LABORATORY MANUAL IN THE PSYCHOLOGY OF LEARNING

WILLIAM HENRY PYLE.

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BY
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To

EDWARD BRADFORD TITCHENER,

my teacher and friend, whose texts and manuals have served as standards and guides in the psychological laboratories of the world for a quarter of a century.

PREFACE

All our lives we are learning. The main concern of the early part of life is learning. The public school has as its purpose the direction and guidance of the learning of children. All people—teachers and parents in particular—should know as much as possible about the nature of the learning process and the laws of learning.

If it is worth while to have laboratory courses in physics, chemistry, and the biological sciences, it must also be worth while to have laboratory courses in the *psychology of learning.*

Only to a limited extent can any science be learned from books and lectures. Sciences dealing with human nature have been too vague and general both as to facts and their application. *They must get closer to the facts. They must rely upon the laboratory.* No amount of book-study about human nature can take the place of even a few carefully devised and executed experiments.

This manual is published in the hope of furthering and facilitating experiments in educational psychology, and is the outcome of fourteen years of experimentation.

I wish to acknowledge the assistance of Mr. E. L. Schott, Mr. S. R. Braden, and Miss Elisabeth Grinstead in the critical reading of proof, and the constant assistance of my wife at every stage in the preparation of this *Manual.*

W. H. P.

University of Missouri,
October 29, 1923.

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CHAPTER I

EXPERIMENTATION

NATURE, AIMS, AND METHODS.

An Experiment.—The method of all science is observation. Our contact with the world is through sensation. The scientist gets all his information through his senses; he has no additional means or method. His eyes, his ears, his other sense organs are no better than those of other people. The experiment is merely a refinement on ordinary observation; it is, we say, *observation under control.* In an experimental science, we do not wait to observe phenomena as they happen in the ordinary course of events. We set about to *make the events happen.* We not only bring about the particular phenomena which we wish to observe, but we bring them about under certain set conditions; we throw certain safeguards about the events; we introduce certain conditions, and vary these conditions to suit our purposes. We aid observation by using mechanical devices which insure greater accuracy. For example, we can use accurate chronometers to measure the length of time in the happening of events; we can use accurate means of measuring distance; we can use magnifiers to make objects appear larger.

In a psychological experiment in human psychology, our purpose is to discover the characteristics of some aspect of human behavior. We wish, for example, to learn the facts involved in memory. First of all, we may want to know how retention differs for different kinds of material. We select our material, such as nonsense syllables, meaningful words, objects, pictures. We must then determine our method. Shall we present the material serially, or all the units at once in a group? In some cases, we must

decide whether we shall present the material to the sense of sight or the sense of sound. We have also to determine how we shall measure retention. There are various methods, such as *recognition*, *reproduction*, and *re-learning*. After we have determined upon our material, and method, and have the results, we have to find an adequate method of treating the results. All these and many other points of procedure have to be discovered or decided upon, and in very few cases can our decision be made upon *a priori* grounds. Every step in our procedure must be scientifically determined or justified. In a psychological experiment, there are so many sources of error, so many ways of going wrong, so much insight and experience required in planning an experiment and in evaluating and interpreting the results, that the psychologist must have many years of experience before the results of his experiments can command any respect.

One circumstance makes psychological experimentation more difficult, perhaps, than that of any other science. I refer to the fact that we experiment with living beings; in human psychology, with human beings. In the quantitative aspects of our experimentation, we have to measure some aspect of human behavior, and in the process of our experiment, we have to control human behavior. It is difficult, in any case, to know the extent of our control. For example, if we are trying to measure individual differences in the case of a definite aspect of memory, if our results are to have any validity, the measure of each subject must be made under the same conditions. If one subject tries with all his might, another, only half-heartedly, and still another, tries not at all, we can make no comparison of the results. In all the experiments which follow in this course, careful consideration must always be made of the condition and attitude of the subjects. Students nearly always come to an experiment with some bias or other; their previous experience favors them or hinders them. In an experiment in habit-formation involving some form of hand movement, it will nearly always be

the case with adults that some have had experience which gives them an advantage over others. Considerable practice in piano playing gives a measurable advantage in certain experiments involving hand or finger movement. Often the subject is not aware of the advantage or interference that comes from past experience, but sometimes there is a definite bias in attitude, making the subject like or dislike the experiment. Account must always be taken of this factor. There is probably no source of error more common in psychological experimentation, or greater, than that of attitude on the part of the subject. Sometimes, indeed, the attitude of the experimenter himself is a source of error. No one has any right to perform an experiment in a psychological laboratory unless he has that degree of impartiality that enables him to conduct his experiment with absolute fairness and give the true and proper evaluation to his results whatever they may be, and wherever they may lead. The psychologist must have but one aim, namely, *the discovery of truth.* He should be afraid of but one thing, *of being the victim of error.*

Experimental Procedure and Records.—We shall now discuss the systematic procedure in the performance of an experiment, and the manner and method of keeping the results. If an experiment is worth performing at all, it should be performed with the greatest possible care. The data obtained from the experiment should be carefully kept, studied and compared from various points of view, graphically represented, and finally interpreted and applied.

The Name of the Experiment.—First of all, an experiment should have a name by which we are to know it and designate it in our treatment and discussion. An experiment may be, for example, a memory experiment, an attention experiment, or an experiment in individual differences.

The Object of the Experiment.—Under this head, we should set forth the exact object of our experiment. This should be stated in terms, definite and precise, so that any one reading the results of our work would know at once exactly what we are trying to discover or illustrate.

Sometimes, of course, we can not set forth the full nature of our aim, for we may not know it. For example, our aim may be to determine the type of learning curve that will be given in a certain kind of practice. We do not know what the type will be, it is our purpose to find out. Or we may wish to discover the factors involved in a certain trial-and-error learning experiment. We have no notion of what they are; we are simply going to do the learning and see what we can discover about the learning.

Method and Material.—In a psychological experiment we always use certain material and a certain method. A student's note book should contain a clear statement of the means used to solve the problem which the experiment undertakes to solve. The kind of material and apparatus used should be named and described. If the material is some kind of printed form, a copy of it should ordinarily be included in the recorded notes of the experiment. The notes should include careful drawings of the apparatus used in the experiment.

The procedure should be described in detail. The method used in overcoming the various difficulties, the precautions taken to keep the results free from errors should be described. If the experiment is one in which the time factor is an element, the method of keeping the time should be stated. The method of scoring should be stated and explained.

The Results.—The student's note book should contain a statement of the raw data obtained in the experiment. By 'raw data' is meant the scores as actually recorded while the experiment is being performed. A careful transcript of the original records should be made to the note book, and this transcript should be checked back to the original records. There is no use to work with data unless we are absolutely sure that the data are the *actual data originally obtained.* When the results of an experiment are being studied and compared, it nearly always happens that one needs to refer back to the original records. Therefore, not only should a transcript of the original records be made and

checked, but the original results of the work should be carefully preserved until all possibility of their being needed has passed. Questions of error often arise which can be settled only by reference to the original records. For this reason, the original work should be preserved till all study of the results of the experiment, all calculations and comparisons, have been finished.

After the raw data have been recorded and verified, they should be transmuted to a form suitable for study and comparison. The original records are usually in terms of the amount of work done in a given time, or the amount of time required to do a given amount of work. In the one case, the amount of work is constant and the time is variable; in the other, the time is constant and the amount of work is variable. In a learning experiment in which we have recorded the varying times required to do a given constant amount of work, the data will give a falling curve. On the other hand if we have recorded the varying amounts of work done in a constant given time, the data will give a rising curve. If we wish to compare such different kinds of curves, the comparison is difficult. It is better to change the data and make all the curves of the same type if comparisons are to be made. In this manual, in learning experiments, the scores are transformed, when necessary, into the amount of work done per unit of time. The quickest and most accurate way in which to make this transformation is by the use of tables. We find in the tables the reciprocals of the time records, the latter being expressed in terms of seconds or minutes. We record some multiple of these reciprocals, *i.e.*, we omit the decimal point. The numbers so obtained represent the varying amounts of work done in successive equal amounts of time.

Tabular Statement.—The form in which data are recorded should depend upon the use to be made of them. In the case of learning curves, we usually wish to study individual curves, compare different curves, and study the curve obtained by combining the scores of all the subjects. In a learning experiment, the table of records should con-

tain in concise systematic form the complete records of each subject in terms of amount of work per unit of time. From this table all learning curves can be constructed, and from the averages can be constructed the learning curve of the group.

If we wish to have a table of results that will enable us most easily to compare the different subjects in a learning experiment, and especially to compare the relative position of subjects at different stages of practice, we must prepare a table in the following manner: from the table prepared as described in the preceding paragraph, we find the average group performance for each practice period. By means of a slide rule, we transform all the scores of each practice to a group average of 50. This number is taken because it is the most convenient for the use of the slide rule. The scores can usually be represented as falling between 10 and 100, the limit of the rule. The transformation is accomplished by finding on the slide the number corresponding to the actual average of the practice period records for the group. We move the slide so as to place this number over the number 5 on the rule. This 5 we call 50, and all the other numbers accordingly. Having set the slide, we proceed to find on the slide the numbers corresponding to the scores of the several subjects. The numbers on the rule corresponding are to be taken for the new scores on the group average of 50.

Graphical Representations.—The results of learning experiments can nearly always be shown to advantage graphically. The graphs most useful are learning curves and frequency surfaces. The learning curve is a means of showing graphically the progress of learning in the case of a subject or a group of subjects. The frequency surface is a means of showing the distribution of a number of subjects with reference to some characteristic. It usually shows the number of cases in a group that possess the characteristic in question in the varying amounts.

In the case of learning curves, each student should show in his note book, a curve representing the group averages,

his own curve and such other typical curves as the instructor designates. It is often well to show the best learner, the poorest learner, and the most variable learner. System and uniformity should prevail throughout the note book. It is well, therefore, to put the group curve in red, and all individual curves in black. The black curves should be made in a way to distinguish them and should be properly labeled.

Study of Results.—A careful study of the data in all their different forms of representation should be made.

(*a*) *The Learning Curve.*—Each individual learning curve should be studied to determine its form, its course, and its peculiarities. We should try to answer such questions as the following: At what point in the curve is the rise most rapid? At what point is the rise least rapid? Does the curve ever fall? If so, where and why? Are there plateaus? If so, can they be explained? Can the individual differences and peculiarities be explained? Each student should especially compare in all respects his own curve with the curve representing the group, in order to discover his own peculiarities as a learner.

(*b*) *The Frequency Surfaces.*—The frequency surface shows the variability within the group. Comparison can be made of the variability of the same group at different stages of learning, and of the variability of different groups of learners. Sometimes the data make it possible to compare the variability of the sexes, races, or of people of the same sex or race at different ages. In order to make such comparisons, however, the frequency surfaces must be constructed from data which represent definite percentages of the central tendency. The data in the tables based on a group average of 50 should be used for constructing comparative frequency surfaces.

(*c*) *Correlations.*—From the data of the experiment, various relationships should be determined, relationships within the data of the experiment, and the relationships with the data of other experiments. For example, to compare initial standing in a learning experiment with final

standing, we find the correlation between the scores representing the first practice with the scores representing the last practice. In a similar way, we can find the relationship between any stage and any other stage, and between standing in one experiment with standing in another experiment.

Interpretation and Explanation.—Up to this point, our chief aim has been to discover the facts. Now comes the search for the meaning of the facts. What do the results of our experiment mean as a whole? How are we to explain all the facts within the experiment? If our experiment is a learning experiment, we must inquire into the causes which make the curve rise. Irregularities in the work of the same subject, and differences in the work of different subjects, must be explained. The explanation and interpretation of our experiment is the most important thing in the whole procedure. We discover something. What does this something mean? It is not a great deal of trouble to get facts, but it takes genius to interpret facts. The relative genius of the members of a class will be shown by the insight displayed in the interpretation of the facts discovered by means of the experiments.

In a careful study of the facts in an experiment, many problems will arise which can not be answered by the results of the experiment. Nearly every experiment raises more questions than it solves. The student in writing up his notes, after the facts have been stated and interpreted, should state the questions which the experiment raises but does not solve. These might be grouped together at the end of the notes under the heading, *Problems for further study*.

Application.—Finally, the student should call special attention to evident application of facts discovered in the experiment, to the work of training children, to teaching in any of its phases, or to any situation in life.

The following outline should be followed with such variations as the experiments warrant:

Experiment number
Name of experiment
Object
Method and material
The results
  raw data
  transformed data, tabular
  graphs
Study of the results
  learning curves
  other graphs
  correlations
Interpretation and explanation
Application
Unsolved problems raised by experiment.

CHAPTER II

THE MATHEMATICAL TREATMENT OF DATA

The Learning Curve.—A learning curve is a graphical representation of the course of progress in learning. It may represent the course of progress in a single individual or the progress of a group as a whole. The method of

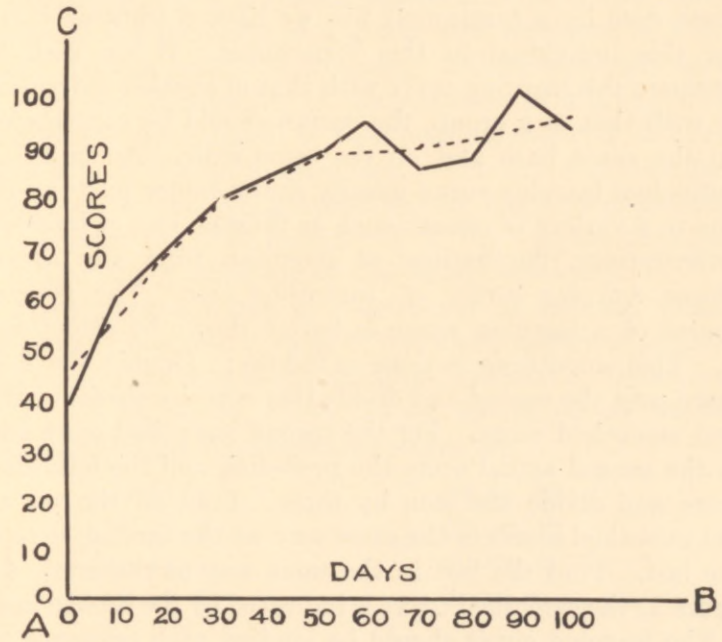

FIG. 1.—A learning curve. The solid line is constructed from the actual scores The dotted line is a smoothed curve.

constructing a learning curve is shown in figure 1. The data are from a ball-tossing experiment. The scores are the numbers of balls out of 200 that were tossed into the basket. An experiment consisted in tossing 25 balls. Eight series of 25 balls were tossed at one period on the same day. The curve represents the scores for every tenth day, and was

constructed as follows: On the horizontal axis AB, every tenth day is indicated. On the vertical axis AC, the scale for the scores is indicated. The score for the first day is 37. We make a heavy dot on the vertical axis at the proper place to indicate the score 37. The score for the tenth day is 60. On the vertical line of the cross section paper above 10 on the base, we place a heavy dot on the horizontal line extending to the right of 60 on the vertical axis. In a similar manner we proceed to place dots at the proper places to indicate the scores for the rest of the experiment, the score for every tenth day being taken. If now we join these dots by a continuous line we have a learning curve for this individual in this experiment. If we wish to compare this learning curve with that of another individual or with that of a group, the curves should be constructed on the same base and on the same scale. An ordinary individual learning curve usually shows minor fluctuations due to a variety of causes, such as fatigue, loss of interest, interruptions, fluctuations of attention from any cause, illness, varying power of incentives, etc. The general course of a learning curve is better shown by smoothing it. This smoothing is done as follows: Double the first score, add the second and divide this sum by three for the first smoothed score. For the second smoothed score add to the second actual score the preceding and the following score and divide the sum by three. Find all the rest of the smoothed scores in the same way as the second, except the last. Find the last in the same way as the first. In figure 1, the smoothed curve is indicated by the broken line.

The learning curve should be studied with reference to the following characteristics: (1) Its general form, the form of the curve as a whole. Does it show a very rapid or a very slow or a medium increase in efficiency? Is its general form convex, concave or straight? (2) Where is the steepest rise of the curve? At what point does learning seem to be most rapid? What is the explanation of what is found to be the fact about the place of greatest improvement? In studying this question, it will be necessary to consider

the nature of the learning involved. Are many bonds involved or few? What is the nature of the bonds? Is the motor element great or small? (3) Are there plateaus? If so, where are they and what is their cause? (4) Does the curve ever actually fall? If it does, what is the explanation? After the curve is smoothed, are there still places where it falls? (5) Finally, one curve can be compared with others, particularly with the curve representing the group-average, with reference to all the various characteristics which learning curves show.

The Frequency Surface.—The frequency surface or curve of distribution is a graphical representation of the distribution of the members of a group with reference to some trait. In this book, the frequency surface is usually used to show the distribution of the members of a group with reference to some aspect of their learning capacity, or some other aspect of mental efficiency. The curve of distribution shows to the eye, graphically, the numbers of persons that possess the trait considered, in the varying amounts from the lowest efficiency to the highest efficiency.

A frequency surface is constructed as follows: Take the scores in column 2, table 1, find the numbers of persons who possess the trait in the amounts indicated by the scores, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69. The numbers for the respective scores are,

30–34, 1	50–54, 23
35–39, 2	55–59, 13
40–44, 6	60–64, 4
45–49, 31	Total cases, 80.

At points along the base line AB are placed the numbers representing the successive scores from the lowest to the highest. On the vertical line AC are placed the numbers representing the number of cases. We decide upon some definite scale. In figure 2, 2 mm. represent one person. To represent 1, 2, 6, 31, 23, 13, and 4 persons, we therefore take points that are respectively 2, 4, 12, 62, 46, 26, and 8 mm. from the base line. We place heavy dots on the cross-

section paper verticals that extend upward from the points on the base line where the successive scores are represented, at the places of the proper height to represent the respective numbers of persons. This proper height is found by referring to the vertical scale on the left, and following the horizontal to the right till we come to the proper vertical.

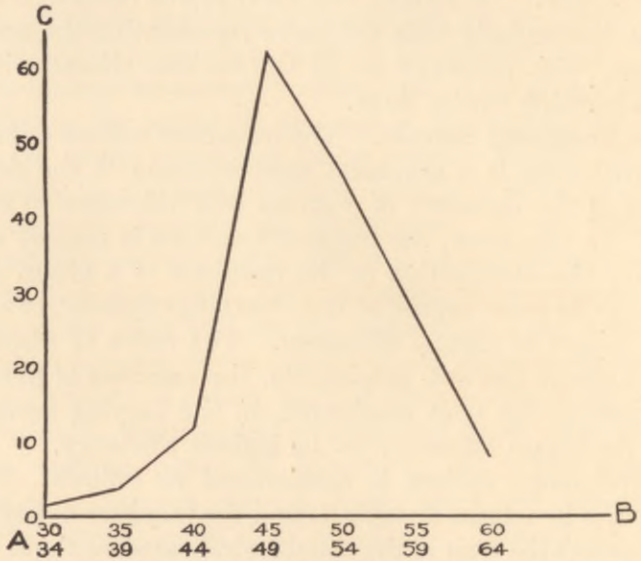

FIG. 2.—A curve of distribution. The scores are represented on the horizontal axis; the number of cases, on the vertical axis.

