

ON THE EXPERIMENTAL INVESTIGATION OF MEMORY.

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It is the purpose of this sketch to give a critical survey of experimental research on memory. In it I have endeavored to discuss the more important results of this study and to refer to the chief works on the subject.

In regard to this purpose I have been anticipated by Dr. Burnham, who, in his work on the history of the investigation of memory (24),¹ has a most admirable account of the experimental work. But unfortunately this was written in 1889, only four years after the publication of Ebbinghaus' researches. It thus takes into consideration only a very small portion of the work now accomplished. Since then Professor Titchener (75) and M. Binet (8) have written accounts of work done along this line. Each of these is excellent, but, being short, does not cover the whole ground.

It was actual work on memory² which caused me to feel the need of a sketch such as this aims to be. Every one who has studied the literature of the subject must be convinced of the general ignorance on the part of the investigator of the work of others. There has been a very large amount of wasted work. The same problems have often been treated several times without the slightest advance being made. The literature on the subject of experiments on memory is far larger than any would imagine, and the problems of this sphere are of great significance. It thus seems desirable to give some account of

¹The numbers in parentheses refer to the numbers in the bibliography at the end of the article.

²I hope later to publish certain investigations of my own on memory for pressure and memory of sound intensity.

the literature and to state in a general way the nature of the problems.

THE METHODS.

In the experimental investigation of memory the general methods of experimental psychology are, of course, employed, the method of right and wrong cases, so called, being most in use. With these general methods we have nothing to do, for memory research has brought about no modification of them. However, leaving these aside, there are several methods peculiar to the sphere under consideration which have been developed and which are of the greatest importance.

In every experiment on memory there are of necessity two terms—*A*, a stimulus of some sort which constitutes the thing to be remembered, and *B*, an expression on the part of the reagent of the state of the condition of the memory *A*. Take, for example, an experiment on the memory for squares. It is first necessary to show the subject a certain square (*A*), then after the lapse of a definite interval of time to require him in some way to express the state or condition of his memory for that square (*B*). Now the methods of the experimental investigation of memory are to be distinguished from each other solely by the character of the *B* of the experiment; that is to say, they differ from each other as the nature of the expression differs. This is proved by the fact that in his research on the memory for squares Professor Baldwin (1) in each experiment gave the subject a single square to remember (that is to say, the *A* term remained constant), although he made use of all of the known methods.

The first distinction between the means of artificially expressing the condition of a memory, which is thus the distinction between memory methods, rests upon a difference between two general phenomena of memory, namely, those of reproduction and recognition. It is a well-known fact that former experiences are much more easily recognized than reproduced, and that we all, *e. g.*, understand many more words than we are able to use. As far as experimental methods are concerned, in reproduction we call up an old experience, unaided directly

by any immediate expression from the outer world; while in recognition we simply feel the identity of a term already in consciousness with one which was there in the past. In the experiment itself this difference takes the following form: In the method of reproduction the subject, having been given some stimulus, is called upon after the lapse of a certain time to reproduce that stimulus without any further aid from the experimenter. In the experiments on memory for squares he is required to draw the square on paper; in those on verbal memory he is required to write or pronounce the words which he was told to remember. On the other hand, in the method of recognition, the subject, having been given the stimulus to be remembered (*A*), is again given one or more stimuli and is required to pronounce upon the relation of identity which the latter holds (or hold) to the former. Thus the method of reproduction is to be distinguished from that of recognition by the fact that in the former only one artificially given stimulus is required in each experiment, while in the latter at least two are necessary.

Now, while the method of reproduction cannot be further reduced, the method of recognition breaks up into two minor forms. These, in the terms of Professor Baldwin, are the methods of identification and selection.¹

In the former of these the second artificially given stimulation consists of one term only. The subject is required to compare a single present stimulus with a past one of the same general sort, in order to determine whether they are identical or not; hence the name, method of identification.

In the latter the second stimulation consists of more than one term. The subject is given a series of stimuli and is required to select from it a single term which was formerly given alone.

In order to illustrate these three methods we may make use of the case already mentioned in which each was employed by Baldwin and his colleagues (Warren and Shaw) in their investigation of the memory for squares (1, 82).

