by the second procedure. The four different rate combinations were used *pari passu* according to a compensating program, and, hence,—*i.e.*, because the experiments with the slow-slow and fast-slow rates were not separated from the experiments with the slow-fast and fast-fast rates—it may be said that in this group the two procedures were combined. Unfortunately, the number of experiments in each set of this group is almost negligibly small.

### *Subjects and Experimenters*

The details in regard to the personnel and dates of the experiments are outlined in the following scheme, in which a "period" means an experimental sitting of forty-five minutes.

Group I, 1910-1911, first semester. Subject, E. A. McC. Gamble—G. Two periods a week. Experimenters, Helen Forney—F.—and Florence Kunkel—K.

### Group II

Subgroup 1, 1910-1911, second semester before Easter vacation. Subjects, G.; F. and K., each two periods a week. Experimenters, G., F. and K.

Subgroup 2, 1910-1911, second semester after Easter. Subject and experimenters as in Group I.

Group III, 1911-1912. Subjects, G., two periods a week, and Josephine Curtis—C.—and Ethel Caution-Davis—D., each one period a week. Experimenter, Agnes Rockwell.

Supplementary experiments, 1910-1911, spring term. Subjects, eleven students in a first year course in psychology, who will be designated as Beginners or B. 1, 2, 3 and so on. About eight periods each, three or four a week, enough periods to learn about ten series each under each set of conditions. Experimenters, eleven other students from the same class, who had been laboratory partners of the several subjects throughout the year.

In the experiments made by G., F. and K. (Groups I and II), the work was done by two experimenters at a time, the one presenting the series and keeping the recitation record and the other taking the total learning time with one stop-watch and the recitation times with another. In Group II, subgroup 1, G., F. and K. served as subjects by turns, the other two persons acting as experimenters. (Each combination of experimenters was, of course, obliged to have ready a separate set of nonsense syllable series.) Miss Rockwell and the several beginners worked single-handed.

Of the various subjects and experimenters who took part in the main groups of experiments, F., K. and D. were seniors, pursuing a second full-year course in experimental psychology; C. was a second-year graduate student and assistant in the laboratory; and G. is the writer. The methods of memorizing peculiar to the individual subjects will be discussed in the section on results. Here it is sufficient to point out that all five subjects had had experience in making out the "normal" series of nonsense syllables and that all (for better or worse) knew something of the question at issue. All the five knew from the outset that the series were to be relearned. As a matter of fact, F. and K. served more extensively as experimenters than as subjects; C. was engaged in making the experiments reported in the following paper during the very months when she was serving as subject in this work; and D. was assisting C. (In this con-

nection it may be remarked that Miss Rockwell, who in these experiments served as an experimenter, is the subject R. of the "fatigue work." (See p. 158 below.)

G. is the much-enduring subject G. of the reconstruction experiments, of the experiments by the method of complete memorizing which supplemented them, and of the preceding study in place associations. It is unfortunate that G. has been for so many years the only subject in our laboratory available for long series of memory experiments. The results, to be sure, have not always realized the expectation of this too-well-informed and too-much-interested subject. The objection to G.'s long continued service lies rather in the fact that the results obtained have only a somewhat "individual" value. G. has had from infancy a facility in *verbatim* memorizing exceeding at each stage the average facility of persons of the same age and degree of education, she has attained a very high level of practice, and she has also certain peculiarities of imagery and method which will be discussed in connection with the actual results of these experiments.

The subjects B. I to B. II, who served in the supplementary experiments, were juniors and sophomores. They did not know when the series were first learned that they were ever to be relearned, nor were they familiar with nonsense syllables of any sort. The equally inexperienced experimenters did not make out the syllable series for themselves and were, of course, more or less prone to mispronounce them. All used the same carefully prepared series.

### *Results*

The interpretation of the numerical results depends so much upon the subject's individual method of memorizing that the discussion of the introspective data cannot well be reserved for a separate section but will be merged with the discussion of the figures. Point by point, the numerical data will be followed by the introspective.

*Group I. All series relearned at the same rates at which they were learned. Two rates of presentation, very slow—VSP, with*

four-second intervals, and fast—FP, with one-second intervals between the syllables. Recitation rate unrestricted. Subject, G. Length of series, twenty-four syllables.

The numerical results may be schematized as follows:

Series Type	N	Learning				Relearning				Saving in	
		W	MV	LT	RT	W	MV	LT	RT	W	LT
				Secs.	Secs.			Secs.	Secs.		
VSP-UR	38	3.3	0.7	248	33	2.2	0.4	165	34	33%	33%
FP-UR	38	7.0	1.4	314	38	5.9	1.0	240	33	16	24

In this scheme and in those which follow, the letters *N*, *W*, *LT* and *RT* are used respectively for *number of series in the set*, for *average number of repetitions necessary for complete memorizing* (*Wiederholungen*), for *average learning time* and for *average final recitation time*. The first line of the scheme may be translated into words as follows: The subject learned and relearned 38 series at the very slow presentation rate (*VSP*) and recited them at an unrestricted rate (*UR*). She learned these series with an average of 3.3 repetitions and a mean variation of 0.7 from this average, and in an average time of 248 seconds; and she made her final recitation on the average in 33 seconds. In relearning, the average number of repetitions was 2.2; the mean variation, 0.4; the average learning time, 165 seconds; and the average recitation time, 34 seconds. Thus, in relearning, 1.1 repetitions and 83 seconds were saved on the average and these savings are 33 per cent respectively of 3.3 repetitions and 248 seconds. The fact has been already noted that in counting repetitions we have been accustomed to exclude the first presentation. The learning time was reckoned with a stop-watch from the *Now* which followed the first presentation to the moment when the subject pronounced the last syllable in her perfect recitation. Thus, *LT* includes the four-second intervals between repetitions and the two-second interval after the first *Now*. (See p. 113.) In taking the recitation times, another stop-watch was started on the *Now* which preceded each attempt at recitation. The values of *RT* are pretty exact; the values of *LT* are merely "gross" since the first watch was not stopped for interruptions of a few seconds' duration.

The figures in the scheme show the following facts:

1. Whatever the rate at which the series were presented, they were finally recited both in learning and in relearning in about the same time. *RT* varies only from 33 secs. to 38 secs. and this value approximates to the time necessary for reciting an *FP* (fast presented) series if recited at the same rate as presented, namely, 25 secs. If a *VSP* series of 24 members was recited at the same rate as presented, the time occupied would be 94 secs. (23 four-second intervals *plus* one two-second interval). From this uniform and moderately short *RT*, we may draw three conclusions: First, the subject preferred to recite the *VSP* series much faster than they were presented, evidently finding very slow recitation unprofitable and wearisome. Second, she could not have made her final recitation of the *FP* series in virtue of perseveration. Not only is the value of *RT* for the *FP* series too great in itself for perseveration-recitation, but it is even rather greater in the first learning than *RT* for the *VSP* series. Third, the subject had mastered the *VSP* and the *FP* series about equally well when she finally recited them. It is important to note before comparing the firmness of the associations in the two cases that we have to do with sets which were equally strong at the time of formation.

2. The *VSP* series were learned with a smaller *W* (average number of repetitions) and a smaller *LT* (average total learning time) than the *FP* series. The fact that the more slowly presented series were learned in the shorter time is only seemingly at variance with the ordinary finding (see p. 105 above) and is due to the unrestricted rate of recitation. The ratio of the times occupied in presenting the *VSP* and *FP* series is, roughly speaking, four to one (94 to 25). The ratio of the *W*'s is a little less than one to two (3.3 to 7.0), for the learning and a little more than one to three for the relearning. If, therefore, the series had been recited at the presentation rate, *LT* would have been considerably longer for the *VSP* series. The series were, however, all recited at approximately the same rate and thus the case is reversed. The ratio of *LT* for the *VSP* series to *LT* for the *FP* series is a little less than five to six (248 to 314) for the learning and a little more than two to three for the relearning.