In figure 3 is shown another form of frequency surface. It is constructed in the same manner as figure 2, except that the scores are represented as distances on the base instead of as points. The number of cases for the different scores is therefore represented by the areas of the rectangles standing above the line on which the scores are represented. But since the bases of all the rectangles are the same, the distances of the various horizontal lines from the base represent the various numbers of cases just as the heights of the dots do in figure 2. Either form shows the facts clearly, but if we wish to show two distributions on the same base for comparison, the plan of figure 2 is the better, since it is less confusing when more than one curve is shown. It

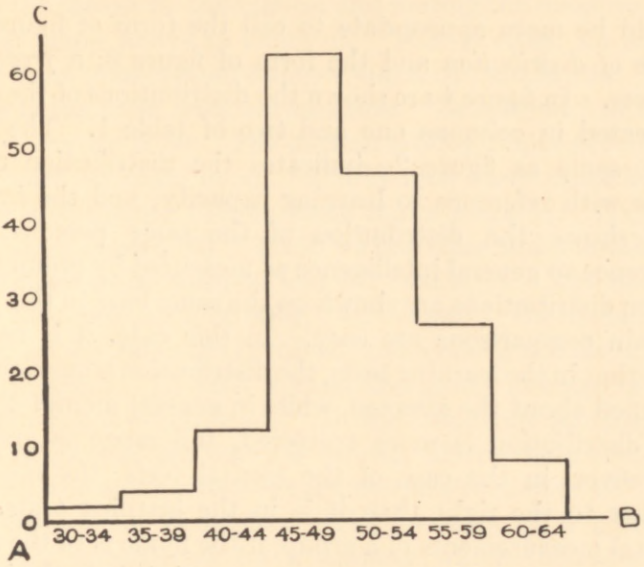

FIG. 3.—A frequency surface. The scores are represented on the horizontal axis, and the number of cases, on the vertical axis.

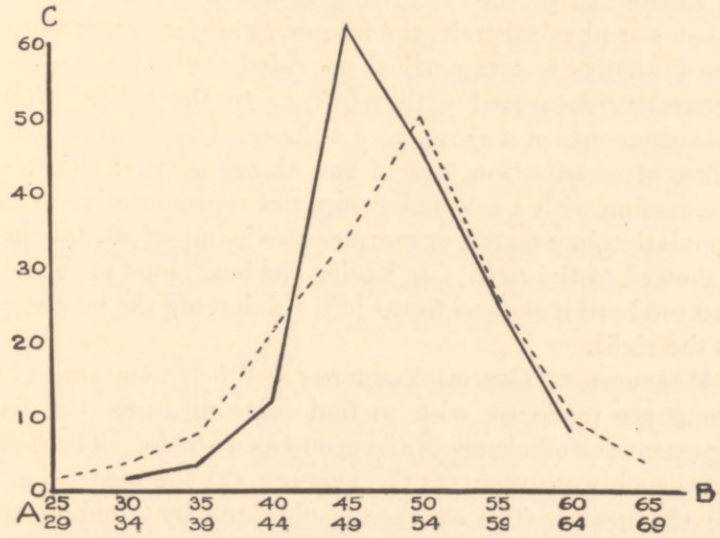

FIG. 4.—Two curves of distribution shown on the same base. The solid line represents learning capacity; and the broken line, general intelligence.

would be more appropriate to call the form of figure 2 a *curve of distribution* and the form of figure 3, a *frequency surface.* In figure 4 are shown the distributions of the cases indicated in columns one and two of table 1. The solid line—same as figure 2—indicates the distribution of 80 cases with reference to learning capacity, and the broken line shows the distribution of the same persons with reference to general intelligence as measured by group tests. When distributions are shown on the same base in this way, certain comparisons are easy. In this case, it is readily seen that in the learning tests, the distribution is more closely grouped about the average, while in general mental ability the distribution is more scattered, the range is greater. Moreover, in the case of the mental tests, the mode is farther to the right than it is in the learning tests. In mental measurements of a group, if the mode is to the right of the average, it indicates an easy test; if it is to the left of the average, it indicates a more difficult test. This statement is based on the assumption that we have measured a large number of unselected persons. For, if a large number of unselected persons is measured with reference to some mental or physical trait, the frequency surface representing the measures is symmetrical provided the individuals are accurately measured with reference to the trait. If the measurements of a group give a skewed (non-symmetrical) curve of distribution, one of two things is true; either we are dealing with a selected group, not representative of the population in general, or our measure is imperfect, too easy if skewed to the right, *i.e.*, having the long slope to the left, and too hard if skewed to the left, *i.e.*, having the long slope to the right.

Measures of Central Tendency.—When measures of a group are made we wish to find some measure that will represent the efficiency of the group as a whole. There are three such measures: (1) the average, (2) the median, and (3) the mode. The average is obtained by dividing the sum of the measures by the number of cases. The median is the middle measure and is found by ranking the scores

from the lowest to the highest and finding the measure that has as many above as below it. This is either an actual score or an interpolated number found by calculation. The mode is the most frequent measure. In column 1 of table 1, the average is 50. The median is 50⅓, found as follows: There are 80 cases in all. Thirty-nine cases make scores of 50 and under. Three cases make score 51. Half the number of cases is 40. To 50 we therefore add one-third of the difference between 50 and 51, that is, ⅓. The median is 50 plus one third, or 50⅓. In column 1, the mode is 54. When so few cases are involved, the mode is not an important measure. In such a case, the group average or the median is more significant. In the frequency surface, the highest point of the curve is directly above the mode. In figure 2, the mode is represented by the scores 45 to 49.

Measures of Variability.—The measure of a group is correctly represented by a number which indicates the central tendency and another which indicates the amount of variation from this central tendency. There are three such measures in common use, *the average deviation, the standard deviation, and the probable error.* The average deviation is found by dividing the sum of the individual deviations by the number of cases. The standard deviation or sigma, σ, is the square root of the average of the squares of the individual deviations. The probable error is the distance from the measure of central tendency, measured both above and below, that includes half of the cases. The probable error is, of course, in terms of the unit of measurement. It may be found empirically by ranking the cases, counting one-fourth the distance from each end of the serial array, and taking one-half the difference of these two values.

The various measures of variability may be illustrated from the scores shown in table 1, column 1. The deviations for column 1 are shown in column 3. The average deviation found by dividing the sum of these deviations by 80 is 6.01. The standard deviation, found by getting the square root of the average of the squares of the indivi-

dual deviations, $\sqrt{\frac{4642}{80}}$, is 7.62. The probable error can be found approximately in the following empirical manner: Arrange the scores in order from 28 to 68 and indicate the frequencies of each. Find the amount of deviation in each direction from the average 50 that includes forty cases. In doing this, it should be remembered that each score extends from the mid point each way. For example, 43 extends from 42½ to 43½. Three and one half units above and below the average include 29 cases. One unit more would add 12 cases. We need only 11 more to make 40 or half the cases. We therefore take $\frac{11}{12}$ or .92 of a unit. 3.5 + .92 = 4.42, P.E. Another method is to count off ¼ the cases from each end, and find one half the difference of the values thus found. Counting from the lower end to 45½ gives 19 cases. Score 46 has 5 cases, we therefore add .2 to 45½ which gives 45.7. Counting from the upper end to 54.5 gives 20 cases. $\frac{54.5 - 45.7}{2} = 4.4$, the P.E.

The scores and their frequencies are as follows:

28	1	41	2	54	7	67	1
29	0	42	2	55	1	68	1
30	0	43	4	56	2		
31	1	44	2	57	4		
32	0	45	1	58	6		
33	1	46	5	59	0		
34	0	47	4	60	2		
35	0	48	4	61	3		
36	1	49	3	62	0		
37	1	50	4	63	0		
38	2	51	3	64	0		
39	0	52	6	65	0		
40	1	53	5	66	0		

In a normal distribution, the P.E. is .6745 of the S.D. In our illustration, .6745 of 7.62 is 5.14, a P.E. somewhat larger than that found empirically.

Correlation.—The correlation formula enables us to determine the relationship that exists between two functions, or the relationship between the efficiencies of the

same function at different times. For example if we have measured the learning capacity in the members of a group of students for one type of learning, and then for another type of learning, and wish to know whether the students have the same rank in one type of learning that they do in the other, we resort to the correlation formula. Or if we wish to compare standing in learning capacity with retentiveness, we resort to the correlation formula.

In this book, we shall use the Pearson formula, $r = \frac{\Sigma XY}{n\sigma_1\sigma_2}$ in which r is the symbol for correlation,

Σ = summation,

X = individual deviation in one function,

Y = individual deviation in the other function,

n = the number of cases, σ_1, the standard deviation in one function and σ_2 the standard deviation in the other function.

The procedure in calculating a correlation is as follows:

1. Find the average of the group for each function.

2. Find the deviations of the members of the group above or below the average in each function. Write these deviations in vertical columns, with the proper signs + or −. Be careful to get the deviations properly paired. If you get a person's deviation in one function coupled with that of another person in the other function, the whole work will be wrong.

3. Find the two sigmas. This is done by finding the squares of the individual deviations in each function, adding the squares of the first array, finding the average of the squares and obtaining the square root of this average, similarly for the squares of the second array. Briefly, σ is the square root of the average of the squares of the individual deviations.

4. Complete the denominator by finding the product of the two sigmas and the number of cases.

5. The first step in finding the numerator is to multiply each individual's deviation in one function with the corresponding deviation in the other function. The multiplica-

tion must be done algebraically, that is, taking account of the signs of the deviations. It is best to set down the plus products in one column and the minus products in a separate column. This is for convenience in adding. The plus products are then added and the minus products added, and the difference found between the sums of the plus and minus products. This difference with the proper sign affixed is the numerator of the fraction in the Pearson formula.

6. The numerator is then divided by the denominator, care being taken to get the decimal point in the right place. The result of this division is the co-efficient of correlation. The correlation co-efficient may have any value between minus 1 and plus 1, the plus values indicating positive relation and the negative values indicating a negative relation. Plus one indicates a perfect positive relation and minus one indicates a perfect negative relation. Zero or near zero indicates no definite relationship. A correlation co-efficient should not be given much weight unless it is at least four or five times its probable error. The formula for the probable error of correlation is as follows:

$$\text{P.E.} = .6745\frac{1-(r)^2}{\sqrt{n}} \qquad \begin{array}{l} r = \text{correlation} \\ n = \text{number of cases} \end{array}$$

The whole procedure in calculating the Pearson coefficient is shown in table 1. The scores for a mental test are shown in column 1, the scores for the results of seven learning tests combined, in column 2. The individual deviations for the mental test are shown in column 3; for the learning tests, in column 4. The squares for the deviations are shown respectively in columns 5 and 6. The plus products are found in column 7; and the minus products, in column 8.

The sums of the squares and the sums of the plus and minus products are shown at the foot of columns 5, 6, 7, and 8.

$$\sigma_1 = \sqrt{\frac{4642}{80}} = 7.62. \sigma_2 = \sqrt{\frac{2387}{80}} = 5.46$$

The sum of the plus products = 2251 and the sum of the minus products = 258. The algebraic sum of these two numbers = 1993.

We therefore have $r = \frac{1993}{80 \times 7.62 \times 5.46} = .599.$

FIG. 5.—A graphical representation of the correlation between the functions represented in columns 1 and 2 of Table 1.

The $\text{P.E.} = .6745 \frac{1 - (.599)^2}{\sqrt{80}} = .049.$

It will be seen that the correlation is over ten times the P.E. The interpretation of these results is that there is a high positive relation between mental ability as measured

TABLE 1

(1) = scores in mental test, (2) = combined scores in 7 learning tests, (3) = deviations from average in column 1, (4) = deviations from average in column 2, (5) = squares of the deviations in column 3, (6) = the squares of the deviations in column 4, (7) = the plus products from the deviations in columns 3 and 4, (8) = the minus products from the deviations in columns 3 and 4.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
54	59	4	9	16	81	36	
58	48	8	− 2	64	4	....	16
57	59	7	9	49	81	63	
40	47	−10	− 3	100	9	30	
54	57	4	7	16	49	28	
50	39	0	−11	0	121	0	0
49	48	− 1	− 2	1	4	2	
36	43	−14	− 7	196	49	98	
46	49	− 4	− 1	16	1	4	
38	45	−12	− 5	144	25	60	
41	44	− 9	− 6	81	36	54	
45	45	− 5	− 5	25	25	25	
58	60	8	10	64	100	80	
60	50	10	0	100	0	0	0
60	59	10	9	100	81	90	
43	47	− 7	− 3	49	9	21	
47	51	− 3	1	9	1	....	3
58	55	8	5	64	25	40	
46	48	− 4	− 2	16	4	8	
52	46	2	− 4	4	16	....	8
47	52	− 3	2	9	4	....	6
48	46	− 2	− 4	4	16	8	
55	46	5	− 4	25	16	....	20
44	53	− 6	3	36	9	....	18
52	55	2	5	4	25	10	
61	61	11	11	121	121	121	
38	38	−12	−12	144	144	144	
43	46	− 7	− 4	49	16	28	
42	50	− 8	0	64	0	0	0
57	51	7	1	49	1	7	
58	48	8	− 2	64	4	....	16
53	48	3	− 2	9	4	....	6
50	56	0	6	0	36	0	0
67	49	17	− 1	289	1	....	17
50	49	0	− 1	0	1	0	0
47	45	− 3	− 5	9	25	15	
48	48	− 2	− 2	4	4	4	
52	54	2	4	4	16	8	
51	47	1	− 3	1	9		3
56	52	6	2	36	4	12	
31	43	−19	− 7	361	49	133	

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
52	43	2	− 7	4	49	....	14
33	32	−17	−18	289	324	306	
50	46	0	− 4	0	16	0	0
61	54	11	4	121	16	44	
61	63	11	13	121	169	143	
57	49	7	− 1	49	1	....	7
54	50	4	0	16	0	0	0
54	46	4	− 4	16	16	....	16
37	45	−13	− 5	169	25	65	
49	47	− 1	− 3	1	9	3	
53	52	3	2	9	4	6	
54	46	4	− 4	16	16	....	16
58	54	8	4	64	16	32	
43	45	− 7	− 5	49	25	35	
58	56	8	6	64	36	48	
57	50	7	0	49	0	0	0
43	43	− 7	− 7	49	49	49	
68	60	18	10	324	100	180	
46	58	− 4	8	16	64		32
56	50	6	0	36	0	0	0
44	47	− 6	− 3	36	9	18	
41	50	− 9	0	81	0	0	0
47	53	− 3	3	9	9	....	9
48	56	− 2	6	4	36	....	12
53	50	3	0	9	0	0	0
52	47	2	− 3	4	9	....	6
53	49	3	− 1	9	1	....	3
53	55	3	5	9	25	15	
54	53	4	3	16	9	12	
42	49	− 8	− 1	64	1	8	
46	55	− 4	5	16	25	....	20
51	52	1	2	1	4	2	
51	52	1	2	1	4	2	
46	51	− 4	1	16	1	....	4
48	48	− 2	− 2	4	4	4	
49	56	− 1	6	1	36	....	6
54	54	4	4	16	16	16	
52	51	2	1	4	1	2	
28	44	−22	− 6	484	36	132	
Sums....	..	....	....	4642	2387	2251	258
S.D.....	..	....	....	7.62	5.46		

by a group test and learning capacity as measured by seven different tests.

A correlation may be represented graphically, as shown in figure 5. The data are the scores in columns 1 and 2 of table 1. The correlation of these two columns, as we have seen, is .599. The graph is constructed as follows: We draw vertical and horizontal axes on the cross section paper. The vertical axis is the basis for representing

column 1; the horizontal axis is the basis for representing column 2. Scores above 50 are measured to the right of the vertical axis, and scores less than 50 are represented to the left. Second column scores above 50 are represented above the horizontal axis, and those below 50 are represented below the axis. For the first pair of scores we take a point 4 to the right and 9 up; for the second pair, 8 to the right and 2 below. The other points are located in a similar way.

Conversion of Scores.—In this book, for purposes of comparison, scores are reduced to a common group average of 50. This is accomplished as explained on page 14. A short example will suffice for illustration. Suppose we have the scores 30, 30, 40, 40, 50, 50, 60, 60, 70, 70, 80, 80, 90, 90. The average of the group is 60. We take the slide rule and place 60 of the slide over 50 of the rule, and read off the following new values: 25, 25, 33, 33, 42, 42, 50, 50, 58, 58, 67, 67, 75, 75. The values are read to the nearest whole number. It will be seen that the average is 50.

CHAPTER III

MOTOR LEARNING

TRIAL AND ERROR TYPE

Experiment I.—*Ball tossing.*

Object.—The object of this experiment is to discover the various characteristics of trial and error learning, and to note such individual differences as may appear.

Material.—The following apparatus is required: (*a*) A cloth bag suspended from a wire ring six inches in

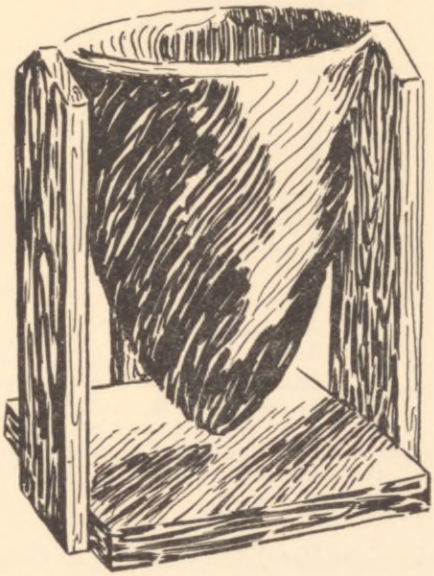

FIG. 6.—Cloth bag for ball-tossing experiment.

diameter, the ring being supported nine inches from the floor by three uprights fastened to a wooden base (figure 6); (*b*) fifty rubber balls $1\frac{5}{16}$ inch in diameter. Suitable cloth screens can be arranged to keep the balls from rolling over the floor.

Method.—A line is marked off on the floor twelve feet from the front of the wire ring supporting the basket. The fifty balls are placed in a container in convenient reach of the subject who stands with one toe touching the mark and the other toe either touching the mark or back of it, that is, neither toe must be within twelve feet of the basket. With everything ready for the experiment, the subject takes a handful of balls in his left hand, and trans-

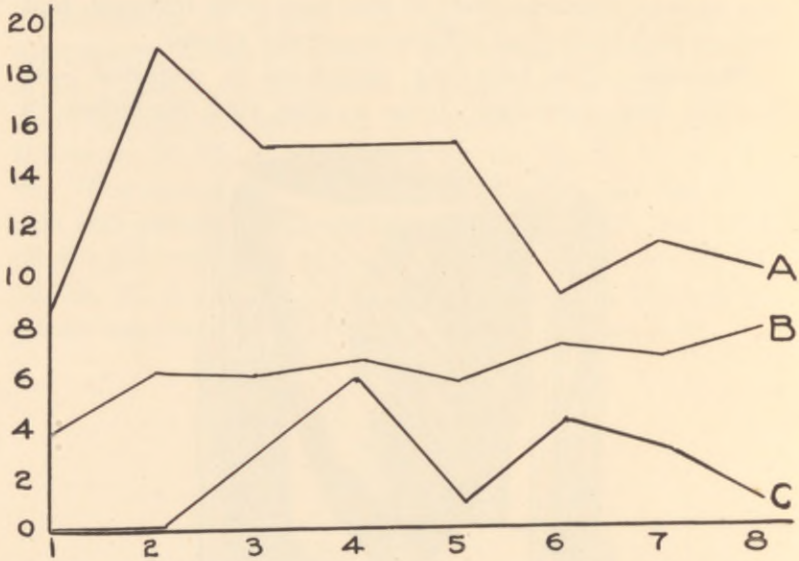

FIG. 7.—Learning curves for ball-tossing. A represents the best subject; C, the poorest; and B, the class average.

fers them to the right hand one at a time as they are pitched. The object is to pitch as many of the balls into the basket as possible. Fifty balls constitute a series. The score is the number of balls out of the fifty that enter and stay in the basket. Four series are pitched in succession on the first day, and four series on the second day, making eight series in all, 400 balls. The subject must try to discover how improvement comes about.

Results.—The actual scores of 24 subjects are shown in table 2. The scores transferred to a class average of 50 are shown in table 3. In figure 7 are shown the learning curves for the group average, for the person making the best total score and the one making the poorest total score.