1. Method of Reproduction.

A normal square of 170 mm. was shown and then immediately removed; after the lapse of a given time (20, 40 min., etc.) the subject was required to draw the same on paper.

¹ For the origin of these terms see below.

2. Method of Identification.

A normal square was first shown, as above, and afterwards another one either of the same size as the first or greater or less. The subject was asked to determine the quantitative relation of the second to the first, *i. e.*, whether it was equal to, larger or smaller than the first.

3. Method of Selection.

A certain time after the removal of the normal a variety of squares of different sizes, one among which was equal to the normal, was shown and the subject told to designate one which seemed to be of the same size as the normal.

These three methods are thus seen to be distinguished by the second term in the experiment, or by the means of expression. In the first method it is not dependent on an artificially given stimulus. In the second method it involves one such stimulus and in the third it involves several. Therefore, these methods seem to be exhaustive. As a matter of fact, all past experiments on memory have been done in accordance with one or more of them.

The distinguishing and naming of the methods of recognition and reproduction were due to Wolfe (85, p. 537), who thereby endeavored to describe the difference between the method first employed by him in his investigation of tone memory and that used by Ebbinghaus. It seemed easier to Wolfe to get at the nature of memory through the phenomenon of recognition than through that of reproduction. For this reason he objected to the method of reproduction used for the first time by Ebbinghaus and developed his method of recognition. This particular form of the method of recognition was afterwards called the method of identification.

The first formulation of the methods of identification and selection is due to Professor Baldwin, and appeared in a report to the American Psychological Association in December, 1893 (80), which was followed by a fuller description published in May, 1895 (1).

In 1894, in his '*Psychologie Experimentale*' (10, p. 76), Binet described the three methods and characterized them as

those of reproduction, comparison and recognition.¹ This was done in apparent ignorance of the work of Wolfe and Baldwin. Inasmuch as these investigators have anticipated him, their terms should evidently be retained.²

Both Baldwin and Binet seemed to consider the method of identification to be of the greatest worth. The method of reproduction is adapted to the study of verbal memory. Indeed, it alone can be used in this work. No attempt has yet been made to investigate the memory of words by any other means. But in other spheres its value is greatly impaired by the fact that the motor factor involved in the act of reproducing inevitably introduces an element into the reproduction which is not an expression of the memory image and which cannot be determined. Moreover, the reproduction is always conditioned by the ability of expression possessed by the particular individual. For instance, in the case of squares the individual *A* may have a more accurate memory for geometrical figures than *B*, but may have had less practice in drawing them, in which case *B* might be accredited with greater accuracy than *A*. It is just for this reason that the method of reproduction is applicable to the study of word memory, for in this case all ordinary individuals have had sufficient practice in expression to rule out the effect of different degrees of ability in regard to expression as possessed by different subjects.

The method of selection should be avoided when possible, for the reason that when a series of stimuli of the same sort is given the attention is normally drawn to the middle of the series. The law of contrast always affects the apparent character of each member of the series. It was found, for example, that in the work on memory for squares done according to this method the apparent size of each square in the series from which the normal was to be selected was conditioned by its relation to the other squares. Moreover, it is only when the stimuli are spacial that they can be given simultaneously.

¹ Binet elsewhere (9, page 608) substitutes the term selection for that of recognition.

² See in this connection foot-note to page 608, No. 9 of the bibliography, and to page 175, Vol. V., of the *PSYCHOLOGICAL REVIEW*.

The method of identification is by all means the simplest and most satisfactory of all memory methods. The only objection to which it is open is the practical one that it must always be coupled with the general method of right and wrong cases, which requires a very large number of experiments in order that there be a sufficient ground for a valid induction.

THE MATERIAL.

By the material of memory researches I mean the stimuli used in the experiments.

There are in general two ways in which a thing may be remembered. In the first place it may be reproduced so that it appears in memory relatively the same as it appeared in reality. Or, in the second place, it may be remembered by means of concepts. On the one hand we recollect the thing immediately; on the other mediately through some *tertium quid*. In mediate memory, if the term may be used, what we remember is not the thing itself, but our classification of it; that is, we remember certain concepts as related to the thing. If, for instance, we endeavor to reproduce on paper the peculiar curvature of a line we had once seen, it will be necessary to bring the line up to the 'mind's eye' as it appeared in reality. But if we desire only to recollect its length it will be sufficient to remember that we judged it to be a certain number of inches long.