It is, therefore, perfectly clear that it was more economical, both as regards time and number of repetitions, for the subject to learn and relearn series at the very slow than at the rather fast rate of presentation. It is also evident that if the *VSP* series are remembered better than the *FP*, this cannot be due to the fact that the total learning time was longer for the former.

3. If tenacity is to be gauged by the fractions of the original work which are saved in relearning, then the *VSP* series were indeed remembered much better than the *FP*. The saving in *W* is for the *VSP* series  $\frac{1}{3}$ ; for the *FP* series, a little less than  $\frac{1}{6}$ . The savings in *LT* are respectively  $\frac{1}{3}$  and a little less than  $\frac{1}{4}$ . The fact that for the *FP* series the saving in *LT* is greater than the saving in *W* is probably due to the fact that in the first learning some of the series were very haltingly recited, thus making the first *LT* disproportionately long.

4. *MV* (the mean variation from the average number of repetitions) is noticeably smaller for the *VSP* series than for the *FP*. The uniform and very small numbers of repetitions in the case of the *VSP* series hints at a fact brought out by introspection, namely, that the subject used a technique in learning them which she was unable to make so useful in the case of the *FP* series.

*Putting all these facts together, we may conclude (1) that the FP series were remembered much more poorly than the VSP, but (2) that this fact is due not to the rôle played by perseveration in the recitation of the FP series but to some positive advantage possessed by the VSP series.*

The introspective statements recorded in connection with this particular group of experiments are scanty but are sufficient to show that the subject did not depart from her usual procedure in memorizing, which must be outlined here. As a memorizer, G. has two peculiarities. In the first place, she is a marked, indeed rather an extreme, case of colored hearing—to the best of her belief congenital and inherited. In the second place, she habitually localizes the material memorized by a sort of projection of images (spots of color) either in external space or in



the internal field of vision. This habit has been much developed, if not acquired, by practice. In the original series of reconstruction experiments, localization became decidedly external but during the experiments here reported, the subject reverted to localizing in the internal field, when learning by the method of complete memorizing although she still projected the series upon the table during certain reconstruction experiments which were in progress, at the same time. During the experiments reported in the last paper, which were made a year or two earlier than these present experiments, the subject already showed a paramount inclination to internal localization although the conditions were designed to foster external projection. (See p. 83 above.) The subject's schemes of localization are plastic, sometimes change without volition on her part, and can be altered pretty readily at will, whereas the color of letters and combinations of letters (strictly speaking, of their sounds) has been fixed for all time within her recollection and has been transferred from one language to another. (During the third group of these experiments, she deliberately ceased to think of a series of twelve syllables as arranged in a horizontal line from left to right and chose to think of it as arranged in three vertical columns of four syllables each. On the other hand, she could no more make the green word *unity* red or blue than she could change the color of the grass on the campus.) She has, however, beside all this kaleidoscopic imagery, a full outfit of auditory-kinaesthetic images. These images serve to differentiate syllables which are the same in color, for although the syllable images are often particolored and sometimes show traces of black letters upon the colored ground, yet the subject has no well-formed images of letters or even of the shape of words as determined by their spelling. (A word is visualized simply as an oblong, ill-defined blotch of color, more or less long.) Thus, this subject presents in a marked degree many peculiarities of the visualizing learner and yet does not belong by any means to the pure type nor even to any normal mixed type. It may be added that, in anticipating a syllable, in recitation, its color is usually most steadily focused by attention. If the syllable is still "far off" and the recitation

rate is slow, the auditory-kinaesthetic image may be clear, but if the time for anticipation is brief, the color touches off the actual *saying* of the syllable without the noticeable presence of even the most fragmentary internal speech. In the rapid recitation of a well-mastered series, many syllables are not anticipated at all but their colors appear as they are uttered.<sup>12</sup>

In all experiments in which G. has had to learn series presented at different rates, she has greatly preferred the more slowly presented series because the intervals allowed her time "to sort and group the syllables and get them into their places." By *sorting* is meant the clear perception and comparison of the elements of the syllables and by *getting them into their places* is meant visualization of the color spots in pretty definite positions in the external or internal field of vision and in very definite spatial relations to one another.

The foregoing description of G.'s method applies to all the groups of experiments reported in this paper and in that which follows. The records taken in connection with the group of experiments now in question show that G. followed her customary procedure, that she had nothing new to report as to imagery, and that she visualized the color spots as grouped by fours in a

<sup>12</sup> On the imagery and learning methods of this subject, see *Memorizing by the Reconstruction Method*, pp. 105 f., 115 f., and 184 f. See also p. 82 f. of these studies. This subject had also the honor of serving for Professor G. E. Müller and is described in his *Analyse der Gedächtnistätigkeit und des Verstellungsverlaufes*, Zeitschrift f. Psych. und Physiol. der Sinnesorgane, Ergänzungsband 8 (1913), pp. 184 f.

One or two additional points in regard to G. should be noted here. In the last few years (since 1910), her eyesight has become so poor that series of words or syllables can be presented to her only aurally if her learning time is to be closely compared with that of other subjects. Thus, aural presentation has been entailed upon whole groups of observers. Before 1910 she did not greatly prefer either aural or visual presentation. This fact is in itself an evidence of the plasticity of her localization schemes. She could with almost equal readiness visualize syllables according to any spatial pattern in which they might be presented or invent a scheme for herself. She has never been able, however, to image many color spots at once, even as arranged in a scheme so simple as one long line. The spots simply emerge here and there in definite spatial relations to one another, somewhat as objects come out in a garden at night when a spot-light is turned from one to another.

horizontal line running from left to right, and had to make special effort to clinch the last member of one group to the first of the next. They also show these two important points, first, that although G. preferred the *VSP* series, she used precisely the same method of grouping and localizing in both sets of series, and second, that she used no more mnemonic devices in the slow series than in the fast. They were "easier to make but less needed" in the slow series.<sup>13</sup> The fact that the recitation rate was unrestricted heightened G.'s preference for the *VSP* series, since it was not necessary to linger over the presentation of these series just because they were slowly presented.

If now we bring the introspective results to bear on the numerical, we find the small numbers of repetitions and small variations, in the learning and relearning of the *VSP* series, fully explained. *The subject learned the VSP series more readily than the FP because she could more easily carry out her grouping and localizing procedure.* We do not, however, as yet find an explanation for the fact that the saving in time and repetitions was greater in the relearning of the *VSP* series. The two sets of series were mastered about equally well at the end of the first learning—the *VSP* series perhaps a little better, judging from the average recitation times,—but the *VSP* series, originally learned more readily, were relearned more readily in a disproportionate degree. The old groupings of syllables, formed with *less* pains, came back with *much less* pains, when the series were again presented. Unless the difference in firmness of associations is to be accounted for entirely by the rather shorter recitation time of the *VSP* series at the end of the first learning, then

<sup>13</sup> By *mnemonic devices* or *auxiliary associations* are meant throughout these papers *not place associations* but a much more artificial class of extrinsic associations. Some of these devices are easier to make in the case of the more slowly presented series. An instance of this kind is the connection of the syllables *jiv, lame, tene, mite*, by the notion (partly pictorial rather than verbal) of *Jove's* kicking Vulcan out of Heaven and making him *lame a tiny (teeny) mite*. Other artificial connections are easier to make, or rather make themselves, when series are read fast enough to blend into pseudo-words or sentences. An instance would be the blending of *vesh, haz* into *vicious*. For the division of auxiliary associations into *Assoziationshilfen* and *Aufmerksamkeitshilfen*, see Ephrussi, *op. cit.*, p. 77.

the *VSP* series have a superiority in the matter of firmness which calls for explanation. We shall, however, make no attempt to explain it until we see whether or not the findings of these experiments are confirmed by others.

*Supplementary Experiments.*—Some very brief series of experiments made upon the subjects B. 1, B. 2 and B. 3 may be regarded as supplementary to the first main group. The results would scarcely be worth reporting if they did not illustrate certain possibilities in experiments of this sort. The general conditions under which these experiments were made are stated on page 118. The syllables in the series numbered twelve.