An Extensive Experiment.—The experiment, the results of which are shown in tables 2 and 3, covered a period of only two days of about a half-hour each day. The experiment so performed can only serve to show the nature of

TABLE 2.—RESULTS OF THE BALL-TOSSING EXPERIMENT
The following results were obtained from 24 university students

Subject	First day scores					Second day scores				
	(1)	(2)	(3)	(4)	Sum	(1)	(2)	(3)	(4)	Sum
A	1	3	7	6	17	6	5	3	5	19
B	7	6	5	6	24	10	7	2	8	27
C	5	9	9	5	28	9	9	9	13	40
D	9	5	4	7	25	6	5	4	4	19
E	10	14	9	9	42	9	9	12	14	44
F	1	7	4	4	16	5	3	6	9	23
G	9	19	15	15	58	15	9	11	10	45
H	2	3	7	7	19	3	5	4	9	21
I	3	11	7	11	32	4	4	6	6	20
J	2	4	6	4	16	3	7	9	10	29
K	6	13	6	7	32	11	8	11	7	37
L	2	1	4	5	12	7	4	7	3	21
M	2	3	5	5	15	5	11	5	8	29
N	0	0	3	6	9	1	4	3	1	9
O	7	2	4	4	17	6	9	6	4	25
P	5	6	5	10	26	4	12	11	12	39
R	3	2	3	4	12	6	8	5	6	25
S	3	6	3	1	13	1	8	7	3	19
T	1	6	9	7	23	6	14	10	10	40
V	2	5	6	2	15	4	5	8	6	23
W	1	4	4	6	15	3	7	4	14	28
X	2	4	4	5	15	5	7	7	4	23
Y	9	8	8	14	39	10	4	11	11	36
Z	2	4	5	8	19	2	8	9	7	26
Averages.....	3.9	6	5.9	6.6	22.5	5.9	7.2	7.1	7.7	27.8

TABLE 3.—RESULTS OF THE BALL-TOSSING EXPERIMENT
Transformed to a group average of 50 for each series

Series	First day				Second day					
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	Av.	C.V.
Subject										
A	13	25	59	45	52	28	22	32	34.5	38
B	90	50	42	45	86	49	15	52	53.6	31.8
C	64	75	76	38	77	63	65	84	67.8	14.9
D	116	42	34	53	52	35	29	26	48.3	39
E	128	116	76	68	77	63	87	91	88.3	19.9
F	13	58	34	30	43	21	44	58	37.6	34.9
G	90	158	128	114	129	63	80	65	103.4	27.9
H	26	25	59	53	26	35	29	58	38.9	34.3
I	38	92	59	83	35	28	44	39	52.3	36.9
J	26	33	51	30	26	49	65	65	43.1	33
K	77	108	51	53	95	56	80	45	70.6	27
L	26	9	34	38	60	28	51	19	33.1	38
M	26	25	42	38	43	78	36	52	42.5	27
N	0	0	25	45	9	28	22	7	17.0	76
O	90	17	34	30	52	63	44	26	44.5	40.1
P	64	50	42	76	35	84	80	78	63.6	25
R	38	17	25	30	52	56	36	39	36.6	26.5
S	38	50	25	7	9	56	51	19	31.9	52.9
T	13	50	76	53	52	98	72	65	59.9	29.8
V	26	42	51	15	35	35	58	39	37.6	26.2
W	13	33	34	45	26	49	29	91	40.0	40.6
X	26	33	34	38	43	49	51	26	37.5	20.6
Y	116	67	68	106	86	28	80	72	77.9	24.5
Z	26	33	42	60	17	56	65	45	43.0	28.4

Av. C.V. (Co-efficient of variability) 33.1.

trial and error learning. The experiment requires such difficult co-ordination that many days are required to show much improvement. A week or two at least would be necessary to discover very many of the factors involved in improvement. The experiment as we have described and reported it may be considered, for the most part, merely illustrative of trial and error learning. If we are to make more of the experiment, we must continue for a much longer period of time. Under the author's direction, the

experiment was continued by one subject for a period of 100 days.* Two hundred balls were tossed each day for six days in the week. Sunday was taken for a rest day. The experiment covered a period of four months and involved the tossing of the balls at the basket twenty thousand times. The results of this experiment are given

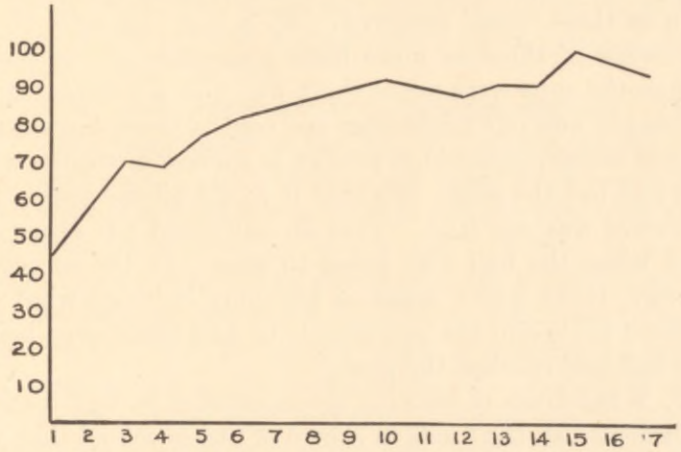

FIG. 8.—Learning curve for ball-tossing, from weekly averages for 100 days.

in table 4, and shown graphically in figure 8 which is constructed from the average weekly scores. The scores are the numbers of balls out of 200 that entered the basket each day.

TABLE 4.—BALL-TOSSING EXPERIMENT, 100 DAYS, 200 BALLS A DAY. Scores, number of balls out of 200 entering basket.

37, 38, 42, 45, 53, 51, 56, 55, 56, 60, 54, 65, 64, 65, 68, 69, 75,
79, 64, 70, 68, 67, 68, 74, 74, 76, 76, 76, 80, 79, 78, 81, 79, 82,
84, 85, 78, 84, 89, 85, 82, 88, 88, 87, 90, 88, 86, 86, 86, 89, 89,
90, 93, 92, 92, 90, 88, 88, 94, 96, 90, 91, 89, 92, 88, 88, 87, 90,
88, 86, 88, 87, 91, 89, 91, 89, 91, 91, 88, 88, 90, 89, 95, 93, 97,
98, 102, 98, 99, 102, 102, 102, 98, 91, 94, 89, 94, 94, 91, 95.

Interpretation and Discussion of Results.—(1) The most important part of this experiment is its qualitative aspect. The student should make a careful introspective study of

*The work was done by Mr. S. R. Braden.

the methods and means of improvement. To aid in this study, the following quotation is given from the notes of the subject who tossed the balls for 100 days: "The second week's practice began with a gain of three over any previous score. At the close of the second week, the scores showed that greater steadiness was being secured. Certain new experiences were noticeable. Often within a day's practice two or three 'runs' occurred. By a 'run' we refer to the throwing of three or more balls accurately in succession. When the runs were made there was now a constant questioning of how one might keep and control these movements. It was usually possible to predict in successful throws when the ball left the finger tips that it would hit the goal. The converse was not true. That is, one could not always be sure when the ball was going to miss. In the successful throws, there was a sense of harmony between what one wanted to do and the movements he had made even before the ball had reached the goal."

2. What kinds of learning are illustrated by ball-tossing? Enumerate all the kinds in school or out of school that you can think of.

3. After performing the ball-tossing experiment, what profitable advice could you give a person forming some similar useful habit in real life?

4. Study your tables and graphs and note all the facts which you can discover, facts concerning the learning itself and facts concerning individual differences. For such study it is best to put your data into the form of table 3. Relative standing of the various subjects is shown in the ninth column. The highest average score is seen to be 103.4; the lowest, 17, the group average for each practice being 50. The variability is seen by following the columns to the right. For example, D is 66 points above the class average in the first practice, and 24 points below the group average in the last practice. The co-efficient of variability is shown for the various subjects in the last column. This co-efficient is found by dividing the average deviation of a subject by that subject's average

score. The result is expressed in per cent. H, for example, has an average score of 38, and an average deviation of 13.125. This deviation is about 35 per cent. of this subject's average. Improvement is best studied in table 2. The improvement of the class as a whole is shown at the foot of the table. The average score of the last practice was about twice that of the first practice. Four subjects, however, made a lower average score on the second day than they did on the first.

Variations and Supplementary Experiments.—(1) The subject can stand closer to the basket, making the experiment much easier. (2) By having a larger basket outside the six-inch one, records can be kept of balls that miss the inside basket but enter the larger one. (3) One or more subjects could continue the experiment for a much longer time, the form of the curve be studied, and comparison made with the curve in figure 8, which is constructed from the average weekly scores shown in table 4. A study of the curve shows a rapid improvement for three weeks, a fall the fourth week, a steady improvement till the 10th week, for four weeks no further improvement, a great improvement the 15th week, and a falling off for the last two weeks. The curve shows four distinct stages: a rapid improvement for three weeks, then a slower improvement up to the 10th week, a plateau for a month, then a climb to a higher level.

4. A related experiment could be performed by tossing spears at a target, or by tossing the balls at a target. In tossing spears, a target similar to those used in rifle practice could be used. In throwing balls, one could use for a target a block of a certain size. The block could be set up so that when hit, it would fall. Still another related experiment could be performed, using balls in the manner described by Swift. Two balls are tossed up into the air in such a manner that one is in the air while the other is being caught.

Experiment II.—*Trial and error learning—The mirror experiment.*

Object.—The purpose of the mirror experiment is to make a study of a different type of trial and error learning, to determine its special characteristics, to study the individual differences of the subjects and to compare the results with the results of the preceding experiment.

Material.—The following apparatus is needed for this experiment: (1) mirrors, (2) blinds to cover the writing hand, (3) the tracing form as illustrated in figure 10, and a Whipple time clock for group experiments in which the subjects do a definite amount of work, or a stop watch or an

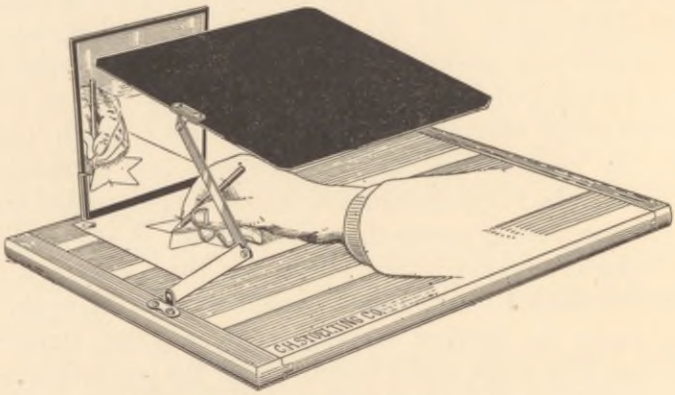

FIG. 9.—Apparatus for mirror experiment.

interval timer for experiments in which the time is kept constant for all subjects. The mirrors used by the author are six inches by eight inches. The top of the blind is 7 by 9 inches. The blind should be so adjusted as to hide the hand except as seen in the mirror. See figure 9.

Method.—The tracing paper is put under the blind with number 1 toward the subject. The mirror is placed behind the blind in vertical position. The subject places his pencil on the dot at number 1. When the signal is given to start, the subject traces a line to the dot at 2, then to 3, then to 4, and so on till the lines are traced back to number 1. This makes 24 lines.

The records may be kept in either one of two ways: (1) The subjects may be allowed to work for a minute, tracing

as many lines as possible. In this procedure, the score is the number of lines traced. Once around would give a score of 24. Two pages traced would be a score of 48. If this procedure is used, several sheets of the tracing form should be placed under the blind before the experiment is begun. As the sheets are finished they are quickly removed,

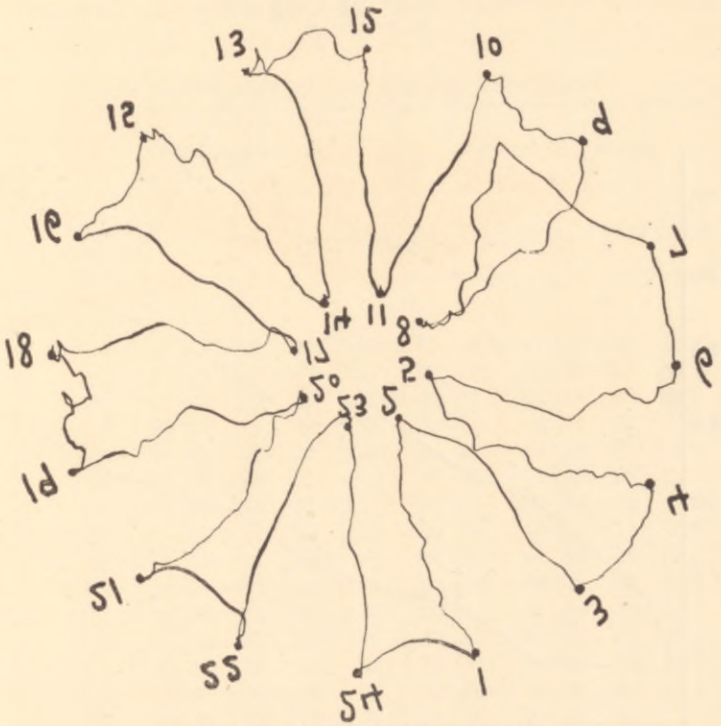

FIG. 10.—A sample mirror drawing.

and the subject proceeds on the next. (2) In the other procedure, the time required to do each page is determined. The tracing of one page constitutes one experiment. The time for this tracing, expressed in seconds, is the score. In either procedure, the experiments are continued till considerable proficiency is reached. If the first procedure is used, the scores show the increased amounts of work done in successive equal periods of time. If the second proced-

ure is used, the scores indicate the decreasing periods of time required to do equal amounts of work. The first procedure gives a rising learning curve; the second procedure gives a falling curve. In the latter case we can get a rising curve by taking the reciprocals of the times, expressed in seconds, or we can determine the speed per minute by the following formula:

$$E = \frac{24 \times 60}{T}$$

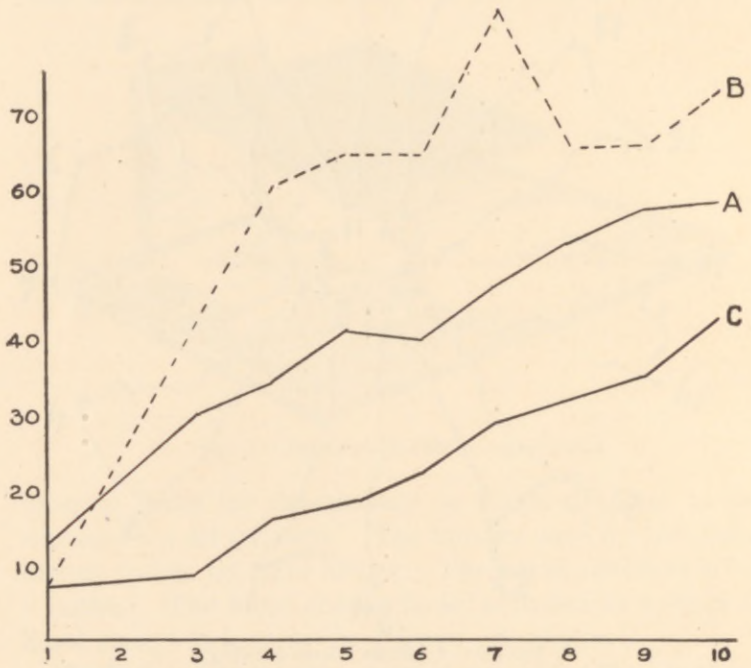

FIG. 11.—Learning curves for mirror experiment. A = the class average, B = the best record, C = the poorest record.

in which E represents efficiency, 24 is the number of lines on one page of the tracing form, 60 is the number of seconds in a minute, and T is the time in seconds required to trace one page.

Results.—In table 5 are shown the results of 24 subjects who worked for five minutes (five one-minute practices)

each on one day and five more minutes each on the second day afterward. In table 6 these results are transformed into scores corresponding to a class average of 50 for each practice. In figure 11 are shown graphs representing the class average, the scores of the subject reaching the highest efficiency and of the subject reaching the lowest efficiency.

In table 7 are shown the records of 88 subjects who traced five pages at one sitting. The time in seconds for each

TABLE 5.—RESULTS OF THE MIRROR EXPERIMENT

Trials	First day scores						Second day scores					
	(1)	(2)	(3)	(4)	(5)	Sum	(1)	(2)	(3)	(4)	(5)	Sum
Subject												
A	5	6	8	13	26	58	35	36	41	44	46	202
B	10	21	27	40	53	151	39	52	56	60	68	275
C	20	32	38	39	46	175	43	47	54	61	63	268
D	15	23	31	39	48	156	29	41	45	52	51	218
E	12	23	31	25	38	129	46	52	59	52	57	266
F	24	33	40	34	51	182	40	50	50	52	58	250
G	6	24	32	42	51	155	40	54	57	65	72	288
H	27	37	53	51	60	228	56	48	56	64	71	295
I	3	7	16	17	30	73	27	33	44	53	48	205
J	8	19	23	29	36	115	34	42	47	49	56	228
K	12	16	25	33	33	119	36	41	51	56	56	240
L	5	24	48	39	50	166	45	44	63	56	58	266
M	4	10	12	10	23	59	25	39	44	55	50	213
N	6	8	17	24	28	83	36	46	52	57	53	244
O	13	23	44	57	54	191	51	47	59	65	57	279
P	21	34	41	49	53	198	54	53	71	66	70	314
R	19	21	23	23	36	122	27	45	47	49	59	227
S	5	11	28	40	48	132	40	46	62	50	56	254
T	7	8	9	16	18	58	22	29	32	35	43	161
V	14	7	18	27	31	97	23	33	37	45	49	187
W	35	48	61	61	58	263	58	72	68	69	70	337
X	8	14	20	27	31	100	33	47	51	58	57	246
Y	7	24	42	60	67	200	67	85	68	66	74	360
Z	16	31	45	43	51	186	55	62	59	59	71	306
Averages...	12.6	21	30.6	34.9	42.5	141.5	40	47.6	53	55.8	58.8	255.4

TABLE 6.—RESULTS OF MIRROR EXPERIMENT
Transformed to class average of 50 for each trial

Trials	First day					Second day					Av.	C.V.
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)		
Subject												
A	20	14	13	19	31	44	38	39	39	39	29.6	35
B	40	50	45	58	64	49	55	53	54	58	52,5	10
C	80	75	63	57	56	54	49	51	55	54	59.4	13
D	60	54	52	57	58	36	43	42	47	43	49.2	14
E	48	54	52	36	46	52	55	56	47	49	49.5	9
F	96	77	67	49	62	50	53	47	47	49	59.7	21
G	24	56	53	61	62	50	57	54	58	61	53.6	13
H	108	87	88	74	73	70	50	53	57	60	72.0	19
I	12	16	27	25	36	34	35	42	48	41	31.7	29
J	32	45	38	42	44	43	44	44	44	48	42.4	7
K	48	38	42	48	40	45	43	48	50	48	44.5	8
L	20	56	80	51	61	56	46	59	50	49	53.4	18
M	16	23	20	14	28	31	41	42	49	43	30.7	34
N	24	19	28	35	34	45	48	50	51	45	37.9	26
O	52	54	73	83	65	64	49	56	58	49	60.3	15
P	84	80	68	64	64	68	56	67	59	60	67.0	10
R	75	50	38	33	31	34	47	44	44	50	44.5	20
S	20	26	47	53	58	50	48	59	45	48	45.3	20
T	28	19	13	23	22	27	30	30	31	37	26.0	24
V	56	16	30	39	38	29	35	35	40	42	26.1	19
W	140	111	102	83	70	72	76	64	62	60	84.1	24
X	32	33	33	41	38	41	49	48	52	48	41.5	15
Y	28	56	70	82	81	84	89	64	59	63	67.6	20
Z	64	73	83	62	62	69	65	56	53	60	64.7	10

TABLE 7.—RESULTS OF MIRROR EXPERIMENT
88 subjects, one tracing at each trial

Trials	(1)	(2)	(3)	(4)	(5)
Average in seconds	139	88	67	58	47
Medians in seconds	123	75	59	49.6	45.1
Reciprocals	72	113	149	172	213
Lines per minute	10.4	16.4	21.5	24.8	30.7

drawing is taken as the score. The table shows the average number of seconds required for each successive sheet, the median record for each successive sheet, the reciprocals of the averages, (multiplied by 10,000), and the number of lines traced per minute for each successive minute. The medians are considerably less than the averages because there were a few subjects unusually slow, for whom the experiment was almost impossible.