Now, the material used in experiments on memory is sharply divisible into two classes, according to the way in which it is remembered. If what we are to remember is some delicate shading of color or some fine variation of pitch, it must be recollected immediately; but if it be simply some concrete object in its general character or some well-known complex of sensation it must be recollected mediately. For the former objects there are no terms in language, but the latter are instantly classified and named. Now, the material to be recollected immediately is relatively simple, while that to be recollected mediately is complex. This is amply shown by the list at the end of this section. It may thus be well to retain the terms simple and complex to signify a necessary and important distinction between the sorts of memory material.

The material chosen by Ebbinghaus for his experiments consisted of about 2,300 nonsense syllables (33, p. 30). Those were preferred to words on account of their relative simplicity. But even meaningless syllables are complex when compared to simple sense impressions, and Ebbinghaus remarks that something still more simple would be desirable, for in the learning of a nonsense syllable there are involved the senses of sight and hearing, together with the muscular sense in respect to the hand and the vocal organs. Wolfe criticises Ebbinghaus still further in this respect, and chooses for his own researches the simplest material of which he can think, namely, the delicate changes of pitch.

Oddly enough, this criticism which Wolfe raised against Ebbinghaus has not retained its force. The material used by the latter is still largely employed. Both of these researches have served as prototypes for all that has since been done. Both Ebbinghaus and Wolfe start out with the purpose of investigating the general laws of memory. Although Ebbinghaus expressly mentions the character of the material to be remembered as a condition of recollection, he and Wolfe both tend to treat memory as a function which operates according to formal laws independent of content to be remembered.

If this presupposition were valid the material best adapted to this line of the work would no doubt be that which is as simple as possible. But later researches show that the presupposition is not true. The accuracy of recollection is largely conditioned by the character of the content to be remembered. Thus, while the memory for words, pitch, space, etc., falls off rapidly in respect to accuracy as the time interval increases, memory for time itself, as far as it has been investigated, shows almost no diminution of accuracy as the time interval increases (Cf. 58). It is, moreover, probable that the memory for certain contents exhibits peculiar phenomena not to be noticed elsewhere. There is no positive reason for believing that Wolfe's formula for expressing the relation of time to the accuracy of memory is necessarily true for any content other than used in his experiments. From the standpoint of the experimenter there are as many different memories to be investigated as there are peculiar contents to be

remembered. The general problem of memory, as it is now conceived, is that of tracing the transformations which take place in each content as it passes through time. The researches of Ebbinghaus are still significant as throwing light on conceptual memory, and Wolfe can claim no more than a corresponding value for his experiments. Thus the question of the relative worth of the different materials, raised by Ebbinghaus and Wolfe, is seen to be without significance.

In all experiments on memory it is necessary that the subject display a certain amount of inaccuracy. This inaccuracy is obtained by making the material of the experiment difficult to remember. Now, two means have been employed to secure this, and they differ according to the nature of the material. Where the content to be remembered is complex, that is, where it is mediately remembered, it is rendered difficult of retention by making it large. Thus Ebbinghaus usually employed about fifteen nonsense syllables as the material for a single experiment. All of these he could, of course, not hold in mind after but one reading.

In the case of experiments on memory for a simple content, that is, where the object is recollected immediately, it is not only necessary to make the material difficult of retention, but it is also necessary to exclude any possible classification of it, for there is in general no choice as to the way in which a thing is remembered. If possible, it is grasped and held conceptionally. Moreover, on account of the extreme fineness of language and the high ability in the formation of new class ideas on the part of the subject, it is not an easy matter to exclude the classification of the material and thus mediate memory. But this exclusion is accomplished and the desired difficulty of retention obtained by using the just discernible shadings of sensation as the material for these experiments. For the threshold values of sense impressions are, at least at first, incapable of being classified and also extremely difficult of retention.

The following is a list of some of the materials which have been used in experiments on memory.

Simple.

Intensity of Light (49).
 Intensity of Sound (48).
 Pitch of Sound (85).
 Localization through Touch (51).
 Space Relations through Touch (76).
 Pressure (76).
 Muscular Sense (Weight) (76).
 Active Movements (55).
 Odor (48).
 Geometrical Figures through Vision (1).
 Time (58).