The numerical results are given in the following scheme:

Series Type	Subject	Learning					Relearning				Saving in	
		N	W	MV	LT	RT	W	MV	LT	RT	W	LT
					<i>Secs.</i>	<i>Secs.</i>			<i>Secs.</i>	<i>Secs.</i>		
<i>VSP-UR</i>	B.1	10	7.5	2.5	288	21	3.8	0.6	108	20	49%	63%
<i>FP-UR</i>		9	12.8	1.2	365	20	7.1	0.8	148	19	45	60
<i>VSP-UR</i>	B.2	10	5.5	1.6	264	24	5.3	1.0	127	21	4	52
<i>FP-UR</i>		10	12.2	2.6	330	28	5.5	1.9	147	27	55	55
<i>VSP-UR</i>	B.3	10	5.8	1.6	246	23	4.6	1.2	177	22	21	28
<i>FP-UR</i>		10	6.7	1.7	225	31	5.4	1.5	199	18	19	12

This scheme is to be read exactly like the scheme on p. 120. (*q.v.*). In looking at the figures one should note the following points:

1. The saving in *LT* and, in general, the saving in *W* is relatively great as compared with the figures for G. This fact is easily explained. These subjects had learned only these twenty series of nonsense syllables in the whole course of their lives and might well remember some of them for a week. In the case of B. 2 the saving in *W* is, for the *VSP* series, negligible, whereas the saving in *LT* is great. This means that the subject *recited* these series much faster in relearning than in learning, although the final recitation times are not very different.

2. Like G. all these subjects learned the *VSP* series with the smaller *W* and, with one exception for the first learning, with the smaller *LT*. For them also, learning with very slow presentation was more economical than learning with fast presentation, the rate of recitation being unrestricted.

3. As might be expected in the case of untrained subjects *MV* and *RT* are much more variable than with *G*. The variations in *MV* are not worth discussing but under *RT* it is important to note that B. 3 recited the *FP* series so much more slowly than the *VSP* at the end of the first learning that she cannot be supposed to have mastered the former as well.

4. B. 1 and B. 3 show the greater saving in *W* and *LT* in the case of the *VSP* series although the superiority of these series in this respect is not very marked. B. 2, on the other hand, shows a slightly greater saving in *LT* and a vastly greater saving in *W* in the case of the *FP* series.

If we turn to the introspection records, we find the cause of this difference between the subjects not far to seek. B. 2 claimed that she learned the series entirely in terms of auditory-kinaesthetic imagery and that with the *FP* series she was "nervous and bewildered." A glance at the figures shows that *W* in the first learning of the *FP* series was in her case very great as compared with the first *W* for the *VSP* series. Evidently, in the first learning, she had difficulty in apprehending syllables rapidly presented, whereas in the second learning, these same syllables were familiar to ear and tongue. Thus in the case of the *FP* series, the saving in *W* is great because the first *W* was particularly large. These figures illustrate a difficulty in gauging tenacity of associations by the amount of work saved in relearning. If with any set of series the number of repetitions required for the first learning is accidentally very high, then the saving of work in relearning is apt to appear large even though the series may not be particularly well remembered.<sup>14</sup> If, on the other hand, the first quotient of work is accidentally small, then the saving in relearning cannot in the nature of the case be very great. We shall later encounter this *difficulty of the accidental first value of W* in its second form.

B. 3 claimed both visual-verbal and auditory imagery and

<sup>14</sup> It should be noted that the relearning of each series is done at a higher level of practice than the learning of that same series. This difference of practice levels is negligible in the case of slowly presented series but with rapidly presented series the unfamiliarity of series when first presented and their familiarity when relearned constitute a serious inequality of conditions.

rather preferred fast presentation, finding the *VSP* series tedious. Since, however, she actually mastered the *VSP* series better in the first learning, it is not surprising that in their case the saving of work in relearning was the greater. B. 1 disclaimed visual imagery but adopted the expedient of naming her fingers with the syllables and was better able to use this device with the *VSP* series. All three subjects grouped the syllables to some extent but B. 2 and B. 3 do not seem to have projected them in any fashion. So far as these experiments go (which is certainly not very far), they appear to be roughly in line with the showing of the first main group.

*Group II. Four sets of series: (1) series learned and relearned at the very slow presentation rate (four-second intervals); (2) series learned at the fast rate (one-second intervals) but relearned at the very slow rate; (3) series learned at the very slow rate but relearned at the fast rate; (4) series learned and relearned at the fast rate.*

*Subgroup 1. Recitation rate unrestricted. Subjects: G., F. and K. Series length: Twenty-four syllables for G. and twelve for F. and K.*

The numerical results are presented in this scheme:

Series Mem. 1	Type Mem. 2	Sub- ject	N	Learning				Relearning			
				W	MV	LT	RT	W	MV	LT	RT
						Secs.	Secs.			Secs.	Secs.
<i>VSP-UR, VSP-UR</i>		G.	11	2.7	0.7	199	43	2.2	0.4	185	39
<i>FP-UR, VSP-UR</i>			10	5.0	0.8	216	39	1.9	0.4	138	51
<i>VSP-UR, FP-UR</i>			10	2.4	0.6	188	34	5.1	0.9	219	38
<i>FP-UR, FP-UR</i>			11	5.0	0.5	220	38	4.5	0.9	199	36
<i>VSP-UR, VSP-UR</i>		F.	12	4.5	1.0	201	14	3.3	0.5	143	18
<i>FP-UR, VSP-UR</i>			8	10.6	2.1	319	15	3.4	0.5	125	19
<i>VSP-UR, FP-UR</i>			8	5.5	0.9	228	17	6.3	1.3	169	23
<i>FP-UR, FP-UR</i>			12	9.8	1.6	256	17	6.8	1.3	182	17
<i>VSP-UR, VSP-UR</i>		K.	12	3.9	1.0	189	22	3.6	0.7	131	23
<i>FP-UR, VSP-UR</i>			9	8.5	1.4	242	21	3.5	0.5	145	24
<i>VSP-UR, FP-UR</i>			10	4.2	1.4	163	18	5.3	0.8	139	18
<i>FP-UR, FP-UR</i>			12	8.3	2.1	240	25	6.4	1.0	186	26

This scheme is to be interpreted in the main like the scheme on page 120. Under the heading *Series Type*, the abbreviations *Mem. 1* and *Mem. 2* stand for the first and the second memorizings. No columns have been made to indicate the fractions of

work saved in relearning because the series were relearned at a different rate from that at which they were learned, and, therefore, neither the numbers of repetitions nor, in strictness, the times occupied in learning and relearning are comparable.

The interpretation of the figures is such a baffling problem and the number of series in each set is so small that the writer is tempted to throw out the whole mass of results but is withheld from doing so by honesty since the results are not entirely in accord with the rather neat results of the first group of experiments. It should be noted that the results obtained from F. and K., even though the number of series is rather small, are more reliable than the figures obtained from the beginners. F. and K. had already served as subjects in experiments which might have been included in those of the first group if the number of series had been sufficient and which may, as they stand, be regarded as practice experiments for the work now in question. Aside from this fact, F. and K. were familiar with nonsense syllables and with the problem.

1. The first point to note is that in the case of G. there is much variation in *RT* as compared with *RT* in the first group of experiments. In the first learning, *RT* for the *VSP-VSP* series (series very slowly presented in both memorizings) is noticeably large, whereas in relearning, *RT* for the *FP-VSP* series stands out from the others by its great length, 51 secs. as against 39, 38 and 36 secs. This variation indicates a fact set down in the introspective records, namely, that in recitation G.'s attention fluctuated. This wavering of G.'s attention, which was, so to speak, an abuse of the unrestricted rate of recitation, led to the abandonment of it in the later experiments. It is *probably* responsible for the puzzling nature of the figures in G.'s case. *RT* is more uniform for F. and for K., to whom the experiments were relatively novel, and is much shorter for F. than for K. It is to be remembered that the series learned by F. and K. were only half as long as those learned by G. With this fact in mind, one can see that in the final trial, F. and G. recited at about the same rate—F. a trifle the faster—and that K. recited much more slowly than either.