When the results of this experiment are compared with those in table 5, it is seen that the members of this group are slower than the members of the group of 24 learners. The 88 subjects were sophomores in the university, while the 24 subjects were seniors. Not only were the latter seniors, but they were much above the average in ability.

Interpretation and Discussion of the Results.—(1). A comparison of the results of the ball-tossing experiment and the mirror experiment shows a much more rapid improvement in the mirror tracing than in the ball tossing. In the latter, about twice as many balls were tossed into the basket the last time as compared to the score for the first 50 balls tossed, while in the last minute of mirror tracing the score was 4.6 times as high as was the case in the first minute. The time spent in ball tossing was about an hour, while the time spent in mirror tracing was only 10 minutes. Why was the difference in improvement so great?

2. Make a study of the variations in the individual results. Note the best learner, the poorest learner, the one who makes the most improvement, the one who makes the least improvement.

3. Compare the learning curves of the subject who makes the best average score with the one who makes the poorest average score.

4. Compare the learning curve of the subject who starts highest with the subject who starts lowest.

5. Compare the learning curve of the subject who ends highest with the one who ends lowest. What conclusions

do you reach from the various comparisons? What is the basis of individual differences?

6. Make various comparisons of the two experiments, ball tossing and mirror drawing. (*a*) Compare relative efficiency in the two experiments. This can be done by correlating final efficiency in one with that in the other, or the improvement in one with improvement in the other. If the latter plan is used, the actual improvement in ball-tossing should be used, determined by subtracting the first score from the last two; but for mirror writing, the actual fourth score should be used as the measure for learning capacity in this experiment. Why?

7. Make a qualitative study of the mirror experiment. Note that it is not only a matter of forming new habits but of overcoming old, long established habits. Carefully work out how this is done. The study is in part a study of inhibition. Note the great individual differences in the amount of this inhibition. What other peculiarities are shown by a person in whom the inhibition is great? Get data on this point from other experiments in the course, and make a final answer to this question later.

8. Make a study of the mirror-experiment curve. At what point is improvement greatest?

9. What aspects of education are illustrated by the mirror experiment?

10. What facts do you learn from the experiment that are important for a teacher to know?

11. Compare the variability of the different subjects. For this purpose, use the co-efficients of variability. Correlate the two columns of co-efficients as shown in tables 3 and 6. The co-efficients shown in the above tables give a correlation of +.61.

Variations and Related Experiments.—Mirror-writing makes an interesting variation or supplement to the experiment as described above. The procedure is the same except that in mirror-writing, the subjects write the alphabet in script so that the letters are legible, having their natural appearance in the mirror.

A study of bilateral transfer can be made by taking a record with the left hand, after the experiment has been finished with the right hand, and comparing the results with the first experiment with the right hand.

Related experiments can be performed, with the subjects using prisms instead of mirrors.

NOTE.—The blank pages following the experiments are for entering the records of the students using the *Manual*.

CHAPTER IV

MOTOR LEARNING (*Continued*)

The experiments of this chapter are in motor learning, but they differ from the experiments of Chapter III in the following way: In trial and error learning the precise movements involved are not known and have not been mastered; they are hit upon by the trial and error procedure. In the experiments discussed here, the movements are known and have been mastered. The movements have been mastered and, in popular language, have been brought under the control of the will. In more scientific language, the movements have been mastered, and organised with the cortical substrate of some idea as their adequate stimulus. This idea is usually the idea of the movement itself. In tossing the balls, one does not at first know what movement to make to get the ball into the basket, but one does know how to toss a ball, so he tosses the balls until one of them goes into the basket. The sensations which the movement gives him serve as a slight clew to the proper movement. By and by, the proper movement is known and becomes coupled with the proper stimulus. In sorting numbered cards as in the first experiment of this chapter, when the subject sees the number of the box into which the card similarly numbered is to be placed, he can successfully make the movement which places the card into the appropriate box. It is not necessary to make random and unsuccessful movements in order to place the card into its proper place. In the experiments of this chapter, neither the stimuli nor the responses are new, but they have not before been coupled together. This experiment therefore consists in coupling known stimuli with known and mastered responses. The subjects are familiar with cards and numbers and have

had much experience in placing the hands in any desired place in front of the body. It must be remembered, however, that mastery of a movement is a relative matter. When we say that we have mastered the movements involved in the experiments of this chapter we mean that we have mastered them *to a degree.* The facility of making these movements does indeed improve much, but the fact remains that we *can* make them and do not have to use the trial and error method to discover the proper movement.

Experiment Number III.—*Card sorting.*

Object.—The object of this experiment is to discover the principles involved in motor learning in which neither the stimuli nor responses are new, but which have not been before associated.

Material.—The material used consists of card-sorting trays, numbered cards and a Whipple clock. The cards

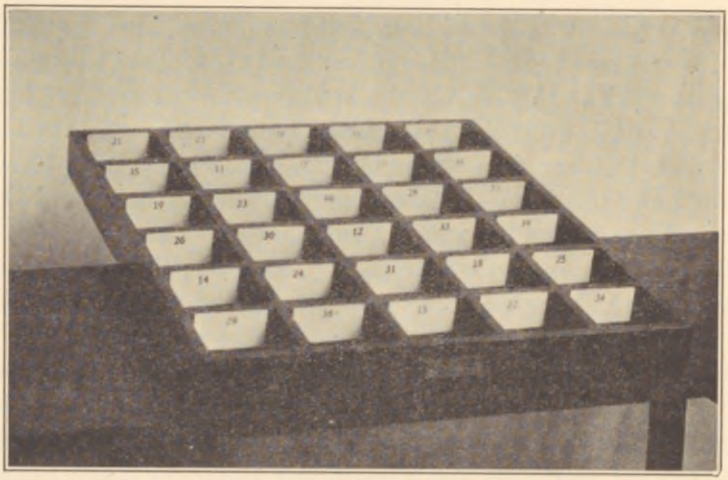

FIG. 12.—Card-sorting tray.

are 2½ by 3½ inches and are numbered from 11 to 40. The trays have on each side 30 pigeon holes 3 inches square numbered from 11 to 40 in miscellaneous order. The trays are so made that both sides can be used. The author uses the following arrangement of the numbers: Row 1 (nearest to the subject) 29, 36, 15, 22, 34; row 2, 14, 24,

31, 18, 25; row 3, 26, 30, 12, 33, 39; row 4, 19, 23, 40, 28, 17; row 5, 35, 11, 37, 20, 38; row 6, 21, 27, 16, 32, 13. The numbering begins at the left. The corresponding numbering on the reverse side of the box is: Row 1, 35, 18, 40, 16, 37; row 2, 17, 33, 26, 13, 11; row 3, 38, 14, 25, 19, 23; row 4, 22, 27, 32, 21, 30; row 5, 34, 20, 39, 15, 24; row 6, 29, 31, 12, 28, 36. The experimenter can, of course, use any number of rows from one to six. In the first experiment reported here four rows were used.

Method.—The subject is seated before the card-sorting tray, and uses the four rows nearest, the first row being numbered, 29, 36, 15, 22, 34; the second row, 14, 24, 31, 18, 25; the third row, 26, 30, 12, 33, 39; the fourth row, 19, 23, 40, 28, 17. Five cards for each number are used. Before the cards are distributed to the boxes, they should always be carefully shuffled. To facilitate careful shuffling, the cards are taken up after each sorting one at a time in promiscuous order. After being so taken up they should be still further shuffled. In the author's laboratory the trays are arranged along the sides of a long table thirty inches high. The time is kept by means of a Whipple time clock which is placed in an elevated position beyond one end of the table. All the subjects are started at the same time. As each subject finishes, he looks up at the clock and notes the time which he then records in seconds. Occasional and unexpected examination should be made for errors. Few are ever found. After all subjects have finished a sorting, the cards are collected and shuffled as above described. Five sortings should be made each day for four consecutive days, twenty sortings in all.

Results.—In table 8 the results are shown in three forms: (1) the actual scores in seconds for each trial, (2) the reciprocals of the actual scores, (3) the number of cards placed per minute.

In table 15 the scores are all transformed to a class average of 50, and the average rate of performance of each subject for the whole experiment is given in the last column. This form of table is given rather than a table of all the

actual scores because in this table the progress of each subject in relation to the group is most easily traced.

For the purpose of determining the part played in the experiment by mere muscular speed, at least two speed tests should be made each day before the sorting begins. The speed test consists in putting the cards into the trays without regard to the numbers.

TABLE 8

In column 1 are the class averages of actual scores in seconds for each sorting. In column 2 are the reciprocals of the actual scores. In column 3 is shown the number of cards sorted per minute. The number of subjects was 24; number of pigeon holes used, 20.

	(1)	(2)	(3)		(1)	(2)	(3)
1	298	336	20.1	11	129	775	46.5
2	204	490	29.4	12	116	862	51.7
3	196	510	30.6	13	113	885	53.1
4	162	617	37.0	14	114	877	52.6
5	152	658	39.5	15	111	901	54.1
6	154	649	39.0	16	114	877	52.6
7	143	699	42.0	17	105	952	57.1
8	138	725	43.5	18	104	962	57.7
9	126	794	47.6	19	102	980	58.8
10	122	820	49.2	20	98	1020	61.2

The test is made as follows: The subjects put the cards into the boxes as fast as possible without regard to the numbers, starting with the upper left hand box and going to the right and then back to the left in the row below, and so continuing to go back and forth to all the boxes till all the cards are distributed. In table 9 the sum of the last two distributions is taken as the score. The table shows the sums of the two distributions, the reciprocals of the sums, and the reciprocals reduced to an average of 50.

TABLE 9.—TEST FOR MUSCULAR SPEED IN DISTRIBUTING CARDS

Subject	Score	Reciprocal	Av. of 50	Subject	Score	Reciprocal	Av. of 50
A	132	758	49	M	150	667	43
B	120	833	54	N	116	862	56
C	108	926	60	O	124	806	52
D	121	826	54	P	130	769	50
E	124	806	52	R	98	1020	66
F	152	658	43	S	115	870	56
G	180	556	36	T	149	671	44
H	155	645	42	V	165	606	39
I	125	800	52	W	130	769	50
J	127	787	51	X	125	800	52
K	168	595	39	Y	106	943	61
L	146	685	44	Z	115	870	56

TABLE 10.—SHOWING THE CO-EFFICIENT OF VARIABILITY IN CARD SORTING

Subject	A	B	C	D	E	F	G	H	I	J	K	L	M
C.V.	7.1	8.1	8.3	7.1	13.4	10.5	6.0	9.4	7.5	3.8	9.3	8.6	5.1

Subject	N	O	P	R	S	T	V	W	X	Y	Z	Av.
C.V.	11.1	8.7	5.8	6.2	6.6	8.0	7.4	8.5	4.6	5.8	9.7	7.78

Expressed in terms of per cent.—C.V. $= \frac{\text{Subject's Av. Dev.} \times 100}{\text{Subject's Av.}}$

TABLE 11.—SHOWING THE PER CENT. OF IMPROVEMENT OF EACH PRACTICE OVER THE PRECEDING, COMPUTED FROM THE RECIPROCALS SHOWN IN COLUMN 2 OF TABLE 8

The upper row of figures indicates the number of the practice, the lower row indicates the per cent. of improvement over the preceding record.

Number of practice	2	3	4	5	6	7	8	9	10
Improvement	46	4	21	7	−1	8	4	10	3

Number of practice	11	12	13	14	15	16	17	18	19	20
Improvement	−6	11	3	−1	3	−3	9	1	2	4

TABLE 12.—SHOWING THE STANDARD DEVIATIONS FROM THE CLASS AVERAGE FOR EACH SORTING

Sorting	1	2	3	4	5	6	7	8	9	10
S.D.	14.3	16.6	14.3	12.4	11.5	11.1	10.6	11.6	10.4	10.4

Sorting	11	12	13	14	15	16	17	18	19	20	Av.
S.D.	8.6	8.8	8.5	10.3	8.4	9.1	8.3	8.9	9.7	8.9	10.6

TABLE 13.—SHOWING THE CORRELATION OF EACH PRACTICE WITH THE LAST

Sorting	1	2	3	4	5	6	7	8	9
Correlation with 20th	.313	.563	.522	.678	.750	.723	.757	.817	.807
Sorting	10	11	12	13	14	15	16	17	18	19
Correlation with 20th	.886	.785	.823	.862	.883	.868	.760	.919	.923	.930

TABLE 14.—SHOWING THE CORRELATION OF MUSCULAR SPEED TEST WITH EACH SORTING

Sorting	1	2	3	4	5	6	7	8	9	10
Correlation with speed	.27	.49	.44	.57	.63	.60	.63	.72	.73	.74
Sorting	11	12	13	14	15	16	17	18	19	20
Correlation with speed	.68	.74	.79	.86	.81	.78	.82	.83	.72	.76

The experiment can be performed with three rows of pigeon holes instead of four. With fewer bonds to form the subjects reach a higher efficiency in a given time. In table 16 the results are shown for sorting into three rows for four days, with five sortings each day, by 18 subjects. In figure 15 the learning curves are compared for sorting into 1, 2, 3, 4 and 6 rows of pigeon holes. The scores used are numbers of cards per minute for each of 12 sortings. It will be seen that efficiency rises more quickly the fewer the number of bonds.

Interpretation of Results.—The class averages obtained should be compared with the results shown in table 8. The raw scores should be transformed to a class average of 50 as shown in table 15. This form of table should be used in a study of the progress of the individual learners, and for a study of individual variability. The co-efficient of variability is computed by finding a subject's average for the whole experiment, then finding the individual deviations of each practice from the subject's average, by dividing the sum of the individual practice deviations by the number of practices, and then by finding the percentage that this average deviation is of the subject's average.

The improvement from one practice to another should be computed from the reciprocals of the raw scores, and the results compared with the results shown in table 11.

TABLE 15.—CARD SORTING REDUCED TO CLASS AVERAGE OF 50

Trial.....	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	Av.
A	53	49	56	45	46	43	55	52	50	47	42	47	47	47	45	51	42	42	43	48	47.5
B	46	45	32	28	35	35	38	43	41	44	46	47	45	47	43	50	49	48	52	50	43.2
C	50	38	52	57	53	52	49	55	57	61	57	61	63	62	58	50	60	61	58	58	55.6
D	46	45	47	51	55	58	64	58	58	58	61	58	51	55	54	50	50	53	53	54	54.0
E	92	82	81	69	63	70	62	60	58	55	55	53	57	53	57	59	54	56	55	52	62.2
F	28	28	28	29	28	28	27	29	30	33	35	35	37	35	39	37	36	36	34	36	32.4
G	44	42	37	36	34	38	39	37	37	36	42	42	37	34	43	37	39	39	38	36	38.4
H	36	30	32	35	34	33	32	33	39	34	42	34	37	36	36	41	41	44	42	41	36.6
I	60	53	57	46	49	49	52	49	47	48	41	47	44	46	46	42	43	44	45	43	47.6
J	65	50	54	60	56	54	52	51	53	49	53	50	51	54	53	49	52	45	46	50	52.4
K	43	33	40	38	36	34	35	27	33	27	33	33	37	26	32	33	33	32	35	32	33.6
L	75	69	63	56	58	61	57	57	57	56	53	52	51	51	52	53	50	50	55	53	56.5
M	38	45	41	46	46	46	49	49	48	47	50	44	50	50	48	50	48	46	46	50	46.9
N	36	37	33	40	39	46	42	49	45	48	51	51	49	52	52	54	49	49	50	50	46.1
O	56	74	68	65	60	61	57	56	55	58	60	54	51	55	49	52	53	50	52	53	57.0
P	39	42	44	42	47	49	47	50	46	48	53	51	51	50	51	52	49	50	49	51	48.1
R	71	89	81	76	76	64	68	72	74	69	65	66	69	68	65	74	68	70	70	69	71.2
S	43	48	54	55	57	66	62	60	62	60	52	54	57	58	57	57	54	60	58	58	56.6
T	43	33	43	48	48	47	44	41	41	46	40	44	44	44	44	50	46	45	44	42	43.9
V	49	52	58	56	55	52	53	53	49	53	55	59	47	47	43	43	50	47	43	53	50.9
W	49	43	47	44	43	43	45	41	46	43	43	44	46	46	51	38	51	53	52	60	46.4
X	48	47	49	55	52	50	50	50	54	52	54	51	53	52	51	48	51	46	47	42	50.1
Y	57	82	68	70	70	65	66	72	64	67	65	67	65	72	63	64	65	67	76	61	67.3
Z	32	40	39	56	55	58	57	59	55	58	54	56	59	61	63	55	62	59	60	63	55.1

TABLE 16.—CLASS AVERAGES FOR 20 SORTINGS INTO THREE ROWS OF PIGEON HOLES

Column 1 shows the average speed in seconds for the successive sortings, Column 2 shows the reciprocals of these averages, and column 3 shows the number of cards sorted per minute.

(1)	(2)	(3)	(1)	(2)	(3)
167	60	26.9	78	128	57.7
135	74	33.3	77	130	58.4
120	83	37.5	75	133	60.0
111	90	40.5	74	135	60.8
99	101	45.5	72	139	62.5
95	105	47.4	74	135	60.8
87	115	51.7	74	135	60.8
86	116	52.3	72	139	62.5
83	120	54.2	71	141	63.4
80	125	56.3	70	143	64.3

Each subject should study his own improvements by comparing them with the class average improvements. The manner of progress of the various members of the group should be studied. It will be noted that some subjects make a rapid initial improvement and continue to maintain a high standard of performance. Others make a rapid initial improvement but do not maintain a high standard of work. Some make a slow initial improvement and never reach a high standard of performance, while some make a slow initial rise and later reach a high standard of performance. What is the rule and what is the exception? What is the explanation of the exceptions?

The correlation of each performance with the last performance should be computed as shown in table 13. Why does this correlation become steadily greater? How soon in this experiment could you predict final efficiency with considerable accuracy? Is there any relation of final efficiency to early score? What is the best criterion of quickness of learning?

A subject's score in this experiment depends partly upon quickness of learning and partly upon muscular speed.

To determine the extent to which mere speed of manipulating the cards is a factor, at least two speed tests should be given each day, the results averaged and reduced to an average of 50, and then correlated with the results of each practice. The correlations obtained should be compared with those shown in table 14 and in figure 13. It will be seen that at first the score is due chiefly to quickness of learning, but later, muscular speed is the main factor. The results of the speed test are a fair indication of the final

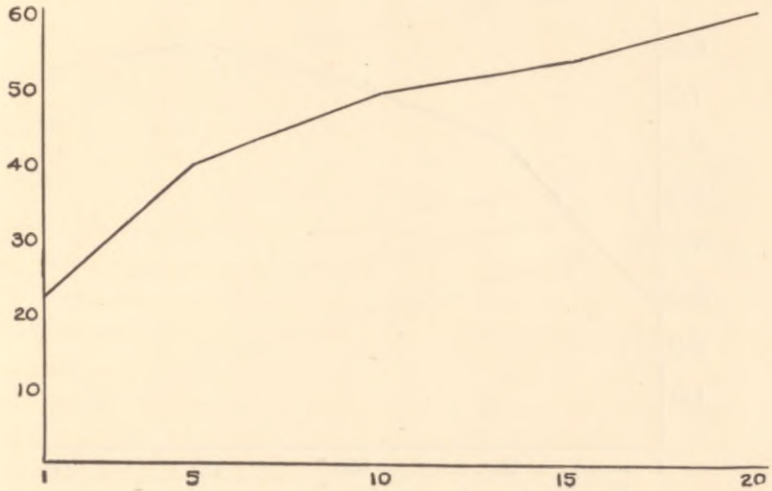

FIG. 13.—Smoothed learning curve from card-sorting. Practices are represented on the horizontal axis; the reciprocals of the scores (time in seconds) on the vertical axis. Four rows of the tray, twenty compartments, were used.

speeds possible for the various subjects. How near each subject's sorting speed comes to the muscular speed should be determined. This can be done by finding the sorting speed per second for the last day's sorting, the speed per second for the muscular speed tests, and determining the percentage which the sorting speed is of the muscular speed.