Complex.

Sentences (13).
 Words (15).
 Syllables (33).
 Letters (27).
 Numbers (30).
 Concrete Objects (46).

THE PROBLEMS.

In order that a certain object be remembered it is necessary, first, that it be experienced, and, second, that some image of it be retained after it has gone. Furthermore, the conditions which govern the chances that a certain object be remembered depend, first, upon the depth and clearness of the impression which that object made on me in my experience of it, and, second, upon the transformation which my image undergoes in the temporal flow. In general we may say that my memory of a thing depends upon the way in which it was received into consciousness and the way in which it is retained. Other things being equal, that object will be best remembered which made the deepest impression on me—which was most thoroughly perceived or apperceived; other things being equal, that object will be best remembered whose image undergoes the least transformation in time. Thus, to the experimenter there are in general but two great memory problems. The first of these is that of dis-

covering the relation of the character of the reception of an object into consciousness to the accuracy of recollection; the second is that of ascertaining the relation of the transformation of the memory image to the same.

I. The reception of the object into consciousness.

There has never been any attempt made to determine directly the depth of the impression which a certain object under certain conditions makes on consciousness. The reason of this lies in the fact that it is impossible to measure directly such a factor. However, it has always been known that the accuracy of our memory of a thing depends upon this term. Moreover, there have been many attempts to measure it. But in these attempts the unit of measurement, instead of being directly that of the depth of the impression or the thoroughness of its association, is the transformation of the memory image in time. The presupposition which underlies all of the experiments on the conditions of the reception of the object as affecting the accuracy of recollection is that there are but two general conditions of the accuracy of recollection. These, as just stated, are the character of the reception of the object and the transformation of its image in time. Now, if this be true and if we can perform an experiment in which the only variable term is that of the conditions governing the reception of the object, we shall be able to measure the depth of that reception in terms of the transformation. Suppose, for instance, that we desire to experiment on the effect of the repetition of an experience on the depth of the impression which that experience makes on us, and thus on the accuracy of our recollection of it, we may arrange our experiments as follows: Let our subject be given an object, say a series of nonsense syllables. Let him repeat them twice, and after ten minutes require him to reproduce them. Then let him repeat an equivalent series five times, and after the lapse of an equivalent period again require him to reproduce. The time interval and other conditions being constant while the number of repetitions is variable, the relative number of errors in the reproduction will serve as adequate terms for the measurement of the relation of the depth of the impression made on the subject by two repetitions to that made by five. That is, we measure the depth of the

impression made by a certain experience in terms of the transformation of the image thereof, for evidently the errors made by the subject in his attempt to reproduce the experience are due to changes in his memory image of that experience. That is, other things being equal, the memory image of an object which has made but a slight impression will be sooner dissolved than that of an image which has made a deep impression.

Now, in the text-books on psychology there are put down at least two factors governing the reception of an object into consciousness which condition the accuracy of recollection. These are attention and repetition. But according to the results of the experimental investigation of this subject these do not complete the list. For it has been shown experimentally that in the case of repetition the rhythm governing the repetition also conditions the probability of the experience repeated being remembered. Moreover, the general character of the object to be remembered has been shown to condition the depth of the impression made by it, and thus also of its chances of being remembered.

(a) Attention and repetition.¹

Common experience teaches and the text-books state that these two factors condition the depth of thoroughness of the impression which an object makes on us, and thus condition the memory of it. Experimental research on this subject has done little more than confirm what was already known, which, however, is not to say that it is, therefore, of no value. Data of considerable future worth have been collected, and from them we have already attained a somewhat more definite conception of the enormous rôle which these two phenomena play in our memory. Indeed, it would be almost possible to state the matter mathematically were that of any immediate psychological significance.

(b) Rhythm and the general character of the object.

These two factors are not usually put down in the text-books as conditions of memory. Indeed, it is one of the peculiar achievements of the experimental work on this subject to have

¹ See the researches of Daniels (30), Smith (72) and Bourdon (21) for attention, and those of Ebbinghaus (33), Smith (71) and Hawkens (39) for repetition.

discovered the former and to have developed the nature and importance of the latter.