The next important point is that at each learning very slow presentation was more economical than fast as regards time and, of course, as regards number of repetitions. Thus, for example, K. learned the two sets of *VSP* series in 189 secs. and 163 secs. respectively but required 242 secs. and 240 secs. for the two *FP* sets. She relearned the two *VSP* sets in 131 secs. and 145 secs. and took 139 secs. and 186 secs. for the *FP* sets. Moreover if we add together the times spent in learning and in relearning the same sets of series (see the figures in the two columns headed *LT*) we find that with one exception (in the case of G.), the entire time spent upon the *VSP-VSP* series is less than the entire time spent upon the *FP-VSP* series and that, with no exception, the entire time for the *VSP-FP* series is less than the entire time for the *FP-FP* series. These experiments, then, are in entire accord with those of Group I in showing that, with an unrestricted rate of recitation, presentation at four-second intervals was more economical than presentation at one-second intervals.

Nevertheless, in spite of the agreement between the two groups, we find the second group diverging from the first when we come to the question of percentages of work saved in relearning. The only series which can be compared as regards work-saving are, of course, the *VSP-VSP* and the *FP-FP* series. (The lines to be compared in the scheme are the first and fourth for each subject.) If we compare the percentages of the original *LT* which are saved in relearning, we find that with F. they are the same (28 per cent) for the *VSP-VSP* and the *FP-FP* series, that with G. the difference is negligible though slightly in favor of the *FP-FP* series (9% as against 7%) and that with K. alone it is decidedly in favor of the *VSP-VSP* series (37% as against 23%). The percentages of the original numbers of repetitions saved are for the *VSP-VSP* and *FP-FP* series respectively as follows: G., 19% and 10%; F., 27% and 31%; K. 8% and 23%. G.'s results are not really in sharp opposition to those of the first group. The saving in repetitions is still clearly in favor of the *VSP-VSP* series and the times are undoubtedly distorted by the subject's lack of attention. With F.



it is clear that neither set of series has an advantage over the other. All that can be said of K.'s results is that the difference between the values of  $W$  in learning and relearning seems anomalously small.

We now come to the second of the two methods of gauging retention, namely, the comparison of series learned at different rates but relearned at the same rate. (The lines to be compared in the table are the first with the second and the third with the fourth for each subject.) The results are certainly disconcerting. They speak decidedly for the better retention by G. of series rapidly presented. She relearned the *FP-VSP* series in a much shorter time than the *VSP-VSP* series (in 138 secs. as compared with 185 secs.) and with a smaller number of repetitions (1.9 as against 2.2). Similarly the *FP-FP* series have an advantage over the *VSP-FP* series (an *LT* of 199 secs. as compared with an *LT* of 219 secs. and a  $W$  of 4.5 as compared with a  $W$  of 5.1). With K., on the other hand, the *VSP-VSP* series retain the advantage over the *FP-VSP* series and the *VSP-FP* over the *FP-FP*. With F. the difference between the values of  $W$  is negligible and the *VSP-FP* series have a smaller *LT* than the *FP-FP*, but, as with G., the *FP-VSP* series have a smaller *LT* than the *VSP-VSP*.

Since the number of series in each set of this much divided subgroup of experiments is so small, it seems better to spend no more time in discussing the results until we see whether or not they are confirmed by the experiments of the next subgroup.

*Group II, Subgroup 2. Conditions the same as in Subgroup 1, except that the recitation rate was restricted and made the same for each set of series as the presentation rate. Subject G. Length of series, twenty-four syllables.*

The results are given in the following scheme:

Series Mem. 1	Type Mem. 2	N	Learning		LT Secs.	Relearning		LT Secs.	Saving in W
			W	MV		W	MV		
<i>VSP-VSR, VSP-VSR</i>		9	3.9	0.6	394	2.3	0.4	237	41%
<i>FP- FR, VSP-VSR</i>		10	9.8	2.2	297	2.5	0.5	258	
<i>VSP-VSR, FP- FR</i>		10	2.8	0.8	291	8.1	1.1	257	
<i>FP- FR, FP- FR</i>		9	11.9	2.5	356	8.2	1.8	263	31

It is almost unnecessary to say that among the symbols under *Series Type*, *VSP-VSR*, *VSP-VSR* means *very slow presentation and recitation, both in learning and in relearning*, and so on. For brevity, the series will be spoken of as *VSP-VSP* series, and so forth. This scheme contains no *RT* columns, for since the recitation rate was restricted to the presentation rate the final recitation of *VSP* series had to take place in 94 secs., counting from the signal *Now*, and the final recitation of an *FP* series in 25 secs. The actual values of *LT* are all somewhat in excess of the times which would have been occupied if there had been no interruptions, such, for example, as were occasioned by the subject's breaking in to ask, "*Min* or *Nin*?" when she failed to grasp the first element of a syllable. To take an actual instance of divergence, the first *LT* for the *VSP-VSP* series should be 375 secs. and is 394 secs.

In discussing the results the first, though not the most important, point to note is that the slowly presented series no longer have a uniform advantage over the rapidly presented series as regards learning time. One set of series very slowly presented took longer in the first learning than either of the two sets rapidly presented. In relearning, one set very slowly presented took one second longer than one of the *FP* sets. Moreover, the total time spent upon the *VSP-VSP* series, in learning and relearning, is longer than the total time for any other set. It must be remembered that, in these experiments, the subject was compelled to recite the *VSP* series very slowly, whether she could have recited them faster or not, and that at the prescribed rate the recitation of a *VSP* series took upwards of four times as long as the recitation of an *FP* series (94 as against 25 secs.). Hence, *LT* for the *VSP* series cannot be as small as *LT* for the *FP* series unless *W* for the *VSP* series is only about one-fourth as great as *W* for the *FP* series. It will also be remembered that this subject, in the earlier experiments, made her final recitation of *VSP* and *FP* series in about the same time, namely, thirty-odd seconds. In face of these facts, we are compelled to conclude that *there is little profit in comparing the learning times of series which must be recited at different rates. We never can tell how*

*much faster than the slower rate the subject could have recited*, nor, for that matter, what the consequences of artificial retardation may be in the way of inattention.

As regards *W*, the *VSP* series retain their old decisive advantage over the *FP*. Roughly speaking, *W* for the *FP* series is about treble the *W* for the *VSP* series. In these experiments, slow repetition appears to have accomplished, in proportion to the time spent upon it, nearly as much as fast repetition, though not more.

The *VSP-VSP* series have regained their old advantage over the *FP-FP* as regards the percentages of repetitions saved in relearning, 41% for the former and 31% for the latter.

Although the differences are small, the *VSP-VSP* series have in relearning a smaller *W* and *LT* than the *FP-VSP* series, and the *VSP-FP* series have the same advantage over the *FP-FP*.

In view of these facts, we must conjecture that in the experiments of the preceding subgroup, G., who confessed to fluctuating attention, was less on the alert in the relearning of those series which were really the more familiar, namely, those which were very slowly presented in the first learning.

F. and K. also served as subjects in these experiments, but as they learned only four series of each type, their results cannot be taken seriously. F.'s averages chance to be exactly in line with G.'s; K.'s are not.

The numerical results of this whole group of experiments are so scanty that little time need be spent upon the introspective records. The only important points in G.'s statements are her confession of slack attention (of "taking it easy") in the recitations of the first subgroup, and her remark that in the fast recitations of the second subgroup she sometimes "could not read the mental copy fast enough to get the syllables on the right beats", whereas at other times she purposely avoided "looking ahead" because if she "failed to see a color spot coming" (in its place on the line), she was frightened and apt to break down. This remark testifies to the paramount attention paid to the visual images of the syllables and to their spatial projection in the internal field.

F. and K. were both visualizers, also. K. made more use of internal speech than F. who instantly translated the aurally presented syllables into visual-verbal images and then often mispronounced them in reading them off. F. was "sure" she had auditory images "of the *g*'s and *j*'s," a declaration which certainly implies a dearth of auditory images. It is curious that F., who was the most exclusively eye-minded of the three subjects, was also the most rapid reciter. Both F. and K. grouped the syllables and F. projected them upon a horizontal line from left to right, grouping the first four together and pairing the next two and the very last two. K. used mnemonic devices both in the *VSP* and the *FP* series; F. used extremely few. K. like G., liked the *VSP-VSP* series best of the four sets, whereas F. preferred the *VSP-FP*, saying that in relearning it was tiresome to have to go over a series slowly when one already knew part of it.