In this experiment as performed by the author, there were five practices each day. By reference to table 8 it will be seen that the first score on each day was poorer than the last score on the preceding day. Why was this?

Why should the correlation with the last practice be lower for these same practices, sixth, eleventh, and sixteenth? See table 13 and figure 14.

Each student should write up fully an account of his own learning, giving everything possible which throws light on how it was done. These accounts should be studied and compared with especial reference to the fastest and slowest learners. Does the study furnish any explanation of the peculiar characteristics of a fast learner?

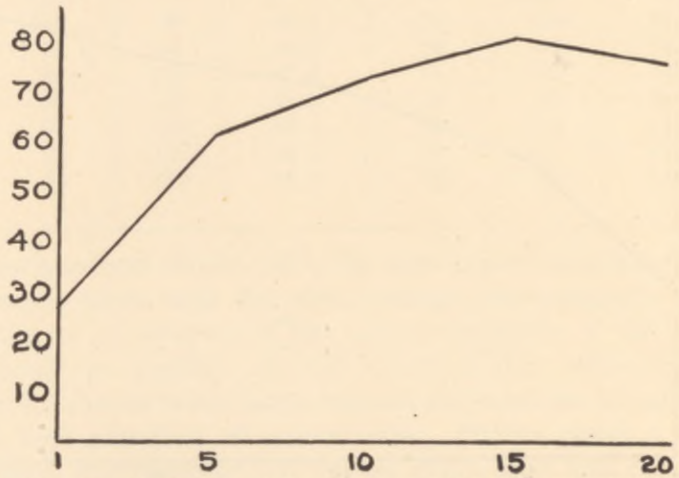

FIG. 14.—Graphical representation of the correlations of card-sorting with speed of movement. The practices are represented on the horizontal axis and the correlation, on the vertical axis.

Special study should be made of subjects who start out slowly and reach high efficiency late in the experiment. Is such a form of learning curve due to individual attitude and temperament? Is such a learner slow at first because of care and caution? Are the early low scores due to careful learning, which shows its results later? Careful study should also be made of curves very high at first but showing relatively low final efficiency. What are found to be the characteristics of such a learner?

The instructor should determine as far as possible the attitude of the several learners, to see what effect attitude

has on the results. Is attitude toward the experiment a result or a cause?

What is the significance of the fact that, as practice proceeds, the standard deviation decreases as shown in table 12?

Related Experiments.—The card-sorting boxes can be used for many different types of experiment. By learning

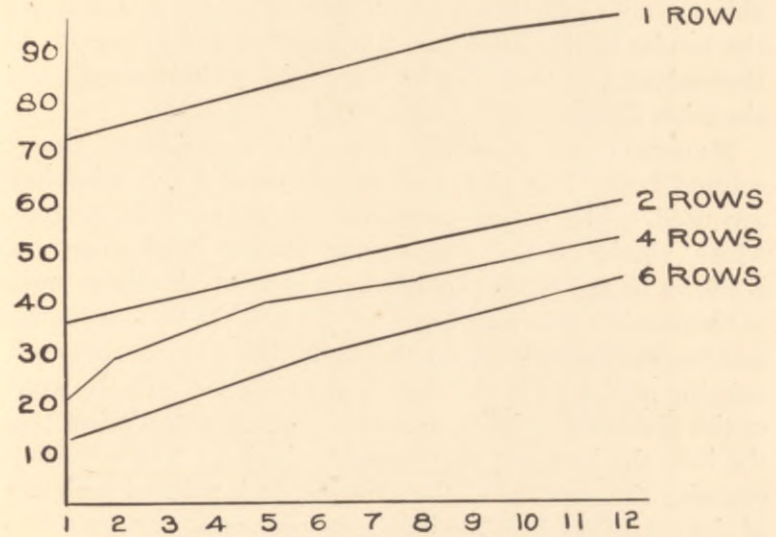

FIG. 15.—Learning curves for sorting into one, two, four, and six rows of the card-sorting tray. Twelve sortings are represented on the horizontal axis. The number of cards sorted per minute is represented on the vertical axis.

to sort in one row at a time, spending an hour a day on each of the 6 rows, the class can demonstrate the quicker learning of each succeeding row. By learning to sort on one side of the box, carrying the work to a high degree of efficiency, then using the other side, the class can study interference. By proper numbering of the boxes, the number of the bonds involved can be made many or few. One can study interference in the case of one row, two rows, three, four, five, or six rows. It will be found that the results are different according as one uses many or few bonds. How is the difference to be explained? In the interference

experiments, which suffers most from the interference, fast or slow learners? What is the general significance of this fact?

Experiment IV.—*Motor learning, sorting colored marbles.*

Object.—The object of this experiment is much the same as was that of experiment number 3. However, in this experiment, the associations are more complicated than they were in the preceding experiment, and we are here able to make a further study of interference. Not only are the results of this experiment interesting and important in themselves but they can be compared with the results of the other similar experiments, 3 and 5.

Material and Method.—For this experiment ninety colored balls, two pieces of apparatus and the color key are used. The colors used are red, green, blue, yellow, white, black, orange, purple, and violet. The apparatus is shown in figure 16. In the back row are the three parts of the marble receiving box; on the left, the bottom; in the middle, the partitions; on the right, the lid. Beside each opening of the lid is the outline of an animal. In the front of the picture are the two parts of the marble-container; on the left, the bottom; on the right, the lid. The color-key contains the outlines of the animals, each painted with one of the colors used on the balls.

The method of the experiment is as follows: The subject sits before the apparatus which is set up as in figure 17, but arranged with the container horizontal in front and the receiver behind. The color-key is kept face down until the experiment is begun. The instructions are to sort the marbles correctly and as fast as possible. The subject takes out a marble, looks at the key to see what animal has the same color, and then places the marble in the hole by the corresponding animal outline. Another marble is then taken, the key is consulted and the marble deposited. In a similar manner the subject proceeds till all the marbles are deposited. Only one marble must be taken up at one time; a separate movement must be made for each marble.

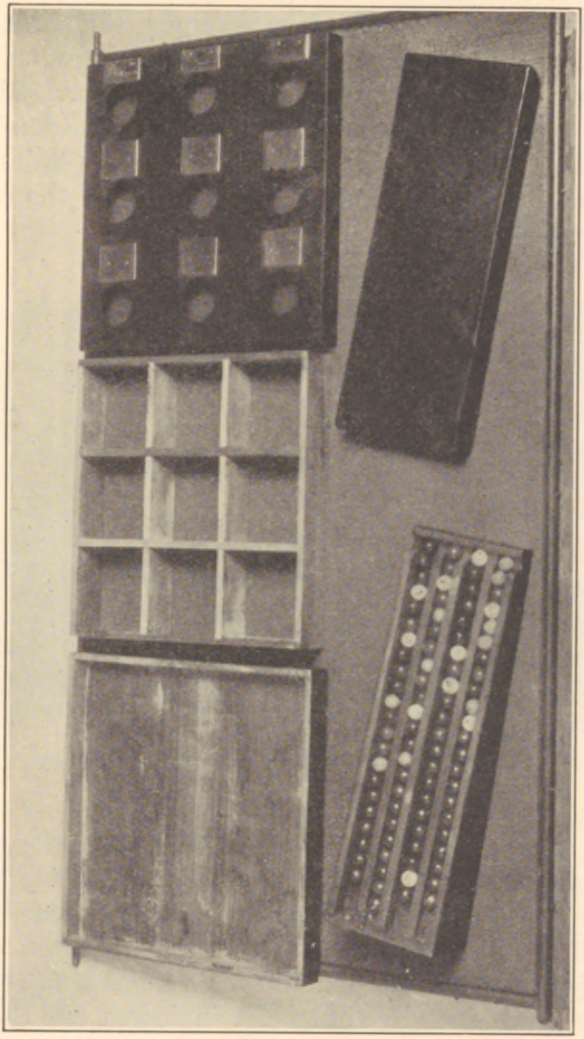

FIG. 16.—Photograph of marble-sorting apparatus, showing parts.

After all the marbles are sorted, the lid of the marble-receiving box is removed, and the number of errors is ascertained. A marble in a wrong compartment is an error. After the number of errors is ascertained, the partition is removed and the marbles are thoroughly mixed. They are then placed back in the marble-container. The lid of the marble-container is removable, and should be removed for the purpose of putting the marbles into the container, but is to be placed back on before the experiment proceeds.

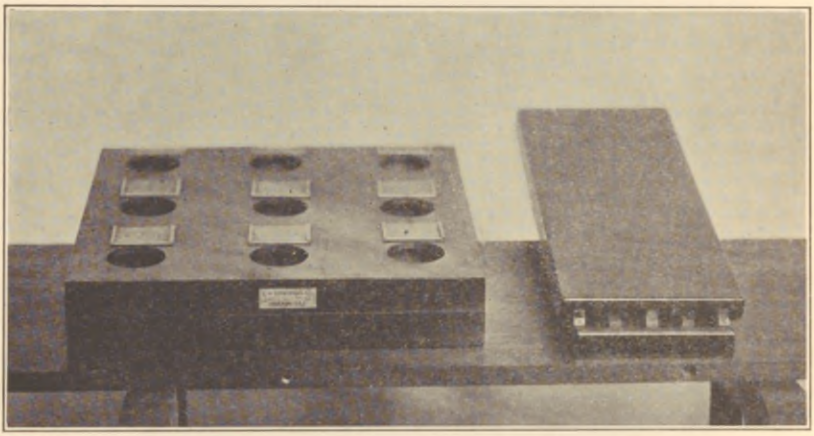

FIG. 17.—Photograph of marble-sorting apparatus set up.

After the first sorting, the experiment can proceed in either one of two ways: (1) A lid having a different arrangement of the animals can be used the second time, and a different arrangement each succeeding time, or (2) the subject can use the same lid for a number of sortings until the bonds are formed to a certain degree, and then the form of lid alternated each succeeding time. If it is wished to compare the amount of interference with quickness of learning, the second procedure is the proper one, and is the one for which data are first given below. However, the results of six sortings by the first method are also given.

Results.—In table 17 are given the average results for 23 subjects sorting five times the first day using the same form of lid, seven times each on the second and third days, with the form of lid changed each time. Column 1 gives the number of the sorting; column 2 gives the number of seconds for the distribution; column 3 gives the number of errors; column 4 gives the number of marbles correctly placed per minute.

TABLE 17.—MARBLE-SORTING, 90 MARBLES, NINE DIFFERENT COLORS, 23 SUBJECTS, UNIVERSITY SENIORS

Column 1 gives the number of the sorting; column 2, the number of seconds for the distribution; column 3, the average number of errors; column 4, the number of marbles correctly placed per minute. In the first 5 sortings, the same form of lid was used; in the sixth to the nineteenth sorting the lid was changed each time.

(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
1	230	6.7	21.7	10	136	1.5	39.1
2	150	2.7	34.9	11	129	1.3	40.8
3	124	1.9	42.6	12	132	1.0	40.5
4	112	1.6	47.3	13	124	1.0	43.1
5	108	1.0	49.4	14	119	1.4	44.7
				15	116	1.4	45.8
6	144	2.3	36.5	16	115	1.0	46.4
7	123	1.3	42.8	17	113	1.0	47.2
8	140	1.5	37.9	18	119	1.3	44.2
9	139	1.6	38.1	19	114	.6	47.0

TABLE 18.—MARBLE-SORTING AS IN TABLE 17

The form of lid is changed each time, 90 subjects, university juniors, six sortings, the arrangement of columns is the same as in table 17.

(1)	(2)	(3)	(4)
1	272.9	6.5	18.3
2	222.2	3.1	23.4
3	190.2	1.9	27.8
4	175.6	2.4	29.9
5	161.7	1.8	32.7
6	152.5	1.1	34.9

In table 18 are shown the results from an experiment with 90 university juniors for six sortings. A different form of lid was used each time. This is an interference experiment merely. The results are not comparable with the results shown in table 17 for two reasons: (1) The 90 subjects constituted a relatively unselected university group, while the 23 subjects were seniors whose ability was much above the average for university students. (2) The method of procedure was different.

In table 19 the results from 23 subjects are given, reduced to a class average of 50. The first five columns show the results before the form of lid was changed, and constitute an experiment of the same general nature as the card-sorting experiment. From the sixth to the nineteenth column are shown the results of using a different form of lid each time, with the same colored animals, but with each picture of an animal placed by a different hole. The association of the color with the animal continued the same for the whole experiment, but beginning with the sixth practice, the same color of marble was placed in a different hole at each sorting. In column 20 are given the averages of the first five practices. In column 21 are given the results of the sixth to the nineteenth practice.

In table 20 are shown the results of four speed tests, also the four records combined and reduced to an average efficiency of 50. The speed tests consisted in placing the marbles into the holes without regard to the color of the marbles. The object was to determine the muscular speed of the subjects in this sort of action.

In table 21 are shown the co-efficients of variability.

In table 22 are shown correlations within the marble-sorting experiment, and in table 23, correlations with the card-sorting experiment.

TABLE 19.—MARBLE-SORTING RESULTS REDUCED TO A CLASS AVERAGE OF 50

Letter to the left indicates the subject; numbers at the top indicate the sorting; 20th column indicates the average for the first day; column 21 indicates the averages for the interference part of the experiment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
A	50	57	56	57	54	36	37	46	41	50	50	53	61	45	53	50	56	58	53	54.8	49.2
B	49	57	65	60	58	52	64	60	54	64	56	56	55	56	57	59	54	59	55	57.8	57.2
C	61	68	64	66	65	60	69	72	68	55	55	68	53	53	52	54	57	62	65	64.8	60.2
D	37	42	49	46	48	49	52	49	45	49	50	46	45	47	46	47	46	53	50	44.4	48.1
E	101	90	77	60	67	74	65	79	71	81	65	69	61	64	58	60	59	67	57	79.0	66.4
F	37	38	36	39	43	42	39	44	44	52	51	49	41	41	50	47	45	43	47	38.6	45.4
G	29	44	49	53	51	43	54	49	48	46	41	43	45	56	43	38	46	48	45	45.2	46.1
H	59	38	28	27	31	53	40	50	41	53	52	51	52	44	47	48	50	48	47	36.6	48.3
I	45	66	53	54	55	45	56	47	51	53	55	53	55	52	53	52	55	49	56	54.6	52.3
J	37	46	51	49	49	46	57	42	46	51	49	41	53	52	47	54	50	47	53	46.4	49.1
K	44	47	42	43	45	43	49	37	45	34	40	45	42	42	43	45	47	46	49	44.2	43.3
L	40	52	49	52	52	59	58	47	52	45	42	51	55	51	47	47	49	47	43	49.0	49.5
M	64	45	37	37	27	32	27	38	38	31	43	44	40	47	36	35	36	36	26	42.0	36.4
N	45	41	43	50	47	50	53	41	49	40	42	37	38	38	48	47	44	42	45	45.2	43.8
P	38	36	42	40	44	44	49	49	51	44	42	45	50	49	47	44	44	42	46	40.0	46.1
R	58	59	70	71	63	56	56	59	56	55	84	56	50	64	60	61	55	57	52	64.2	58.6
S	36	57	59	56	59	59	59	60	61	55	56	54	49	52	56	57	53	51	50	53.4	55.1
T	28	31	34	34	35	33	29	36	38	38	37	40	39	37	37	36	38	35	37	32.4	37.4
V	41	56	50	44	46	47	51	45	44	46	49	43	51	40	48	47	49	36	51	47.4	45.2
W	34	51	43	38	49	55	47	44	54	44	43	42	45	41	55	48	47	44	41	43.0	46.4
X	68	46	61	59	59	62	56	69	56	67	60	67	67	62	56	55	59	62	62	58.6	61.4
Y	78	55	53	53	45	53	38	40	36	48	47	42	47	59	59	60	56	53	52	56.8	49.3
Z	71	34	42	57	56	58	44	46	46	46	43	46	61	44	55	63	56	64	62	52.0	52.4

TABLE 20.—SHOWING THE RESULTS OF FOUR SPEED TESTS MADE AT THE END OF THE SORTING EXPERIMENT

The letters at the left indicate the subjects. The scores are in terms of the number of seconds required to place the 90 marbles without regard to color. The 5th column shows the speed efficiency reduced to a class average of 50.

Subject	Time in seconds					Subject	Time in seconds				
	(1)	(2)	(3)	(4)	(5)		(1)	(2)	(3)	(4)	(5)
A	75	70	61	60	56	M	124	125	124	122	31
B	75	75	65	70	52	N	72	68	68	64	55
C	65	65	68	65	57	P	80	70	75	73	50
D	70	80	75	65	51	R	69	64	69	60	57
E	60	65	58	55	62	S	90	85	85	80	44
F	67	67	64	62	58	T	130	135	136	129	28
G	90	90	90	86	42	V	85	82	90	88	44
H	68	65	69	68	48	W	75	77	85	75	48
I	78	65	70	64	54	X	77	63	70	74	52
J	75	74	68	70	52	Y	65	64	74	68	55
K	75	70	70	72	52	Z	70	66	64	62	57
L	81	78	80	75	47						
						Average...	79.0	76.7	77.3	74.2	

TABLE 21.—CO-EFFICIENTS OF VARIABILITY IN MARBLE-SORTING

Subject.....	A	B	C	D	E	F	G	H	I	J	K	L
C.V.....	12.0	5.0	11.0	4.0	9.0	8.0	7.6	6.6	4.8	7.5	7.3	8.3
Subject.....	M	N	P	R	S	T	V	W	X	Y	Z	Av.
C.V.....	12.6	9.6	5.0	8.4	5.6	7.1	6.5	8.5	6.2	13.0	16.4	8.26

TABLE 22.—CORRELATIONS IN THE MARBLE-SORTING EXPERIMENT

SORTING	SORTING	r		
6 + 7 with 14 + 15	= .645	Speed with 18 + 19	= .708
First 5 with 6 to 19	= .838	Speed with 7 + 8	= .61
First 5 with 7 to 9	= .71		
First 5 with 17 to 19	= .81		
6 + 7 + 8 with 17 + 18 + 19	= .66		

TABLE 23.—CORRELATIONS BETWEEN CARD SORTING AND MARBLE SORTING

MARBLE SORTING		CARD SORTING	r
4 + 5	with	4 + 5	= .496
19 + 20	with	4 + 5	= .36
4 + 5	with	9 + 10	= .583
18 + 19	with	19 + 20	= .349
First 5	with	9 + 10	= .616
First 5	with	Av.	= .63
7 to 19	with	Av.	= .486
7 to 19	with	9 + 10	= .464
Speed	with	Speed	= .478

Interpretation and Discussion.—A study of the *first* five sortings should *first* be made. As a measure of learning capacity in this kind of learning, the average efficiency score for the first five performances may be taken. The average of the last two sortings may also be taken. In each case the scores should be reduced to an average of 50. The results of the experiment should be compared with the results from the preceding experiments. Compute the various correlations and compare with the preceding tables.