It was Ebbinghaus who first brought out the effect of rhythm on memory. Afterwards Müller and Schumann (53) discovered that in repeating a series of nonsense syllables there was an almost irresistible tendency to break the series up rhythmically into sections, and that this so far conditioned memory that syllables belonging to the same metrical whole tended to be held together.¹ Thus rhythm was found to condition the reception of the object into consciousness, but in regard rather to its apprehension than to its perception. Its effect has been tested only in respect to memory for complex contents where the material is easily associated. If possible, it would be an extremely interesting problem to examine the relation of rhythm to memory for simple contents.

Bigham and Münsterberg (6, 56), Hawkens (39), Kirkpatrick (46), Smith (70), Cohn (27), Whitehead (84), Tschisch (76) and others have examined the effect of the character of the object to be remembered on the accuracy of our recollection of it.² The particular results of these researches are too varied and often too contradictory to be stated here. Their especial value is largely pedagogical, the chief point of interest being the discovery of the great importance of the muscular sensations (*i. e.*, motor terms) in our memories. This, again, is one of the places in which experimental psychology is justified of its task.

In general we may say that the reception which an object gets into consciousness depends very largely upon the sort of object it is and upon the sense by which it is perceived.

The study of the conditions which govern the depth and thoroughness of the reception which an object gets into con-

¹ See also Cohn (26, 27).

² By the term general character of the object I do not merely refer to differences of character which are objectively recognizable, such as the difference between a strain of music and a nonsense syllable, but also to differences which are due to the sense by means of which the object is received into consciousness. On the ground of this I would speak of the logically same nonsense syllable as forming four different possible psychological objects according to whether it is read, heard, spoken or written.

sciousness needs overhauling. Much is lacking from the standpoint of the experimenter and very much more from the standpoint of the analyst. An example of this is the lack of distinction between the attention and the character of the object as conditions of memory. An attempt should be made to analyze these conditions into their lowest terms.

Almost all of the work on this subject up to the present has been done on complex material. It seems to me that it would be very profitable to extend the former experiments so as to cover the problems of memory for simple material. For instance, as far as I know, there has never been an attempt made to determine the effect of repetition on immediate memory. This is also true of rhythm and attention.

II. The transformation of the memory image in time.

The laws which govern the retention of an experience are evidently different from those which govern its reception. An object which has once been fully experienced, but is now for the time forgotten, will come up again in the future, bearing the marks of the unconscious processes which determine its transformation while in retention. Now, experimental psychology has succeeded in doing little but describe in part these marks. The processes themselves have not been investigated—the conditions of the transformations have not been experimented upon. However, something has been done in the way of determining the nature of the transformations themselves.

If we omit from consideration the relations among ideas, we may say that the memory image of an object in consciousness may differ from that object itself in three ways: It may be more or less distinct, it may be greater or smaller, or it may be of another quality. The forces working upon the memory of a thing to dissolve it may affect it as to distinctness, quantity or quality.

The method of determining the transformation which the image undergoes in time is just the opposite of that of determining the effect of the conditions of the reception of the object. In the latter case the forces operating upon the image in time were kept constant, while the conditions of the reception of the object were varied. Now the conditions of the reception must

be kept constant, while the time interval (*i. e.*, the time between the moment of the experience itself and the moment of recollection) must be varied. That is, in order to discover the changes undergone by the memory impression we must always start out with exactly the same experience to be remembered.

It must, of course, be understood that the forces which cause our memory of a thing to become inaccurate are unconscious, and that the object on which they operate is always unconscious. The memory image is the conscious factor which corresponds to the latter term.

(*a*) The fading of the image in time.

The growing indistinctness of the memory image in time is the most evident of these three expressions of the forces which may attack the memory impression, and the only one which has attained any degree of recognition. In the handbooks it is generally spoken of as the effect of time on memory. The description of the stages in the fading of the memory images of different objects has been the theme of most of the experimental work on memory, and almost all of the treatises put down in the bibliography contain something on the subject, while many of them are devoted entirely to it.