Before we pass to the third and last main group of experiments, we should glance at the results of some experiments on beginners, which are supplementary to the work of the first subgroup of the present group, that in which the rate of recitation was unrestricted. The general conditions of these supplementary experiments are stated on p. 118. The following scheme gives sufficient indication of the series types used and of other details except the number of syllables in the series, which was twelve.

Series Mem. 1	Type Mem. 2	Sub- ject	N	Learning				Relearning			
				W	MV	LT Secs.	RT Secs.	W	MV	LT Secs.	RT Secs.
<i>VSP-UR, FP-UR</i>		B. 4	10	10.5	3.4	459	15	8.1	2.3	204	15
<i>FP-UR, FP-UR</i>			9	16.6	3.7	405	14	7.4	1.5	176	14
<i>VSP-UR, FP-UR</i>		B. 5	10	7.2	1.6	390	30	9.5	2.5	234	16
<i>FP-UR, FP-UR</i>			10	15.0	3.6	513	27	11.1	2.9	267	20
<i>VSP-UR, FP-UR</i>		B. 6	10	3.5	0.9	235	20	3.2	0.7	168	26
<i>FP-UR, FP-UR</i>			9	6.2	1.4	307	17	3.9	0.8	178	28
<i>VSP-UR, FP-UR</i>		B. 7	10	5.2	0.7	242	30	4.7	1.1	159	21
<i>FP-UR, FP-UR</i>			9	8.4	2.0	318	24	6.0	1.3	205	20
<i>VSP-UR, FP-UR</i>		B. 8	10	5.8	1.9	303	27	4.7	1.5	156	21
<i>FP-UR, FP-UR</i>			9	10.6	2.4	475	26	5.6	1.1	188	22
<i>VSP-UR, FP-UR</i>		B. 9	10	5.2	1.2	240	26	4.1	1.1	135	23
<i>FP-UR, FP-UR</i>			9	9.1	1.9	265	29	4.3	0.8	108	27
<i>VSP-UR, FP-UR</i>		B. 10	10	8.8	2.4	330	21	7.2	1.2	213	30
<i>FP-UR, FP-UR</i>			10	14.1	2.9	375	24	7.2	1.4	195	15
<i>VSP-UR, FP-UR</i>		B. 11	10	5.7	1.0	285	22	6.5	1.0	118	21
<i>FP-UR, FP-UR</i>			10	7.9	1.3	283	22	5.0	1.4	169	16

In these experiments we find eight untrained subjects learning some series with a slow and others with a very fast presentation rate and relearning all at the same fast rate. All the subjects in the first learning mastered the *VSP* series with the smaller *W*, and all the subjects, except B. 4 and B. 11, had the smaller *LT* with the *VSP* series. From the values of *RT* we judge that all the subjects, with the probable exception of B. 7, knew the two sets of series about equally well at the end of the first learning. All, excepting B. 4, B. 10 and B. 11, relearned the *VSP-FP* series with the smaller *W* and all, except B. 4, B. 9 and B. 10, with the smaller *LT*. The differences are in some cases considerable. Only in the cases of B. 4 and B. 10 do we fail to find any advantage for the *VSP-FP* series over the *FP-FP*, either in the second *W* or in the second *LT*, and in the case of B. 10 the two values of the second *W* are equal. Turning to the introspective data, we find that only B. 4 and B. 10 expressed a preference for fast over very slow presentation. All the others objected to fast presentation because it made them "nervous" or because it made the syllables "a confused series of sounds" or because it "gave no time for review" (B. 7) or because it allowed less time for naming fingers with syllables. On the other hand, both B. 4 and B. 10 objected to very slow presentation as unnecessary and tiresome, though it should be noted that neither was a facile memorizer as compared with B. 6, B. 7, B. 8, B. 9 or B. 11. All these subjects except B. 9 were visualizers and all except B. 8 grouped the syllables in some fashion. B. 8 spoke of "reading off" the syllables but appears to have seen them in an unbroken line or column. All, except B. 7 and B. 8, used some form of mnemonic device but no one of them, except possibly B. 7, made any great use of spatial associations.

From the second main group of experiments and its supplement, we may draw the following conclusions:

(1) *As in the first main group of experiments, the chief subject G. retained associations formed by the presentation of syllables at four-second intervals better than those formed by presentation at one-second intervals. This is shown by the comparison both of series learned at different rates and relearned at*

the same rate as learned and of series learned at different rates but all relearned at the same rate.

(2) This better retention of the very slowly presented series cannot be considered a personal peculiarity of G., since we find unmistakable evidences of it in the fragmentary results obtained from other subjects. Nevertheless, the results obtained from F., B. 4 and B. 10 suggest that all subjects are not like G. in this respect.

(3) An unrestricted rate of recitation is dangerous in experiments of this type on account of the inequalities of attention which it permits and yet it is a convenience in giving us in the final recitation times a clue to the subject's relative mastery of different sets of series.

Group III. All series relearned at the same rates at which they were learned. Four rates of presentation: (1) slow—SP, with three-second intervals; (2) moderately slow—MSP, with two-second intervals; (3) fast—FP, with one-second intervals; and (4) very fast—VFP, with eight-tenths-of-a-second intervals between the syllables. Series recited at the same rate as presented. Subjects, G., C. and D. Number of syllables in series, twelve for all alike.

Series Type	Sub-ject	Per-iod	N	Learning			Relearning			Saving		Total
				W	MV	LT Secs.	W	MV	LT Secs.	W	LT	
SP- SR	G.	1	18	2.9	0.6	107	2.6	1.0	96	10%	203	
MSP-MSR			17	4.1	0.9	108	3.8	1.1	100	7	208	
FP- FR			18	8.0	1.8	125	6.2	1.2	96	23	221	
VFP-VFR			17	9.6	2.3	121	8.4	2.1	105	12	226	
SP- SR		2	42	2.4	0.6	88	2.2	0.6	81	8	160	
MSP-MSR			42	2.8	0.8	73	2.9	0.8	75	—	148	
FP- FR			42	5.5	1.5	87	4.4	1.0	67	20	154	
VFP-VFR			42	6.9	1.3	86	6.8	1.2	85	2	171	
SP- SR	C.		23	4.7	1.5	176	4.0	0.8	149	26	325	
MSP-MSR			22	6.1	2.4	162	4.5	1.2	119	18	281	
FP- FR			23	9.9	2.6	155	7.3	1.9	114	26	269	
VFP-VFR			24	14.0	4.0	177	9.0	2.1	113	36	290	
SP- SR	D.		13	6.7	1.5	252	5.8	1.4	217	13	469	
MSP-MSR			15	7.9	2.1	210	7.4	2.3	197	6	407	
FP- FR			15	11.7	2.9	184	8.8	2.2	140	25	324	
VFP-VFR			16	14.4	2.4	182	9.7	1.6	122	33	304	

In this table, the times given under the *LT* headings are not the learning times actually recorded but times which have been calculated on the basis of the numbers of repetitions. The original records of these experiments were burned and the time averages were not entered in the table of results, which (with a scanty record of introspection) now remains in the hands of the writer. For practical purposes, the times entered in the table probably resemble the real times closely enough but they must all be slightly lower than the real times. (*Cf.* p. 132 above). For the convenience of the reader the values of *LT* in learning and in relearning have been added together and entered in a column at the extreme right of the table.

As the recitation times were restricted, the times occupied in the final and perfect recitation were respectively for the *SP*, *MSP*, *FP* and *VFP* series, 35 secs., 24 secs., 13 secs., and 10.4 secs., counting from the signal.