For the second part of the experiment, the scores should all be reduced to a class average of 50 and the results of interference noted. What can be discovered by following the scores from left to right? What different types of students can be discovered? The main question to be answered is whether good learners or poor learners are affected most by interference. The answer to the question can be found in part by an inspection of the table, more accurately by correlating the results of the first five sortings with the average of the last 14 sortings. The results shown in table 22 give a correlation of .838 between the first part of the experiment and the second. This high correlation shows that the fast learners as indicated by the first part of the experiment are also able to adapt themselves best to the interference. The correlation of part 1 with the second, third, and fourth practices of the second part is .71, while the correlation of part 1 with the last three practices of part 2 is .81, and the correlation of the early part of the

interference experiment with the last part is .66. What is the significance of the last three correlations?

The correlation of the averages of the speed test with the last two practices combined is .71, and with the first two practices combined (of part 2) is only .61. The student should compute similar correlations and compare with these and explain the results.

Compute the variability as shown in table 21 and compare your results with those of that table. Is there any

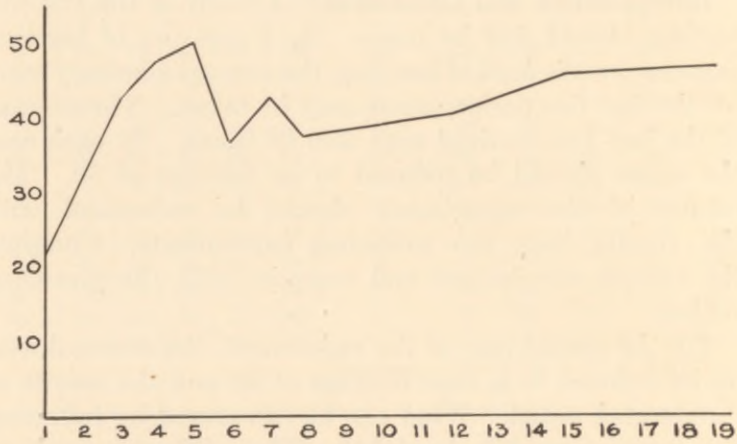

FIG. 18.—Learning curve of marble-sorting—five practices with same arrangement, fourteen practices with arrangement of lid different for each sorting, from table 17.

relation between variability and learning capacity, or is great variability found as often among good learners as among poor learners?

Write up a detailed statement and discussion of the qualitative aspects of this experiment, touching upon method of learning in the first part and methods of overcoming the interferences in the second part. In this experiment the association between the color and the animal is more and more firmly established as the experiment proceeds, but the location of the animal on the lid cannot be established because, in the second part of the experiment,

this location changes with each practice, therefore the score of a student depends upon how well the association between the color and the animal is established and upon how quickly he can find the location of the animal in each new trial and *learn this new location*. The second part of the experiment is, therefore, a good test of quickness of perception and quickness of adaptation.

Make drawing similar to figure 18. Notice the rapid rise of the curve in the first five practices, and the slower rise in the remaining practices. Would it be possible to continue the second part of the experiment till the scores would be as high as they would be if the first part of the experiment were continued till the subjects reached their maximum speed?

Related Experiments.—Many variations of the experiment suggest themselves. Perhaps the most obvious variation is to study interference by changing the color of the animal, or by changing both the color of the animal and the location of the animals on the lid.

Experiment V.—*Complicated motor learning.*

Object.—In this experiment we deal with motor learning as in experiments 3 and 4. However, the movements in this experiment are more complicated than in the preceding experiments. The simultaneous movements of both hands are involved, and the movements of both feet. It is a better test of the power of concentration than is either of the preceding experiments. Our problem here, then, is to study a complicated form of motor learning involving a high degree of concentration. We shall expect to learn about the nature of the learning curve, the relation of speed to accuracy, the individual differences, and the relation of ability in this experiment to ability in the preceding experiments.

Material.—The manthanometer, Ranschburg Apparatus, telegraph key, color disk, six dry batteries, and stop watch are needed in this experiment. The apparatus is set up as shown in figure 19. The 24 large marbles and the 24 small marbles are placed on the left of the marble con-

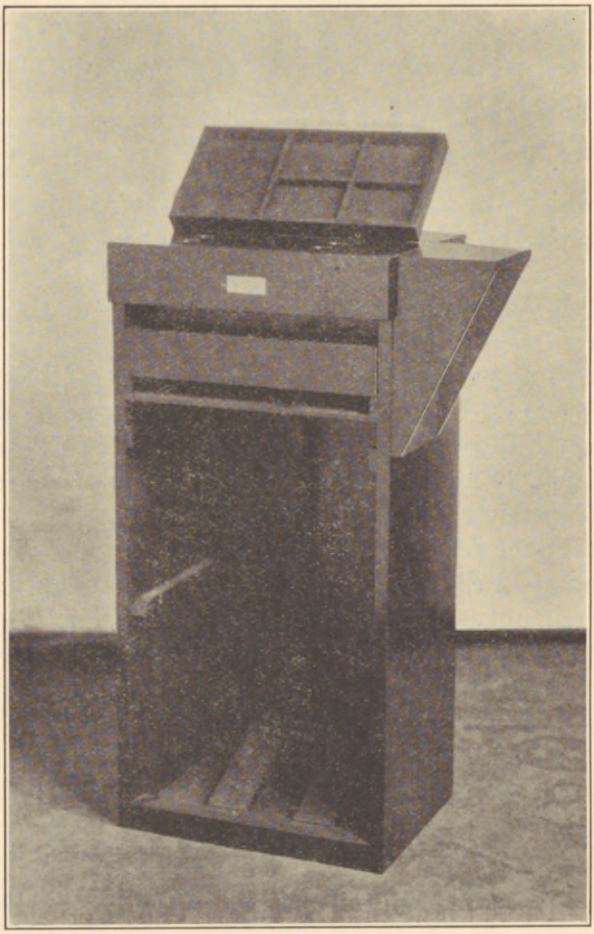

FIG. 19.—Manthanometer (an apparatus for measuring learning capacity).

tainer in the same compartment, and are always to be mixed together before the experiment begins. The colored marbles are placed in the four compartments on the right of the container, the green marbles are placed in the upper left of the four compartments for the colors, the blue marbles in the upper right, the red in the near left and the yellow in the near right. The placing of the marbles is shown in figure 20. The marble container is placed on top of the manthanometer, flat, not inclined as in picture.

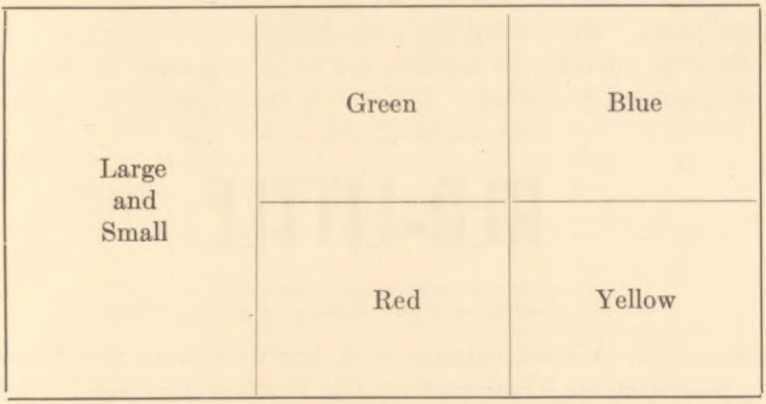

FIG. 20.—Showing arrangement of marbles for manthanometer.

The telegraph key is clamped to the shelf even with the top of the instrument, on the right. The Ranschburg instrument with the color disk is placed on a table immediately behind the apparatus. Inside the apparatus is a drawer with compartments to receive the marbles as they are sorted.

The electric current to operate the color disk should be brought first to a switch, then to the key, then to the Ranschburg apparatus, then back to complete the circuit.

Method.—The subject is told that the object of the experiment is to learn to sort the marbles as fast as possible. The apparatus should be thoroughly explained to him. The colors blue, red, and yellow are to be placed in the hole on the right farthest back, green in the hole nearest, on the right. The large marbles are to be placed in the

hole farthest back on the left, and the small marbles in the hole nearest on the left. The right pedal is to be pressed for the red marbles; the left pedal, for the blue marbles.

To get the stimulus for sorting, the subject presses the key. A colored circle appears in the exposure slit of the Ranschburg apparatus. If this color is red the subject is to get a red marble with the right hand. If the color is large, in the outside of the slit, the subject is to get a large marble with the left hand. If the color is small, toward the left of the slit, the subject gets a small marble with the left hand. Each hand has a marble, a *color* in the right and a *size* in the left, the marbles are to be deposited according to previous directions. The key is then pressed for a new

FIG. 21.—Illustration of card stimulus for manthanometer.

stimulus. A brief statement of the directions should be typewritten and fastened on the front of the top of the apparatus. The subject is allowed to refer to this scheme as the experiment proceeds if he wishes.

While the Ranschburg apparatus is the best means of supplying the stimulus for this experiment, it can be supplied by the use of inexpensive cards. The author has used cards 3¼ by 3¼ inches. On six cards are printed in large letters the words RED-BIG; on six are printed the words RED-LITTLE; on six, GREEN-BIG; on six, GREEN-LITTLE; on six, BLUE-BIG; and on six, BLUE-LITTLE; on six, YELLOW-BIG; and on six, YELLOW-LITTLE. A sample card—reduced in height—is shown in figure 21.

The cards are thoroughly shuffled and placed upright in a small box on the top of the manthanometer to the right side. The cards are taken out one at a time and tossed behind in the back part of the box. The card RED-BIG, for example, means that the subject's right hand is to get

a red marble and the left hand is to get a big marble. The Ranschburg apparatus is preferable if it is available.

After everything is explained to the subject, he should be questioned to ascertain whether he understands the directions and should be allowed to place eight marbles, using the samples on the color disk. After the placing of the samples, the marbles are taken out of the drawer below and placed back in the container. When all is ready, the subject begins and the stop watch is started. When all the marbles are placed, the watch is stopped and the time recorded. The drawer is pulled out and the number of mistakes counted. Every marble not in its proper bin counts as one mistake. The record for each sorting should be kept in terms of number of seconds and number of errors.

The Results.—In table 24 are shown the results obtained from 10 subjects who performed the experiment 31 times.

TABLE 24.—THE MANTHANOMETER EXPERIMENT

The stimulus used was the color disk on the Ranschburg exposure apparatus. Column 1 gives the number of practice; column 2, the number of seconds required to sort the 96 marbles; column 3, the number of errors; column 4, the number of marbles placed per minute.

(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
1	304	7.1	17.5	17	120	1.5	47.2
2	238	4.5	23.1	18	117	1.9	48.2
3	202	3.7	27.4	19	116	1.9	48.7
4	182	3.5	30.5	20	117	1.5	48.5
5	156	4.2	35.3	21	116	1.3	48.9
6	161	2.9	34.7	22	112	1.8	50.5
7	145	1.8	38.9	23	110	1.5	51.5
8	143	1.8	39.5	24	115	1.4	49.4
9	135	1.5	42.0	25	109	1.2	52.2
10	132	1.3	42.3	26	109	.9	52.3
11	127	2.1	44.4	27	107	1.4	53.0
12	126	2.3	44.6	28	109	1.2	52.2
13	124	2.2	45.4	29	105	2.2	54.1
14	117	2.7	47.8	30	104	1.0	54.8
15	117	1.4	48.5	31	105	1.9	53.8
16	126	2.1	44.7				

The subjects were university seniors and graduate students. The experiment was performed three times the first day, four times the second day and eight times on each succeeding day for three days.

Table 24 should be used for comparison in showing the course of the learning curve in an extended experiment. Table 25 should be used as norms if the card form of stimulus is used. The card-stimulus is not suitable for an extended experiment but is perfectly satisfactory for a short experiment as a measure of learning capacity of this type. Table 26 is given to afford a comparison with the results of experiments previously given. It is the basis of the correlations shown in table 28. Table 27 is given to serve as a norm for a three-sorting experiment when

TABLE 25.—MANTHANOMETER EXPERIMENT, CARD STIMULUS

Subjects, 24 seniors, 3 sortings at one sitting

Trial	Time in seconds	Errors	Marbles per minute
1	244	5.1	22.4
2	194	3.8	28.5
3	168	2.4	33.4

TABLE 26.—MANTHANOMETER EXPERIMENT, CARD STIMULUS

Three sortings, scores reduced to a class average of 50 and the three scores combined as a measure of quickness of learning.

Subject	Score	Subject	Score	Subject	Score
A	40	I	50	R	55
B	52	J	49	S	47
C	58	K	61	T	36
D	56	L	53	V	44
E	75	M	31	W	37
F	27	N	56	X	68
G	44	O	59	Y	67
H	39	P	48	Z	53

TABLE 27.—MANTHANOMETER EXPERIMENT

Subjects, 82 juniors, Ranschburg stimulus, 3 sortings

Sorting	Time in seconds	Errors	Marbles per Minute	
			Average	Best
1	270	8.9	19.4	32.3
2	216	4.4	25.4	36.0
3	195	2.8	28.6	39.7

TABLE 28.—CORRELATIONS OF MANTHANOMETER EXPERIMENT RESULTS AS SHOWN IN TABLE 26 WITH THE EXPERIMENTS INDICATED

Substitution, 4th and 5th practice combined	.617
Substitution, Average of the 30 practices	.679
Marble sorting, Average 1st 5 sortings (non-interference)	.767
Marble sorting, Average 7 to 20 (interference)	.734
Card sorting, 9th and 10th sorting combined	.655
Mirror experiment, Average score	.092

TABLE 29.—SHOWING THE CORRELATION OF EACH MANTHANOMETER PRACTICE WITH THE SCORES OF THE 12TH AND 13TH PRACTICE COMBINED, PRACTICALLY THE CORRELATION WITH FINAL EFFICIENCY

Data, the scores of 18 university seniors.

PRACTICE	CORRELATION
1	.59
2	.58
3	.68
4	.79
5	.77
6	.81
7	.80
8	.89
9	.91
10	.84
11	.88

the Ranschburg apparatus is used for the stimulus. The scores are higher than those shown in table 23, because the 10 subjects used for the long experiment were slow learners. The 82 subjects of table 27 are representative university students.

Interpretation and Discussion.—The student should carefully write up the qualitative aspects of the experiment,

touching on such topics as the methods used in learning and remembering the different associations and movements, the easiest things to learn, and the most difficult things to learn.

If an extended experiment is performed, the results may be compared with those in table 24, and the learning curves with that in figure 22. Make a study of the rise of the

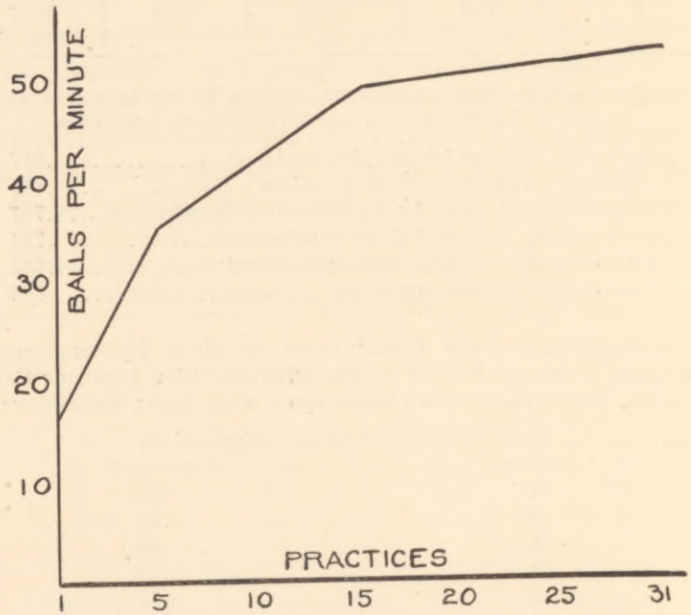

FIG. 22.—Learning curve from manthanometer experiment. Data from Table 24.

curve as compared with the learning curves of other experiments. What are the factors which contribute to improvement? By extended study and comparison, determine what type of student succeeds best at this experiment, and what type has poorest success. Characterise the type of attention which this experiment seems to demand. What kinds of work in life and what situations in life demand the characteristics which give success with this experiment? In the case of an extended experiment, make correlations of standing at various stages with

final efficiency. How early in the experiment can you predict final efficiency? How does this experiment compare with other experiments in this respect?

Whatever the method of performing the experiment, make correlations with the results of preceding experiments. For the purpose of comparing with table 28, the correlations should be made from the combined results of the first three practices. This experiment has characteristics, not found in any of the preceding experiments, demanded in the mastery of complicated simultaneous movements of hands and feet. A careful study should therefore be made of all the correlations. Study should be made of individual subjects. If a student appears very successful in this experiment and very poor in most of the other experiments, additional study should be made of this student in the hope of explaining his success.

Related Experiments.—The manthanometer can be used to test fitness for various industrial occupations, those involving the control and operation of complicated machinery, in which many details must be looked after, such as running an automobile.

Many variations of the experiment can be made. The experimenter can operate the stimulus. Interference can be studied by changing the location of the marbles in the container, or by putting the marbles into different compartments, or by making both changes at once. What type of student most successfully meets the interference? In using the manthanometer, the instructor can learn much by noting the various types of reactions to the instructions. It is instructive to make a classification of the different types.

CHAPTER V

SEMI-MOTOR LEARNING

Experiment VI.—*Semi-motor learning, the substitution experiment.*

Object.—The object of this experiment is to make a study of learning in which there is still a motor element, but in which the motor element is not prominent. In the substitution experiment, two ideas are associated. How well the association is fixed at any time is determined by the quickness of motor response. The motor responses, however, are simple and there is little improvement in the movements themselves, as compared with the improvement possible in the complicated muscular co-ordinations of the three preceding experiments. The essential thing to be fixed in this experiment is the connection between ideas.

Material.—The materials needed for this experiment are the digit-symbol test form and key number 1. For additional experiments, key number 2 may be used.

Method.—The test forms are distributed to the students, as many sheets as they will need for the hour. The instructor then explains to them that they will be given a key which gives a symbol for each of the nine digits, and that they are to use the key in changing the digits to the appropriate symbols. The key is always to be kept before them. The students will not use it after the first few practices. After all is explained and it is sure that the subjects understand, the keys are distributed and turned face down on the desks. At the signal to begin, the keys are turned over by the students and the stop watch is started by the experimenter. It must be clear to the subjects before the experiment begins that they are always to work as fast as possible. At the end of five minutes the signal is given to stop, and the papers are collected immediately. In a similar way the practices are continued till the end

of the period. In the table given below—No. 30—are shown the results of six practices a day for five successive days, a total of 30 five-minute practices.

Results.—The records are kept in terms of the number of squares correctly filled in, in five minutes. As a rule very few mistakes are made. It is fairly accurate to count the

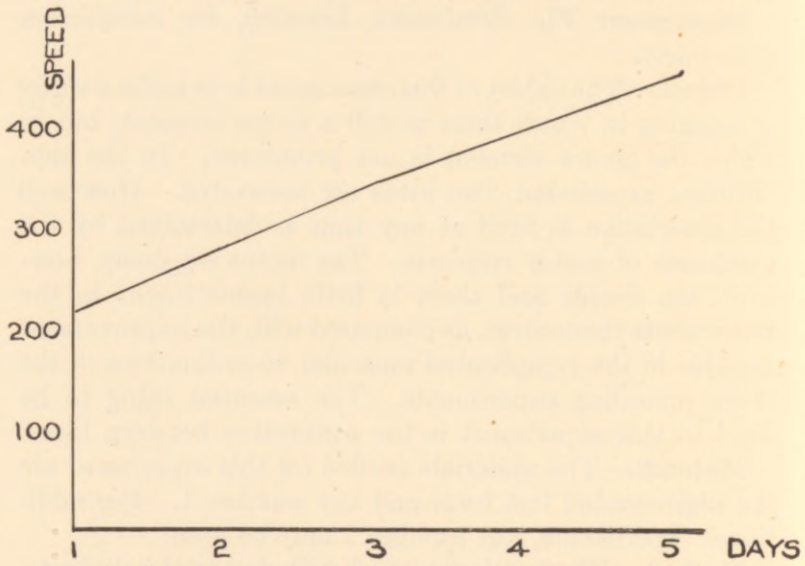

FIG. 23.—Learning curve for digit-symbol substitution experiment. Data from Table 30. The curve shows the average for five minutes for each of five days of practice, six practices daily.

number of squares filled, then grade 25 squares in a group selected at random and grade these for accuracy. Find the per cent. of accuracy for these 25 substitutions and

TABLE 30.—DIGIT-SYMBOL SUBSTITUTION, 30 FIVE-MINUTE PRACTICES, [1] 24 SUBJECTS

Column 1 gives the number of practice, column 2 gives the number of substitutions in 5 minutes.