As far as is now known, our memory of all objects is subject to fading. To this, however, there is one surprising exception. Paneth (58) found that for time intervals not exceeding five minutes, which were the only ones examined by him, the memory image for time intervals fades so little, if it fades at all, that it was impossible to determine by means of the methods he employed that it does fade. In all other cases, as far as is now known, the growth of indistinctness in the image sets in immediately. Indeed, there is evidence for the belief that the memory for several sorts of material is more accurate at an interval of two or three seconds than at any interval of one.¹ Perhaps, as Lewy suggests, this is due only to the necessary haste in judgment on the part of the subjects experimented upon. At any rate, the discovery is an important one and should be held in mind in respect to experiments on other subjects, es-

¹ See Wolfe (85), Lewy (51) and Bigham (6).

pecially in respect to researches which involve the comparison of non-spatial stimuli.¹

If we leave this phenomenon aside as one which perhaps is to be accounted for on other grounds than those which properly govern the transformation of the image itself, we should naturally expect, from all we know introspectively concerning the course of our memories of the different objects, that the rate of fading of the memory image is a mathematical function of the time interval. Such in general it has been found to be.² However, Wolfe (85), Baldwin (1), Bigham (6), Lewy (51) and others have found certain wide variations in the memory curve in its relation to time, which suggest a decided periodicity in the memory for certain contents. Thus Wolfe, who was the first to investigate such disturbances, discovered that in all the subjects examined by him there is a point in the temporal curve lying between fifteen and twenty-five seconds at which the memory for pitch is more accurate than at a point five seconds before.

There are in some cases forces at work on the memory image which cause decided aberrations from what would naturally be supposed would be the curve for the fading of the same. What these forces are no one has yet discovered, and the problem seems to be a difficult one. In this connection it must be remembered—and the point is one which almost without exception has been overlooked—that if there be such a thing as quantitative or qualitative change in the memory image such change would affect the accuracy of memory. The matter will be referred to again, but I may here suggest that, as far as I know, there has never been an attempt made to discover the relations of such possible transformations in the image to the general

¹ In most of the experiments attempting to discover the relation of Weber's law to sound the two sounds to be compared follow each other at an interval of a second or less.

² The formula of Ebbinghaus expressing the relation of the accuracy of memory to time is as follows:

$$\frac{\text{that which is remembered}}{\text{that which is forgotten}} = \frac{k}{(\log t)^c} \text{ and that of Wolfe:}$$

$$\frac{\text{that which is remembered}}{\text{that which is forgotten}} = \frac{k}{\log t} + c. \text{ In both of these formulæ } k \text{ and } c \text{ are constants.}$$

curve for the accuracy of memory. Until the possible effects of such changes are abstracted from this curve, we may never be sure that the curve for the increasing inaccuracy of memory is the curve for the fading of the image.

(b) The quantitative change in the memory image.

By the term quantitative change I mean those changes in our memory of a thing which cause the image of the object remembered to seem greater or less in respect to duration, extent or intensity than the object itself seemed to be. That is, the transformation of the image would be such that if an object equal to the object remembered be presented to consciousness it will be judged unequal to it.

Tschisch (76), Lehmann (48), Merkel (*Philos. Studien* IV., 137), and Starke (*Philos. Studien*, III., 270) have discovered that when two sounds objectively equal in intensity are given, one after the other, the second is judged to be the louder.

Leuba, in his admirable experiments on the classification of artificial stars of different intensities (50), has shown that in case a normal light stimulus of a certain intensity is held in memory the comparative stimulus, if its intensity be small, is judged to be greater than it actually is, and if its intensity be great is judged to be less than it actually is.¹

Baldwin and his co-workers (1, 82) found that squares of certain sizes held in memory are judged to be greater than the objects of which they are the memory images.

Moreover, I may be pardoned if I state that in experiments on the memory for pressure performed in the Princeton laboratory last winter I found that if two successive pressures of the same objective intensity be given one after the other the second will be judged to be the less.²

¹ The effects of Weber's law are, of course, eliminated.

² These experiments, the results of which will, I hope, be published later, extend only to cases of about 25 gm. at intervals of about three seconds.

In this connection see also T. Bolton (18, page 304).

This account of the work on this subject would be larger were it not for the fact that, for reasons stated above, researches made according to the method of reproduction are without significance in this connection. Thus the investigations of Binet and Henri (14) and Jastrow (45), which otherwise might point to a quantitative change in the memory image, have to be ruled out, because the method used prohibits any such deduction.