As represented in the table, the results of *G.* fall into two sections. The experiments covered by the first section were made before Christmas and the results worked out in the holidays. The outcome was so surprising to the experimenters that the results obtained after Christmas were averaged separately to see if they would make the same showing. When we scrutinize the figures, we see that they amount for *G.* almost to a reversal of the findings of the earlier experiments but that the number of series is so large that the work cannot be set aside. Moreover, the results of the other two subjects are quite in line with the new showing of *G.* In detail, the points to be noted are as follows:

1. As in the preceding experiments, *W* increases with the presentation rate. This is true for all the subjects, both in learning and in relearning, and is the common finding when series are learned at different repetition rates.

2. The more slowly presented series do not have such an advantage in *W* that they have an advantage in *LT* as well. We find that in each period of *G.*'s work, the learning times differ little among themselves and the relearning times still less. In the first period, the average total time spent upon the different sets

of series rises slowly but steadily with the rate—from 203 secs. for the *SP* series to 226 secs. for the *VFP* series. In the second period, the longest total time—171 secs.—was spent upon the *VFP* series, but the *SP* series are a close second, and then comes a considerable drop to the *FP* and *MSP* series—from 169 secs. to 154 secs. and 148 secs. In the cases of C. and D., the more rapidly presented series have a clear advantage in *LT*. With D., the advantage is very marked since *LT*, both in learning and in relearning, decreases steadily and, in relearning, decreases considerably with the increase of presentation rate.

3. As regards the percentage of work saved in relearning, the more rapidly presented series, not the more slowly presented, have in these experiments the marked advantage. With all three subjects the saving is least in the case of the *MSP* series. This fact is hard to explain and is very conspicuous. With G., the saving is greatest in the case of the *FP* series. In both sections of the figures, the advantage of these series is marked. In the first section, the difference between the *SP* and *VFP* series is negligible but, in the second section, the saving in the case of the *VFP* series is itself negligible. With C. and D., the *VFP* series show decidedly the greatest saving. In C.'s case, the *SP* and *FP* series rank together but, in D.'s case, the *FP* series are greatly ahead of the *SP*. In G.'s case, the numbers of repetitions are smaller, both in learning and in relearning, than those of the other subjects and the saving in repetitions is also less than theirs. The saving in repetitions is greatest with C., although her numbers of necessary repetitions are smaller than D.'s.

These surprising results raise three questions: (1) How is the divergence of G.'s results from those obtained in the experiments of the year before (Groups I and II) to be explained? To be sure, the numbers of series in Group II were not large but, on the other hand, those in Group I were considerable—thirty-eight in each set as against forty-two in the second section of these experiments. (2) Is the advantage of the more rapidly presented series in the cases of C. and D. (an advantage which is marked in comparison with their showing in the case of G.



even in these experiments) an indication of an "individual difference"? (3) What is the meaning of the fact that the *MSP* series, and not either the *VFP* or the *SP* series, show the minimum of saving in relearning? In the discussion of these questions such introspective data as remain in the possession of the writer will be interpolated.

(1) As regards the first question, it is probable that G.'s results are not really so much at variance with her showing in the earlier work as appears on the surface. Three facts are to be taken into consideration. In the first place, G.'s percentages of saving are, in these experiments, small as compared with her percentages in Group I and in the second subgroup of Group II. (See the schemes on pp. 120 and 131.) They are also small as compared with the percentages of C. and of D. As a matter of fact, G. was memorizing so many series at the time when this present work was done that her retention was very poor. She was serving as subject in the "fatigue experiments" described in the following paper and was very much aware of the displacement of one series of impressions by another. This fact does not explain the advantage of the *FP* series but simply shows that these experiments were made under conditions different from those of the preceding year, which were made when G. was learning no other series of nonsense syllables. In the second place, G. was, in these experiments, using somewhat different methods in learning the more slowly presented and the more rapidly presented series. With the slower series, she was using her old device of projecting the color spots which represented the syllables in a definite pattern in the mental field of vision. In the second section of these experiments, she ceased to project the spots in a single horizontal line and, for the express purpose of emphasizing spatial relations and comparing colors, took to projecting the spots in three vertical columns of four syllables each, so as to bring the first, fifth and ninth syllables, which were the initial syllables of each group, side by side from left to right in the same line, and so as to bring the syllables second in each group side by side in the line below, and so on. She tried to use the same method in the more rapidly presented series and had

usually succeeded in projecting the syllables before the final recitation. She had, however, a great deal of trouble in "hearing" the syllables of the *FP* and *VFP* series and, in her perturbation, caught at every mnemonic device within mental reach. If some of the syllables could thus be bound together and disposed of, her attention could be concentrated on "getting hold" of the rest. In relearning, these artificial associates frequently came back to mind, whereas the more slowly presented series often seemed entirely unfamiliar. The artificial associates differed from series to series; the framework of the syllable pattern was the same for all series and gave little assistance in reviving old impressions.<sup>15</sup> In the third place, we meet, in the case of the *SP* series, "the difficulty of the accidental first value of *W*" mentioned on p. 127 above. After all, G. was memorizing series of twelve syllables only and was memorizing at a slow presentation rate. This task had become very easy work for her. In the majority of cases, it was performed with two presentations. As the subject frequently remarked during the year in which these experiments were made, the first slow presentation enabled her "to take stock of the syllables in the series" and the second enabled her "to link them together." A third was entailed only by nervousness in recitation. But even in relearning these two presentations seemed to be necessary except when the subject was in exceptional learning trim. She had to "see what was in the series all the way to the end" before she could "connect it up." To put the matter numerically, the value of the first *W* had almost reached the lower limit for *W*, namely, one, and the value of the second *W* could not fall far below it. Putting all

<sup>15</sup> The reader in these experiments was a Southerner of "opened vowels and softened consonants," and the subject, though of the Middle West by birth and speech, could not learn the syllables so well when they were presented by her as when they were presented by either of the two New Englanders who read in the "fatigue experiments." While she was learning the 70 series of the first section, she learned 116 series in the fatigue work, half of them *SP* and half *FP* series. *W* for the *SP* series was 2.7 as against 2.9 in these experiments, and *W* for the *FP* series was only 5.6 as compared with 8.0. It is evident that in the aural presentation of series, considerable inequality of conditions may arise through the provincial differences of pronunciation which are common even among educated persons.

these facts together, the writer concludes that *in these experiments the superiority of the more rapidly presented series was accidental, and, therefore, that these experiments do not overturn, although they certainly do not support, the conclusions to be drawn from the earlier groups.*

(2) We must answer the second question in the affirmative. *In the cases of C. and of D., the advantage of the more rapidly presented series, not only in regard to total learning time but also in regard to the percentage of the original work saved in relearning, does really indicate a genuine individual difference between these subjects and G. The difference is probably rooted in the degrees of attention paid to the more slowly and to the more rapidly presented series.* The difference in attention may be traced to the difference in imagery. In one respect, this difference *may* have worked against the better retention of the more rapidly repeated series by C. and D. C.'s imagery, like G.'s, consisted of visual-verbal images (C.'s were of the normal type) blended with internal speech, but, unlike G.'s, C.'s imagery became decidedly auditory-kinaesthetic in the case of the more rapidly presented series. C. claimed expressly that, in the case of the fast series, she was helped by auditory-kinaesthetic "perseveration," that is, by the mental echo of the series in internal speech. Even G. remarked that sometimes a very rapidly presented series would seem to "say itself," but usually in the recitation of these series G. read from her mental copy and occasionally complained that the color spots would not form fast enough in the internal field. D. took a somewhat antagonistic attitude throughout the work and maintained that she "had no imagery at all" but that she could have visualized the syllables if she had liked the work. From this statement, we may glean, first, that she had little or no *visual* imagery and, second, that in reciting she took no pains to anticipate syllables. Her relatively short learning times in the case of the *VFP* series indicate that internal-speech perseveration came into play in her case also. Now the writer assumed at the outset of this paper that if series were recited with the aid of perseveration they might be recited before the associations between the syllables were firmly impressed, and