1	167	7	269	13	322	19	395	25	448
2	197	8	277	14	340	20	401	26	449
3	209	9	292	15	348	21	413	27	459
4	229	10	303	16	357	22	413	28	457
5	243	11	309	17	357	23	418	29	472
6	252	12	307	18	363	24	416	30	463
Daily Av.	216	Av.	293	Av.	348	Av.	409	Av.	458

TABLE 31.—DIGIT-SYMBOL SUBSTITUTION, 93 UNIVERSITY JUNIORS, 2 FIVE-MINUTE PERIODS ONE DAY, AND 2 ON THE SECOND DAY AFTERWARD

PRACTICE	AVERAGE SCORE
1	164
2	191
3	215
4	230

TABLE 32.—SUBSTITUTION EXPERIMENT. SCORES REDUCED TO A CLASS AVERAGE OF 50

Every fifth record is shown. The eighth column is the average for the whole experiment. The ninth column is a speed record in writing. The tenth column is the co-efficient of variability.

Practice.....	(1)	(5)	(10)	(15)	(20)	(25)	(30)	Av.	Sp.	C.V.
Subject										
A	48	56	42	43	44	47	48	46.6	47	.069
B	51	56	60	56	60	59	61	58.6	55	.038
C	44	59	52	54	58	54	50	54.3	53	.036
D	55	53	52	56	55	52	54	53.0	49	.036
E	54	60	56	58	56	50	50	56.3	55	.055
F	40	38	44	43	48	47	48	44.3	49	.081
G	43	31	37	40	38	37	39	38.1	37	.051
H	54	48	44	52	59	53	53	49.9	47	.088
I	39	45	48	47	46	46	45	45.9	52	.053
J	52	58	61	50	51	55	52	54.5	51	.061
K	46	38	31	29	26	29	32	31.6	50	.134
L	36	37	37	39	40	41	30	36.1	56	.073
M	55	51	38	39	44	45	50	44.9	51	.087
N	54	55	57	58	58	55	59	57.4	58	.029
O	51	41	47	51	53	57	55	50.2	53	.088
P	48	49	55	55	56	56	57	53.1	52	.058
R	60	54	63	60	60	58	55	57.4	53	.039
S	54	55	56	51	53	53	58	54.6	46	.038
T	39	40	46	43	36	38	39	41.3	37	.062
V	41	47	42	46	43	44	48	44.3	49	.060
W	49	45	41	39	36	37	36	38.2	51	.098
X	58	68	65	70	68	66	67	67.5	53	.030
Y	63	68	65	62	65	68	64	66.9	56	.033
Z	54	60	58	54	50	51	48	53.9	47	.069

TABLE 33.—SHOWING THE CORRELATION OF EACH SUBSTITUTION PRACTICE WITH THE SCORES OF THE 29TH AND 30TH COMBINED

Column 1 indicates the number of practice, column 2 indicates the correlation of this practice with the 29th and 30th combined.

(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1	.70	8	.83	15	.91	22	.94
2	.70	9	.83	16	.86	23	.93
3	.62	10	.84	17	.94	24	.97
4	.67	11	.85	18	.91	25	.95
5	.76	12	.91	19	.88	26	.96
6	.71	13	.89	20	.93	27	.99
7	.85	14	.90	21	.93	28	.98

TABLE 34.—SHOWING THE CORRELATION OF THE SUBSTITUTION TEST WITH OTHER TESTS

SUBSTITUTION		
4 + 5	with 9th + 10th card sorting	.52
Average	with average of card sorting	.53
4 + 5	with average manthanometer	.62
Average	with average manthanometer	.68
Average	with marble sorting, non-interference	.55
Average	with marble sorting, interference	.57

TABLE 35.—SHOWING THE CORRELATION OF MUSCULAR SPEED IN WRITING WITH VARIOUS STAGES OF PRACTICE IN THE SUBSTITUTION TEST

Speed was determined by two tests of speed in writing a phrase and two tests in writing a letter over and over. The first column of the table indicates the number of practice and the second column indicates the correlation with speed.

TRIAL	r
1	.33
5	.45
10	.39
15	.41
20	.50
25	.42
30	.38

correct the raw score accordingly. For example, if one error is found in the 25 substitutions, deduct 4 per cent. from the total score.

Study and Interpretation of Results.—(1) Make a study of the class-average curve. Compare this curve with the learning curves of preceding experiments.

2. Make a study of individual differences, comparing the curves of different types of learners.

3. Make a special study of the relation of each individual to the class average at various stages of practice. Can any general statement be made concerning this relationship? What do the correlations show on this point? See table 33.

4. Compare individual ability in this type of learning with ability in types of learning studied previously. For such comparison use the average scores for the first day of practice in the substitution experiment.

5. How important is the motor element in this experiment? Interpret table 35.

6. How soon, in this experiment, can final efficiency be predicted?

Related Experiments.—(1) An interesting related experiment can be performed by writing with a key alphabet. The procedure is as follows: The instructor prepares a key alphabet, representing each letter by a very simple symbol. Each subject is provided with a copy of the symbol-alphabet. Printed matter such as an article in a magazine is transcribed into characters of the symbol-alphabet. In this experiment there are twenty-six characters to learn instead of nine. Progress is therefore much slower. Half-hour periods are therefore best in this experiment. The character of the curve should be compared with the curve for digit-letter substitution.

2. The substitution experiment affords a good opportunity to study economical methods of learning. In such learning as digit-symbol learning is it best to begin at once to use the key, or is it profitable to study the key for a time before using it? On the basis of the digit-letter substitution experiment, the class should be divided into two groups of equal learning capacity. One group proceeds to use the key from the beginning, the other group studies the key for a time. Of course, a new key is used for this experiment. If it is desired to compare the relative value of different lengths of study periods, the class should be

divided into several groups. Different groups can then study for different lengths of time. If the class is small, the divisions should be limited to two. The value of different periods of study can be determined by using different keys for each comparison. Whatever the procedure used, there should always be a control group. If the digits are used for the different experiments, the effects of inhibition will have to be considered. It will be best to use a procedure that rules out the effects of inhibition. This can be done by using the digit-letter substitution as a basis for division into groups, then use letter-symbol substitution to determine the effects of study before using the key.

CHAPTER VI

RETENTION OF MOTOR LEARNING

Experiment VII.—*Retention of motor learning.*

Object.—The purpose of this experiment is to make a study of the retention of motor learning with particular reference to individual differences and the relation of retention to quickness of learning.

TABLE 36.—RETENTION EXPERIMENT—CARD SORTING

Subject	(1)	(2)	(3)	(4)	(5)
A	67	89	112	43	45
B	90	94	106	41	32
C	75	86	116	45	42
D	80	86	116	45	42
E	63	75	133	51	62
F	65	74	135	52	57
G	64	71	141	54	50
H	70	81	123	47	41
I	71	72	139	54	47
K	63	67	149	57	64
L	66	67	149	57	64
M	61	68	147	57	57
N	79	90	111	43	39
O	51	52	192	74	77
P	82	82	122	47	53
R	89	105	95	37	31
S	69	80	125	48	55
T	73	79	127	49	42
Average.....	71	73.1			

In the table above the first column of figures gives the final speed attained in the original experiment, the second column gives the average speed attained in the retention experiment, the third column gives the reciprocals of the relearning scores, the fourth column gives the reciprocals reduced to a class average of 50, and the fifth column of figures gives the average scores of the first day of the original experiment—reciprocals reduced to a class average of 50.

Apparatus, Material and Method.—For this experiment, the card-sorting apparatus and cards are used. One month after the close of the card-sorting experiment—No. 3—the experiment is performed again for four sortings. This is sufficient for most subjects to regain their highest speed attained in the first experiment. In the experiment

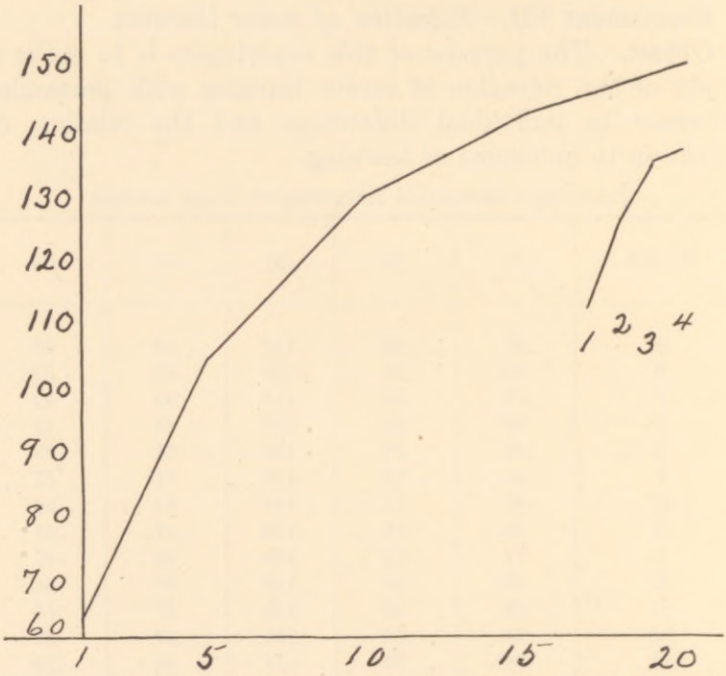

FIG. 24.—Card-sorting retention. Four practices compared with the original learning—twenty practices.

as here reported, three rows of the sorting box were used, fifteen pigeon holes, 75 cards, in both the original and retention experiments.

Results.—In table 36 are shown the final speeds attained in the original experiment, obtained by averaging the two final sortings, the average of the four sortings, the reciprocals of the averages, and these reciprocals reduced to a class average of 50. The final column shows the average efficiency attained by each subject in the first day of the original experiment.

The retention scores give the following correlations:

With first day original card sorting	.89
With final speed original sorting	.92
Per cent. of retention with first day of original sorting	.20
Per cent. of retention with final speed	.25

If we divide the class into two halves, the one composed of those students making the best scores in the first day's work

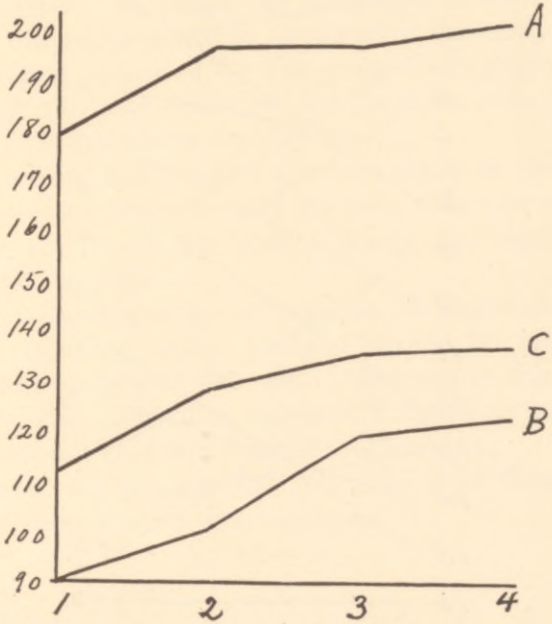

FIG. 25.—Comparing the re-learning curves of the best and poorest in the original learning. A = best, B = poorest, C = class average for re-learning.

of the original sorting, and the other composed of those making the lowest scores on the first day's work, we find that the average per cent. of retention of those having the high first day scores is 81.6, and the average per cent. of retention of those having the low scores is 79.8.

The course of relearning as compared with the course of the original learning is shown in figure 24. Figure 25 shows the relearning of the person who was the quickest

learner in the original experiment and the person who was the slowest learner in the original experiment, together with the curve of the class average for relearning. Figure 26 shows the relative position of each subject for the first

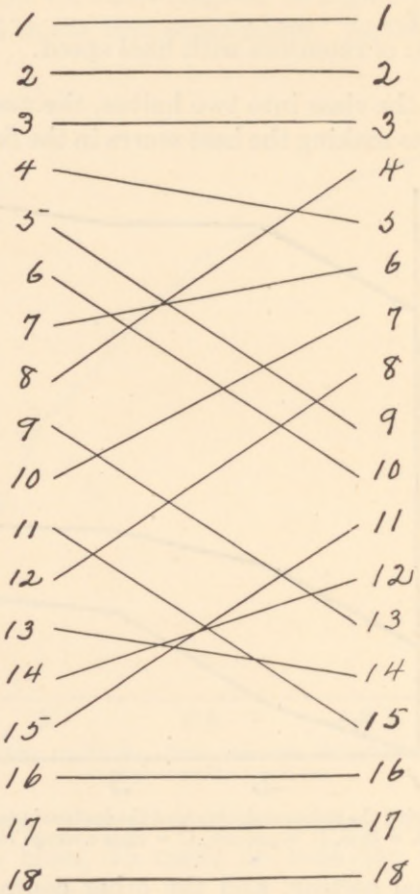

FIG. 26.—Comparing the ranks of the subjects in the re-learning experiment with their ranks on the first day of the original experiment.

day of the original experiment and in the relearning experiment.

Interpretation of the Results.—The various methods of considering the data shown above all lead to the same conclusion: The relative ability of students in retention is

about the same as their learning ability, in the case of motor skill as required in card-sorting. Retention seems to have a slightly closer relation to final efficiency than to learning capacity, but all three functions are closely related. The percentage of retention is much the same for all types of learners. This is shown by two different comparisons. The per cent. of retention correlated with learning capacity as shown by the first day's scores is only .20, and with final efficiency is .25. This is little more than the probable error. Although the correlation is small it is in favor of the better retention of the good learners, and the same thing is indicated by the group comparison of the good with the poor learners, the good learners showing about 2 per cent. better retention.

The student should make a careful study of the results obtained in the experiment of his own class and compare with the results shown here. Clearly summarize your results and conclusions.

Related Experiments.—If possible the retention of skill in other types of motor learning should be made and comparison made with the results obtained in this experiment; and the retention of motor skill should be compared with the retention of skill in ideational learning.

Question.—What are the educational implications of the facts discovered in this experiment?

CHAPTER VII

A STUDY OF INHIBITION

Experiment VIII.—*A study of inhibition.*

Object.—The object of this experiment is to study the interference effects of one habit upon another. In particular, we seek here an answer to the question: Does interference affect most the fast learner or the slow learner?

Apparatus and Material.—For this experiment the same apparatus and material are used as in experiments 3 and 7.

Method.—After the retention experiment—number 7—the sorting box is turned over and the reverse side is used for this experiment. The reverse side contains the same numbers but arranged differently. The habits formed in the original card-sorting experiment are to constitute the interference in this experiment. The habits are revived and brought back to full function by the retention experiment, after which this experiment immediately begins. Five sortings should be made.

Results.—The raw data for the members of the class should be tabulated, the average for each subject determined, the reciprocals of the averages, and then these reciprocals reduced to a class average of 50 for study and comparison. In table 37 the results obtained from 18 subjects are shown. The first five columns show the individual scores; column 6, the averages; column 7, the reciprocals; column 8, the reciprocals reduced to a class average of 50; column 9, the scores made in the original experiment on the first day of sorting; and column 10 the final speed attained in the original experiment.

The inhibition experiment gives the following correlations:

With first day card-sorting	.74
Final speed in card-sorting	.75
Retention in card-sorting	.88
Per cent. retention	.36

TABLE 37.—INHIBITION

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
170	180	162	150	120	156	641	36	45	43
197	137	92	89	84	120	833	46	52	41
162	124	78	78	75	103	971	54	42	45
189	137	120	99	81	147	680	38	42	45
127	103	90	84	70	95	1053	58	62	51
150	100	94	75	80	100	1000	55	57	52
136	93	73	74	73	90	1111	61	50	54
187	131	95	81	77	114	877	49	41	47
171	111	87	80	70	104	962	53	47	54
160	120	80	80	68	102	980	54	64	57
180	99	73	71	71	99	1010	56	64	57
150	92	75	70	70	91	1098	61	57	57
196	170	135	124	115	148	676	37	39	43
154	75	51	51	55	75	1333	74	77	74
190	155	103	90	80	115	870	48	53	47
184	141	129	133	128	143	699	39	31	37
232	140	125	101	100	140	714	39	55	48
141	135	170	111	90	129	775	43	42	49

In the table above, the first five columns give the individual scores in the inhibition experiment; the sixth gives the averages, the seventh gives the reciprocals of the averages; the eighth gives the reciprocals reduced to an average of 50; the ninth gives the scores of the first day of the original sorting, and the tenth gives the retention scores of experiment No. 7. The last three columns are on a basis of 50 for the class average.

These correlations indicate that the fast learners quickly recover from the effects of inhibition and attain the same rank in the inhibition experiment, approximately, that they held in the original card-sorting experiment. The highest correlation of all, in fact, is with retention. Therefore we may say that these eighteen subjects held about the same rank in the inhibition experiment that they held with reference to their learning capacity in card-sorting, and that they held with reference to their retentive capacity in card-sorting.

Another method of treating the results is to make a direct comparison of the three best learners and the three poorest

learners. The three best learners make an average score on the first day of card-sorting of 68⅓, with reference to a class average of 50; the three poorest learners make an average score of 34. In the inhibition experiment, these three best learners make an average score of 61⅓, while the three poorest learners make an average score of 41. This comparison leads to the same conclusion indicated by the correlations, namely, that the good learner overcomes the effects of inhibition as readily as does the poor learner.

Discussion and Interpretation.—In motor learning, the quick learner is not only able to meet a new situation but is adaptable in the face of interference. Of course, there is some question as to the degree of fixity of the habits at the end of the original experiment. If we are to take efficiency shown as a criterion of how well the habits were fixed, the fast learners had the habits best established, and it ought therefore to have been more difficult for them to form a new interfering habit. This was probably the case, but in spite of this greater difficulty they overcame the interference and attained their accustomed rank. The ability to overcome an interference is probably an indication of high learning capacity.

The results may be studied from many different points of view. For example, a comparison may be made of the relative position of the different subjects at the beginning of the interference experiment with their positions at the end. The results of the first sorting may be correlated with the results of the last sorting, and the first sorting and the last sorting of the inhibition experiment may be separately correlated with the results of the first day of the original sorting. The student should make these correlations and interpret the results.

The inhibition learning curves of the fast learners may be compared with those of the poor learners. Their inhibition curves may be compared with their original learning curves for the same number of practices. The averages of the actual scores in the inhibition experiment with the

corresponding averages in the original card-sorting experiment on the first day are as follows:

First 5 original sortings.....	167	135	120	111	99
Inhibition averages.....	171	122	102	91	83

The corresponding reciprocals are as follows:

First original sortings.....	60	74	83	90	101
Inhibition sortings.....	58	82	98	110	120

This comparison is shown graphically in figure 27.