In the case of the intensity of sound we find a decrease in the intensity of the memory image; in the case of light either a decrease or increase in the intensity of the image according to the intensity of the object itself, and in the case of squares and of pressure a quantitative increase in the image.

Most of the work here represented consists of researches on small or unknown intervals, but it is amply sufficient to prove the existence of this remarkable phenomenon of the quantitative change in the memory image.

As yet there exists no entirely satisfactory treatise on this subject. Indeed, as far as I know, there is not a single experimenter on memory who has quoted or used the results of his collaborators in this particular line. In order that the researches on the quantitative change of the memory for any particular content be adequate, it would be necessary to determine first the relation of such transformation to the quantitative aspect of the object remembered and to the time interval. No one treatise has yet examined both of these problems.

In respect to the relation of the quantitative change in the image to the quantitative aspect of the object to be remembered we have the most interesting work of Leuba, and in respect to the relation of the same to the time interval the researches of Lehmann and Baldwin and his colleagues. The result of Leuba's investigations has already been stated. Lehmann, in his work on sound, found that the quantitative change noticed in the memory image increases with the time interval. Baldwin and his colleagues in their work on squares came to the same conclusion. However, their results are not altogether convincing.

There have been three attempted explanations of this phenomenon.

The first of these is offered by Starke, Lehmann and Tschisch. These men noticed the diminution in the intensity of the memory of sounds. This they explain by the assumption that the memory of an experience is in general less intense than the experience itself. This broad explanation seems to be rendered worthless by the experiments of Leuba and myself, in which an increase in the intensity of the memory image as compared to the original experience was noted.

The second explanation is offered by Professor Warren (82), who attempts to relate the phenomenon of the increase of the image in memory for squares to the operations of Weber's Law. In my opinion this theory violates the facts themselves.

Finally Leuba offers the hypothesis that there is formed in consciousness a sort of unitary typical representative for each class of experiences, which is a residuum left over from all the perceptions we have had. Toward this middle and typical term our memory images are drawn. Thus our memories of very intense perceptions tend to become less intense, and *vice versa*.

This, it seems to me, is the most rational of all the explanations and is certainly borne out by the facts of Leuba's own experiments. But whether it will hold in regard to the memory of other contents than the one investigated by him I do not know. The problem is certainly one of great importance and interest.

(c) The qualitative change of the image.

As far as I know, there is not a single work on this subject. I myself have gone over Wolfe's very complete tables and have found in them data which enabled me to draw the curves of qualitative change. This curve for each experimentee exhibited certain variations from the curve for the fading of the image, but I was unable to make the particular curves agree or to obtain any satisfactory results.

If there be such a thing as the quantitative or qualitative change of the memory image in time, such changes will affect the accuracy of recollection just as much as the fading of the image. The presupposition of the handbooks and of practically all of the experimental investigation of memory is that the curve of the increase of the inaccuracy of recollection in time corresponds to the curve of the fading of the memory image. What the experimental investigation of memory most needs at this juncture is thoroughgoing work on the transformation in time of the memory image of some simple content, which would show the curve of the fading of the image, that of the quantitative change and that of the qualitative change, and find relations of these curves to each other. Perhaps were such a work consummated some new light would be thrown on the phenomenon of the periodic changes in the memory image.

III. Certain conditions which affect both the reception and retention of the object to be remembered.

Up to this point we have treated of the reception of the object into consciousness and the transformation of the image of the same in time. There are several individual factors which condition both and which have been investigated experimentally. These are the age,¹ sex,² race³ and health⁴ of the individual who receives and retains.

The work on these subjects has been of considerable value and many details of psychological and pedagogical significance have resulted from it. It, however, has developed no startling results except perhaps the one which seems to show that girls have better memories than boys and colored men better than white.

As was to be expected, the general accuracy of memory in school children increases with age.

The work on the effect of race and pathologic conditions on memory has been extremely meagre.

It has been my purpose in this paper to describe the chief problems belonging peculiarly to the experimental study of memory and to examine the methods by which that study is to be pursued. I have thus carefully omitted from consideration all work on cognate subjects, such as association of the mental span.

Following is a list of works on the experimental treatment of memory.

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³ See Stetson (73).

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