that such series would necessarily be quickly forgotten since perservation is essentially evanescent. If this assumption is correct, it is obvious that the better retention of the more rapidly presented series by C. and D. cannot be explained by the more conspicuous presence of the kind of imagery in which an aurally presented series most naturally tends to perseverate.<sup>16</sup> Indirectly, however, the difference in imagery was an important factor in determining the sorts of attention paid to the slower and to the faster series by C. and D., on the one hand, and by G., on the other. G. learned the slower series *con amore* because she could readily use her color-spot pattern. In presentation, the long intervals never seemed wasted because they were occupied in putting the syllables into their places in the pattern and in comparing the colors of syllables in different positions. In recitation, indeed, the long intervals were somewhat trying but not sufficiently so to make G. prefer the faster series. On the other hand, in the cases of C. and D., the long intervals were worse than wasted, since they evidently allowed time for attention to waver seriously. After a given syllable was presented or recited, the subject had time in a three-second interval to think of the next syllable, if she knew it, and then to think of something else, and she was apt to be thinking of that something else when the time came to hear or say that next syllable. C. expressed a marked preference for the faster series because the slower series were "hard to attend to." D. said that she "hated all alike," but evidently she did pay closer attention to the faster series. Otherwise the *FP* and *VFP* series could not possibly have had their great advantage in the matter of total learning time. Here, then, is the crucial difference between the subjects. C. and D. remembered the faster series better because they gave much more sustained attention to learning them and thus made stronger associations between the syllables. Unfortunately, we have, in this group of experiments, no comparable recitation times to serve as a clue to the strength of the associations when the series of the

<sup>16</sup> An eye-minded subject may undoubtedly have visual perseveration even in the case of aurally presented series, since the aural impressions may instantly be translated into ocular terms.

various sets were perfectly recited. The time of recitation was restricted and every series had to be recited just as fast and just as slowly as it was presented. *It is very probable that the difference in recitation rate led in itself to a difference in the initial strength of the associations, since the slow series could be recited in virtue of very weak associations.*

Incidentally and to complete the introspective data, it may be remarked that C. grouped the syllables in fours as did G., but made no mention of spatial projection. She used more mnemonic devices in the slower series than she used in the faster series, a fact which must in itself have made for the better retention of the slower series (actually less well remembered). D. does not appear even to have taken pains to group the syllables. She said that she was helped by artificial associations when they occurred to her but that she took no trouble to make them.

(3) The minimum saving in the case of the *MSP* series is hard to explain but Miss Rockwell makes the plausible suggestion that, in the cases of C. and D. these series were heard and recited with the least attention, since they required neither the effort to attend which was demanded by the still slower series nor the very alert attention which was necessary if the syllables of the faster series were to be grasped as presented and to be recited on the proper beats. This conjecture in regard to C. and D. is borne out by the fact that G. considered the learning of the *MSP* series particularly easy and pleasant. In the relearning, these series seemed more unfamiliar than any of the others to G., who said at the time that they were "hoodooed."

On the whole, then, we may conclude (1) *that this group of experiments gives no evidence that series of nonsense syllables slowly presented and recited are better remembered than series more rapidly repeated; (2) that, in view of the circumstances under which they were made, they should not be regarded as overturning the conclusion that G. remembered series learned by slow repetition better than those learned by fast repetition; (3) that two out of the three subjects certainly did remember the more rapidly repeated series better than those more slowly re-*

*peated; but (4) that they did so probably because they paid better attention to the faster series and thus formed associations of superior initial strength. The experiments do not preclude the possibility that if these two subjects had really been able to recite the slower series as readily at the outset they might have remembered them as well as they remembered the faster series.*

### *Conclusions*

The conclusions to be drawn from the entire series of experiments fall into three sets: conclusions as to fact, conclusions as to theory and conclusions as to method.

I. The conclusions as to matters of fact have been summarized at the end of the discussion of each group of experiments and need only the briefest review here, since the reader can turn in an instant to the italicized sentences on pp. 122, 135-136 and 143-144. In a few words they are as follows:

a. The chief subject G., who is a predominantly eye-minded person and who projected the color images representing the syllables in a well-defined pattern in the mental field of vision, appears, under normal conditions, to have remembered the series of syllables which were very slowly presented better than those which were presented at a faster rate. This fact is brought out both (1) by the comparison of series relearned respectively at the same slow and fast rates at which they were presented and recited at an unrestricted rate and (2) by the comparison of series learned at different presentation rates but relearned at the same rate and all recited at the rate at which they were presented.

b. There were four other subjects with some degree of training, F., K., C. and D. The results obtained from F. and K. are too few to have much significance. The results of K., who like G. preferred the slow series, appear to be in line with those of G., whereas the results of F., who preferred the fast series, are not. C. and D., who served only in the experiments in which the presentation and recitation rates were the same and in which all series were relearned at the rates at which they were learned, remembered the faster series much better than the slower. D. visualized little, if at all, and C. made little, if any, use of spatial associations.

c. There is much reason to believe that whereas G. learned the slower and faster series (excepting perhaps the *MSP* series) with equally steady and tense attention, C. and D. paid better attention to the more rapidly presented series and had, therefore, linked the syllables of these series by a much stronger set of associations when the first learning was counted complete. The slow rates of recitation in the case of the more slowly presented series may well have concealed a weakness in the associations.

d. In certain rather fragmentary supplementary experiments, the majority of the subjects (who were untrained) appear to have remembered the slowly presented series better than those rapidly presented and there are hints that those who remembered the fast series better found it hard to attend to the slow series.

II. In passing to the theoretical conclusions to be drawn from these facts, the following points should be kept clearly in mind. The *strength* of an association is its *readiness* to function and is measured roughly by the association time, *i.e.*, by the time required for the recalled experience to emerge after the recalling experience comes to mind.<sup>17</sup> The lastingness or wearing-quality or "life" of an association depends (aside from individual differences in retentiveness) upon its initial strength and upon its freedom from retroactive inhibition, *i.e.*, from the dislodging effect of a later formed and very similar association. Its strength at any one time after it is formed and before it is obliterated or renewed must depend upon its initial strength and upon its freedom from retroactive disturbance, and upon the time which has elapsed since its impression. The initial strength of such a series of associations as is formed in learning series of nonsense syllables by the method of complete memorizing may, for our pur-

<sup>17</sup> Aside from the fact that individuals appear to differ in celerity of recall and aside from the fact that the real association time can never be gauged with entire precision, this time is not a perfect measure of the strength of the association, since it may be lengthened by reciprocal inhibition between this association and another. In fact, the strength of an association is best expressed by the probability that it will function sooner or later, a probability which can be gauged by the method of right associates, not indeed for one particular association but for each association as a member of a group formed under certain conditions. See p. 47, note of these Studies.

poses, be reckoned as their strength at the end of the last repetition in the first learning. If the recitation rate is unrestricted and the learner is interested in "doing well" and, therefore, recites as fast as he can, then the recitation time offers a good rough gauge of the initial strength of the associations. But a restricted recitation time cuts out this gauge. A rapid rate of recitation demands pretty strong associations—unless they are helped out by perseveration. A slow rate, if prescribed, may or may not mask weakness in the associations. A rather slow rate of presentation, if *chosen* by the subject in the case of rapidly presented series, must indicate that they are not recited in virtue of the mental echo or, in other words, of perseveration.

We are now ready to restate the main issue and to formulate the main conclusion of this study. Its chief interest lay in determining whether series rapidly repeated (*i.e.*, series quickly presented and recited either at this same quick rate or as fast as the subject chooses) are more quickly forgotten than series learned at a slow rate of repetition. If they are, then it may be inferred that the final recitation was accomplished in virtue of rather weak associations eked out by perseverative (or if one prefer, by *impressional*) tendencies. If they are not, then no tendencies which are in their very nature evanescent can have accomplished a recitation premature in the sense that it took place before the associations were clinched. Now we are forced to conclude that *it cannot possibly be inferred from these experiments both that quickly repeated series are remembered less well than slowly repeated series and also that their poorer retention is due to the fact that in the first learning the final recitation was achieved with the aid of perseveration. For, in the first place, in the only clear and well-substantiated case in which series presented fast were not so well remembered as series presented slowly (that of G. in the first group of experiments), the slow rate of recitation chosen by the subject precludes the possibility that perseveration played a very significant part. And, in the second place, we find that in those cases in which we may be pretty sure that the "mental echo" was present in the case of the rapidly repeated series, they were better remembered than those*



*slowly repeated.* Thus, the main question of this study is settled in the negative in so far as these experiments can settle it. The reader will realize that the subjects were few and that the fastest rate of presentation and recitation (one syllable to eight-tenths of a second) was really not so very fast, though fairly rapid for the aural presentation of meaningless material.

Two or three questions of minor interest remain. In the first place, we have the task of explaining why G. on the whole remembered the slowly repeated series better than those rapidly repeated and of stressing the reason why this showing was reversed in the cases of C. and D. The answer to the question as to G. is probably as follows: She remembered the slow series better than the fast because slow presentation gave her more leisure for visualizing the spatial patterns in which she imaged the syllables and thus for forming criss-cross associations between them. These associations were less conspicuous in the case of the rapidly presented series, even though the associations between each syllable and the one next following were just as strong. For instance, although the associations between the first and second and between the fourth and fifth syllables were no stronger in the slow series than in the fast, yet the first syllable was more strongly associated with the fifth, which was imaged either beside it or in a corresponding position in the next group of four syllables (really of four color spots). These criss-cross associations (secondary associations intrinsic to the series), like the true mnemonic associations (which are secondary but extrinsic), are revived in relearning and appear to facilitate it. G. made no more mnemonic associations in the slow series than in the fast but she did dwell more on criss-cross connections. G. certainly did not in general pay higher-level or steadier attention to one set of series than to another although, as we have seen, the moderately slow series of the third group of experiments seem to have fared ill at the hands of all the subjects. Rapidly presented series cannot be mastered at all unless the learner strictly attends to business, and the slowly presented series were zealously attended to by G. because she took pride in keeping the number of necessary repetitions as low as possible,

always hoping to make a perfect recitation after a single slow presentation of a twelve-syllable series and sometimes succeeding. On the other hand, C. and D. certainly paid closer attention to the more rapidly repeated series, thus disproportionately reducing the learning time. This fact would not explain the better retention of the rapidly repeated series if we could believe that the associations formed in learning the slow series were in the end equally strong. We have no numerical evidence that they were not, since in the experiments in question the slowly presented series had also to be slowly recited. Since, however, slow recitation was allowed, the series *could* be recited in virtue of weak associations. Since, moreover, C. complained that the slow series were hard to attend to and since D., throughout the experiments exerted herself as little as possible, we have much reason for supposing that the initial strength of the associations in the slow series was actually low. Superiority in the initial strength of the primary intrinsic or "intentional" associations (the associations between each syllable and the one next following) probably then explains the better retention of the quickly repeated series by these two subjects. This conclusion is, of course, in direct contradiction to the supposition which gave rise to this study.

In the second place, it must be frankly confessed that the experiments *fail to give the slightest indication of any physiological advantage in slow repetition—of any consolidation process as involved by it.* The advantage of the slow series in the case of G. is sufficiently explained by her peculiar method of memorizing. On the other hand, in the cases of C. and D., the disadvantage of slow repetition, namely, its failure to enforce steady attention, was great enough to *hide* a considerable physiological advantage.

Finally, it must be said that the explanation of the feeling of automatism which one has in reciting a rapidly and frequently presented and recited series must remain an open question. The series—often rather suddenly—rolls out before the mental eye or reels off in internal or actual speech as if the reciter were a mere reader or mouth-piece. This sort of thing does not seem

to happen in the case of slowly repeated series. Why? One can scarcely explain it as a vocal-motor automatism because speech, whether internal or actual, is not always prominent in this self-thrusting of the series into consciousness. There are two possible explanations of the experience. (1) It may be that the associations, very strong because they are very fresh and repeatedly stamped, function so quickly that the learner suffers a slight emotional shock. (2) It may be that the mental echo is really a perseveration of the members, a perseveration forced into serial order by the associations between them. (Cf. p 108 above.) The question reduces itself to this: Are "impressional tendencies" more important in this phenomenon than in ordinary recall? If so, they produce all that the present writer means by perseveration. *These experiments show that such perseveration, if it exists, is less important in the recall of rapidly repeated series than the writer had supposed, but they do not explain away the feeling of suffering, or being passive under, the intrusion of the series members.*

III. The conclusions as to method the writer believes to be the only important contribution made by this study. Although she has clearly seen how her method might be improved, she has never made any more retention experiments of this type. At the end of this study, she had become completely discouraged in the attempt to make such experiments with undergraduate co-operation. Under the conditions of undergraduate life and work, it is absolutely impossible to secure the learning and re-learning of a large number of series, under parallel conditions, by a satisfactory number of subjects. If, however, one has the temerity to make experiments similar to those described in this paper, the following points should be noted:

*a. Parallel experiments should be made with a restricted and with an unrestricted recitation rate.* An unrestricted rate is likely to have a dangerous effect upon attention unless the subject is taking a keen and unflagging interest in his work. On the other hand, the restriction of the recitation rate withdraws the invaluable gauge of the initial strength of the associations

which is furnished by the recitation times, if the subject is allowed to recite the syllables without nervous haste and yet as fast as they occur to him.

*b. Even if the recitation rate is to be restricted, slow recitation should not be required.* In other words, the subject should be required to recite the slow series not at the rate at which they were presented but at the rate at which he recites the fast series. At first, a certain emotional disturbance is involved in passing from slow presentation to fast recitation, but this soon wears off. (This the writer knows by experience as subject in work which is not yet ready for publication.) If the series are all recited at the same rate, one can, of course, compare, as regards firmness of associations, only the effects of slow and of fast presentation and not the effects of the slow and fast traversing of the whole series, the part recited as well as the part presented. The first comparison, however,—that is, the comparison of presentation rates—is simpler and needs to be made before the more complicated comparison is attempted. In any case, the artificial lengthening of intervals in recitation permits and conceals the recitation of the series in virtue of weak and lagging associations, allows the attention of some subjects to wander, and tempts others to fill up the pauses by inventing far-fetched mnemonic connections or by making private reviews of parts of the series, reviews which are not counted in the numbers of repetitions which the experimenter guilelessly sets down in his record-book.

*c. Of the two methods of gauging retention described in the section on method, the second is greatly preferable.* That is, it is better to compare the ease with which series, learned at different rates, are relearned all at the same rate than to compare the fractions of work saved when series, learned at different rates, are relearned at the rates at which they were, respectively, learned. The objections to the latter method are perhaps three. The two certain objections have already been mentioned. In the first place, if the rate of recitation is restricted, the subject is as likely to be frightened in relearning as in learning and his fortuitous break-downs in relearning obscure the residual difference

between the numbers of necessary repetitions and learning times. (For illustration, see p. 116.) In the second place, if the average number of repetitions is accidentally high in the first learning, as it is likely to be if the subject has difficulty in reading or in "hearing" unfamiliar syllables, then the percentage of work saved in relearning these same syllables, now more familiar, exaggerates the firmness of the associations formed in learning. If, on the other hand, the number of repetitions necessary to the first learning is approaching unity (as when G. was learning slowly repeated series of twelve syllables), it is numerically impossible that the saving in repetitions should be large. Lastly, it is at least possible that series learned and relearned at a slow repetition rate might appear to be better (or worse) remembered than series learned and relearned at a fast rate, not because they were *learned* at a slow rate but because they were *relearned* at a slow rate. In other words, if two sets of series were learned at the same rate but relearned at the different rates, those relearned at the slower rate might appear to be better (or worse) remembered than those relearned at the faster rate. It is very possible that one repetition rate more than another favours the revival of associations equally moribund when the relearning commences. In our experiments there is evidence neither for nor against this supposition, but if there be any truth in it, then, in a test of relative firmness of associations, series learned at different rates should be relearned at the same rate.

In conclusion, the writer wishes some one else joy in making similar experiments under conditions more favorable than she has been able to secure.