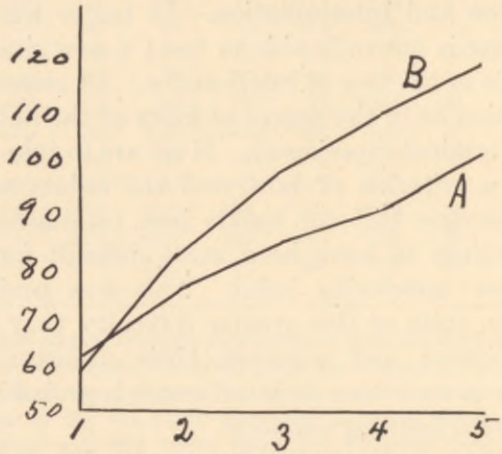

FIG. 27.—Comparing efficiency in the card-inhibition experiment with efficiency in the first five sortings of the original experiment. *A* = original sortings. *B* = inhibition sortings.

It is seen that after the first sorting, the scores in the inhibition experiment are better than in the first sortings in the original experiment. The student may interpret this fact.

Related Experiments.—Inhibition may be studied in relation to almost any habit. The marble sorting experiment was devised as an inhibition experiment. The habits may be definitely fixed with reference to one scheme of sorting, then the lids may be changed, or the color scheme may be changed, at the same time or separately. The manthanometer experiment lends itself to several forms of inhibition. By using different keys, the substitution

experiment may be used as an inhibition experiment. A study should be made with inhibition in at least one other type of learning and the results compared with the results from this experiment.

The inhibition experiment should be correlated with all the other types of experiments performed by the class to see what further facts may be discovered with reference to the relation of inhibition to learning capacity and to intelligence in general.

Make a clear statement of the facts learned in this experiment. Apply to education and to life.

CHAPTER VIII

TACHISTOSCOPIC LEARNING

Experiment IX.—*The spot pattern test.*

Object.—The object of this experiment is to make a study of the learning of visual patterns, to make a study of individual differences in this type of learning, and to compare this type of learning ability with other types.

Material and Apparatus.—The Whipple tachistoscope (see figure 28) and visual exposure cards are used for this experiment. The weights are set on the meter stick pendulum so as to give an exposure of three seconds. In the experiment as reported below, three seven-spot and two eight-spot patterns were used. The spot-pattern material can be prepared on a mimeograph. The material standardised for this experiment consists of five seven-spot patterns, numbered from 1 to 5. A square 48 mm. on a side is divided up into 36 squares 8 mm. on a side. On these squares the patterns are made by placing heavy dots at the intersections of the lines, seven dots on each pattern. After the exposure pattern is made it is pasted on a piece of cardboard 20 cm. by 13 cm. The top of the card must be designated, and the cardboard is placed in the large exposure holder always with the proper side up. The subject is provided with blank cross section squares exactly like the exposure cards except that the pattern is not on them.

Method.—The subject is placed in a chair in front of the tachistoscope and the head rest is adjusted. The nature of the experiment is then thoroughly explained to the subject. The working of the apparatus is demonstrated by operating it without a card in the holder. After the subject understands and everything is ready, the subject

places his head in the head rest and fixes his eyes on the place where the exposure is to be made. After a ready signal and an interval of about a second and a half, the pendulum is released and the exposure made. As soon as the exposure card is completely covered up, the subject reproduces the pattern as nearly as he can. His reproduction is then turned over out of sight and another exposure

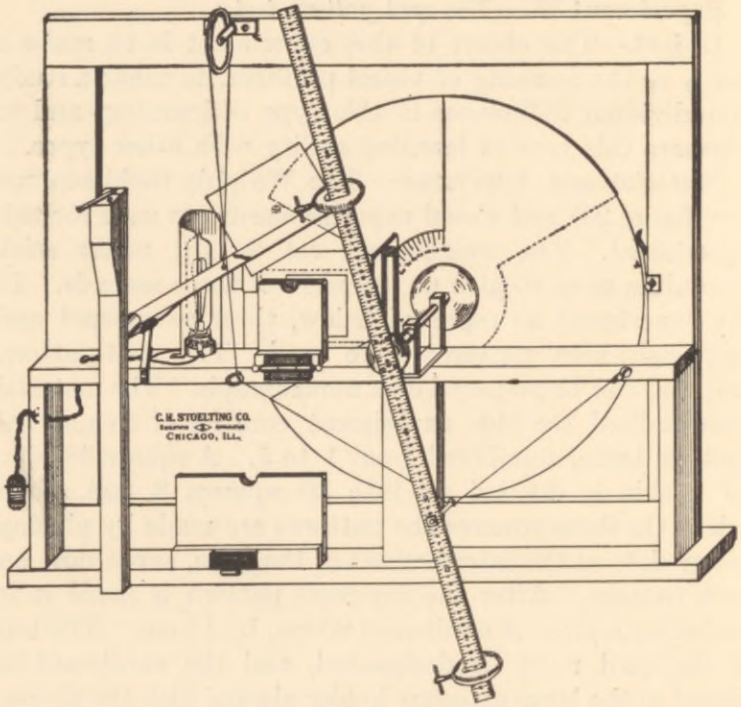

FIG. 28.—Whipple tachistoscope.

made and reproduced as in the first exposure. The experiment proceeds till the subject makes a perfect reproduction. The score is the number of exposures required for a perfect reproduction. In the process of the experiment, whenever the subject thinks he has a perfect reproduction, the experimenter examines the reproduction. If it is perfect the experimenter puts in another exposure card,

but if it is not perfect, the experimenter proceeds to give more exposures till the pattern is perfectly reproduced. After one pattern is correctly reproduced, the experimenter proceeds with the other patterns in a similar way until the

TABLE 38.—SPOT-PATTERN

Subject	Practices					Sum	Rec.	Av. 50
	(1)	(2)	(3)	(4)	(5)			
A	4	9	5	5	4	27	37	39
B	4	3	3	4	3	17	59	62
C	3	5	3	7	3	21	48	50
D	3	4	1	7	3	18	56	58
E	5	6	6	4	2	23	43	45
F	4	11	4	14	5	36	28	29
G	2	3	3	7	4	19	53	55
H	5	8	5	2	7	27	37	39
I	4	6	5	3	3	21	48	50
J	2	4	2	5	2	15	67	70
K	3	7	6	8	5	29	34	35
L	4	8	2	4	1	19	53	55
M	7	5	7	13	3	35	29	30
N	2	6	4	8	5	25	40	42
O	2	8	2	6	6	24	42	44
P	1	7	5	3	2	18	56	58
R	3	3	7	2	3	18	56	58
S	5	5	3	3	2	18	56	58
T	5	7	4	4	4	24	42	44
V	4	8	3	6	3	24	42	44
W	2	10	2	5	2	21	48	50
X	2	3	4	4	3	16	63	65
Y	3	4	5	6	3	21	48	50
Z	3	3	3	4	2	15	67	70
Average....	3.4	6.0	3.9	5.6	3.3	22.1	48	50

In the table above, the first three columns of scores are for the seven-spot patterns and the fourth and fifth are for the eight-spot patterns. The scores for the standard seven-spot patterns, as obtained from 18 university students, are: for pattern 1, 4 exposures; for pattern 2, 8 exposures; for pattern 3, 3.7 exposures; for pattern 4, 4.7 exposures; for pattern 5, 4.4 exposures. The average for the five patterns is just under five exposures.

five are given. Of course, if there is time, the experiment can be extended to include as many patterns as the instructor desires.

Results.—In table 38 the raw data for 24 subjects are shown in the form of the number of exposures required for the first three seven-spot patterns and the first two eight-spot patterns. The sum of the number of exposures is given, and then the reciprocal of the sum which may be taken as the efficiency. The last column shows the reciprocals reduced to an average of 50.

The correlations of the results of the spot-pattern test with the results of the preceding experiments are as follows:

With ball tossing	.107
With mirror writing	.219
With card sorting	.522
With manthanometer	.222
With marble sorting	.52
With card-sorting retention	.648
With card-sorting inhibition	.733

Discussion and Interpretation.—It is seen that ability in the spot-pattern test has a high positive relation to ability in card-sorting and marble sorting but not a high relation to the abilities shown in the other types of experiment. It is also evident that the spot-pattern ability gives a higher correlation with card retention and inhibition. This indicates that the retention and inhibition experiments have high diagnostic value. They are measures of highly important mental functions. The spot-pattern results should be carefully compared with the results of all succeeding experiments, in an attempt to determine what, if any, specific abilities are required in the spot-pattern test. If there is time, the spot-pattern experiment may be much extended for the purpose of discovering what subjects show most improvement in it.

Suggestions to be Followed by Students.—(1) Each student, in writing up this experiment, should give a

detailed description of the methods used in learning the patterns. If different methods were used by the same learner at different times, the fact should be noted and the results compared. The methods used by different learners, and by the same learner at different times should be studied and the results compared in order to discover, if possible, the relative value of different methods. In order to provide the data for this study, each student should make careful notes during the progress of the experiment stating how each pattern was learned, mentioning the difficulties and the easy points of each pattern. When the experiment is over, each student should take his notes and write an extended and critical discussion of his methods. The instructor should make a study and comparison of these reports and give his results and conclusions to the class; or a group of students could make the study and comparison and report to the class. If desired, each student could make the study and draw his own conclusions.

2. A careful study of individual differences should be made. Are good learners uniformly good throughout the experiment? Are poor learners uniformly poor? Does it ever happen that a person, poor at first, discovers a method that puts him among the best learners? If such a case is found, it should be studied and its significance discussed.

3. Study the correlations to determine the relationships of this type of learning. Interpret what you find.

4. Does the spot-pattern test demand a specific ability? If so, give the evidence and characterise the ability.

5. If a specific ability is required, what are some other tasks in life that require the same ability? Is there any evidence that artists, mechanics, or inventors have a specific ability? What is the evidence? Can you throw any light on the question by testing such people with the spot-pattern test?

Related Experiments.—By using the same tachistoscope with the same setting, studies similar to the spot-

pattern test can be made. One type of such experiment is the following: Expose pictures for three seconds and require the subject to make a simple sketch of the parts of the picture. If there is time to perform such an experiment, compare the results with those of the spot-pattern experiment. By using a large picture, the experiment can be made a group experiment. The picture can be exposed by holding it before the class for a definite number of seconds. This, however, is a very rough method, because some members of the class will not be able to see the picture as well as others.

Experiment X.—*Quickness of perception.*

Object.—This and similar experiments have been called measures of the span of attention. They have also been called measures of the immediate memory span. This experiment might very well be called a measure of the quickness of perception. Of course, it involves what is ordinarily called *attention,* and it also involves *memory.* In this experiment we have learning reduced to very simple terms. The characters (letters) used are already known by name to the subjects, who are merely required to report as many as possible after a group of the letters have been shown for a very brief time. The primary object of this experiment is to ascertain what relation may exist between efficiency and quickness of perception and more complicated forms of learning.

Method and Material.—The apparatus for this experiment is the Whipple tachistoscope set up to give an exposure of 60 thousanths of a second (60σ). To secure this exposure, set one weight of the pendulum at 5 cm. and the other at 60 cm. See Whipple's Manual Vol. I, page 266. For material, use exposure cards containing groups of letters, 10 cards each containing six letters and 10 cards each containing seven letters. First the six-letter cards are exposed, then the seven-letter cards. The procedure is as follows: The head-rest is adjusted to suit the subject. The subject places his head in the head-rest and fixates the fixation spot. He is told that a group

of letters will be shown for a very brief time and that after the exposure is made he is to write down on a sheet of paper provided all the letters that he can of those shown. The letters must be written in their place and order. Only letters in their proper position are counted. Before the experiment proper begins two or three sample cards should be shown so that the subject may become accustomed to the apparatus and procedure. The experimenter should before each exposure give the ready signal so that the subject may be on the alert and have the eyes focused on the fixation mark. It is important to be careful and uniform in this procedure. After each exposure the subject writes down the letters he can recall, and in their proper place. After the experiment is over, the written report of the subject is compared with the letters on the stimulus cards, and given credit for each letter in its proper position. The subject should indicate omitted letters by dashes, thus, EW_H_ _G. The student's note book should contain a complete and detailed record of the experiment. In one column he should give the letters of the *stimulus* card and in a parallel column, the letters which he reported which might be called the *response*. The class record should contain for each student the total number of letters reported correctly for the six-letter cards and the total number reported correctly for the seven-letter cards. The score for the whole experiment is the total number of letters reported correctly for both the six and seven letter cards.

Results.—The raw data and the raw data reduced to a class average of 50 are shown in table 39.

Study and Interpretation of Results.—(1) The average co-efficient of variability should be computed and compared with the variability in other experiments.

2. The correlation between the six-letter and the seven-letter cards is only .52. What does this low correlation indicate?

3. Study the correlation table and interpret the results shown there.

TABLE 39.—QUICKNESS OF PERCEPTION

Subject	6-letter	7-letter	Sum	Sum to 50
A	28	29	57	50
B	28	27	55	49
C	27	31	58	51
D	21	33	54	48
E	23	27	50	44
F	8	29	37	33
G	36	32	68	60
H	24	23	47	42
I	26	31	57	50
K	39	42	81	72
L	27	19	46	41
M	25	31	56	50
N	26	22	48	43
O	34	37	71	63
P	20	27	47	42
R	23	26	49	44
S	37	40	77	68
T	30	27	57	50
Average.....	26.8	29.6	56.4	50

The table above is self explanatory. The first column of figures gives the scores for the six-letter cards; the second column, for the seven-letter cards; the third column, the sum of both; and the fourth column gives the scores reduced to a class average of 50.

CORRELATIONS

Six-letter with seven-letter quick perception		.52
Quick perception with spot-pattern		.09
	inhibition	.19
	retention	.39
	marble sorting	.25
	substitution	.59
	manthanometer	.37
	card sorting	.33
	mirror writing	.08
	ball tossing	−.03
manthanometer marble sorting substitution	combined	.41

4. To what extent is acuity of vision a factor in this experiment?

5. In all the experiments which follow, make a careful comparison with the results of this experiment.

6. If possible compare quickness of perception in adults with that of children, and with subjects of very low order of intelligence.

Related Experiments.—Quickness of perception may be studied by using objects as stimuli. The method is to arrange ten common objects in a group on a table. The subject is allowed to look at them for six seconds, and then required to turn around and name as many as he can. The experimenter keeps a record of the objects named. The experiment should be repeated with a half dozen different groups of objects. Another similar method is to use pictures of objects. The pictures can be cut from mail order catalogues and pasted on a large cardboard, ten pictures on one cardboard. At least six sets should be used. The subject's score is the average number of objects or pictures reported.

The results of all the various experiments in quick perception should be compared with one another, and the combined results with the results of all other experiments performed. In the study of individual differences in quick perception, special attention should be paid to types. Do artists, for example, show up better in this type of experiment than do other people?

Experiment XI.—*Tachistoscopic verbatim learning.*

Object.—The object of this experiment is to make a study of verbatim learning under the definite and precise conditions afforded by the use of the Whipple tachistoscope. We shall expect to learn the relation of ability in quick verbatim learning to ability in other types of learning. We shall be especially interested in the comparisons with the other types of tachistoscopic learning and with the motor learning experiments. Later, we shall compare the results with other types of verbatim learning and with substance learning.

Material and Apparatus.—The apparatus used in this experiment is the Whipple tachistoscope set to give an exposure of three seconds. The large card holder is used, and the apparatus is set up as described in Whipple's Manual page 280.

The material used by the author in this experiment consists of ten stanzas of poetry, four lines to the stanza. The stanzas are typewritten on ordinary letter paper and pasted on stiff cardboard of the proper size for the card holder of the tachistoscope. The size of the cardboard is 20 cm. by 13 cm. The title of the poem used is *The World's Music.*

Method.—The subject is seated before the tachistoscope and the head rest adjusted as in the spot-pattern experiment. The stanzas are exposed in order from the first to the tenth, each stanza for three seconds, and once only. The usual signal for the exposure is given a little over a second before the pendulum of the tachistoscope is released. Immediately after the exposure, the subject repeats as much of the stanza as he can. The experimenter, who quickly takes the card from the holder, looks at the stanza as the subject repeats and notes the number of words correctly repeated. The score for the stanza, the number of words repeated correctly, is then recorded, and the next stanza given in a similar way, and so on till all are given. Before the experiment begins, the subject should understand exactly what is expected of him. He should be especially instructed to fixate the eyes carefully just as the exposure is made and to give an oral reproduction as soon as possible after the exposure.

Results.—The scores for 18 subjects are shown in table 40. The scores for the first and second half are given separately and the two columns are correlated to give a measure of the constancy of the test. The third column is the sum of the two halves and constitutes the score for the experiment. The last column gives the scores reduced to a class average of 50.

Study and Interpretation of Results.—(1) Compare standing in this type of learning with standing in other types of learning. How does the average correlation of this experiment with the other experiments compare with the similar averages of the correlations of other experiments?

2. Make a study of individual variability. Compare students having low variability with those having high variability. What type of student is variable? What type is constant?

TABLE 40.—TACHISTOSCOPIC VERBATIM LEARNING

The first column of figures gives the individual scores for the first five stanzas; the second column gives the scores for the last five stanzas; the third column gives the total score for the experiment; the last column gives the scores reduced to a class average of 50.

A	36	44	80	38
B	28	31	59	28
C	57	58	115	54
D	31	48	79	37
E	49	60	109	51
F	47	58	105	49
G	52	65	117	55
H	44	61	105	49
I	51	62	113	53
K	71	84	155	73
L	44	52	96	45
M	53	65	118	56
N	42	58	100	47
O	66	65	131	62
P	41	48	89	42
R	64	67	131	62
S	45	54	99	47
T	49	54	105	50
Average	48.3	57.4	105.9	50

TABLE 41.—SHOWING THE CORRELATION OF TACHISTOSCOPIC VERBATIM LEARNING WITH OTHER TYPES OF LEARNING

WITH	r	WITH	r
Ball tossing	−.50	Substitution	.42
Mirror writing	.48	Retention (cards)	.49
Manthanometer	.29	Inhibition (cards)	.54
Card sorting	.38	Spot-pattern	−.03
Marble sorting	.59		

3. Each student should make a detailed statement of his method of learning the stanzas. The methods of learning should be compared with the scores in an effort to discover what methods are best.

4. The individual differences in this experiment should be studied from all points of view. The subjects making the highest scores should be compared with those making the lowest scores, from the points of view of interest in literature, previous courses taken in college, age, sex, experience in committing poetry to memory, etc.

Related Experiments.—Different types of poems can be used in order to show whether students maintain the same rank in learning different kinds of poetry.

CHAPTER IX

SERIAL LEARNING

Experiment XII.—*The learning of series of nonsense syllables.*

Object.—The object of this experiment is to make a study of the learning of nonsense syllables serially presented. In detail, we shall expect to discover the factors involved in such learning and the relation of ability in this type of learning to ability in other types of learning.

Apparatus and Material.—The apparatus for this experiment is a Jastrow tachistoscope (see figure 29). The material consists of five series of nonsense syllables, ten syllables in a series. The syllables are printed on a cardboard which fits the tachistoscope.

Method.—The experiment is a group experiment and can be given to as many as twelve in a group. The subjects are seated along the sides of a long table. The apparatus is placed on one end of the table. The syllables are exposed at the rate of one a second. It is convenient to have a second's pendulum swinging on the wall opposite the experimenter. The subjects look at the syllables as they are exposed, and after the ten syllables are exposed the subjects write down as many of the syllables as they can recall. The syllables are to be written down in their proper order and position. After they are written down, the report is labeled "exposure 1" and collected or put out of sight and must not be seen again until the end of the experiment. Ample time should be given for the writing, but *no more*. The subjects are merely to write down what they can *readily* recall. A second exposure is then made and a report made as at first. The experiment proceeds till five exposures have been made. After each exposure the subjects write down the syllables in their proper order

and the written reports are taken up or put out of sight, each report being properly labeled and numbered.

Results.—Since some subjects learn all the syllables with four repetitions or exposures, efficiency in this experiment is represented by the sum of the syllables learned in the first four exposures of each series. After

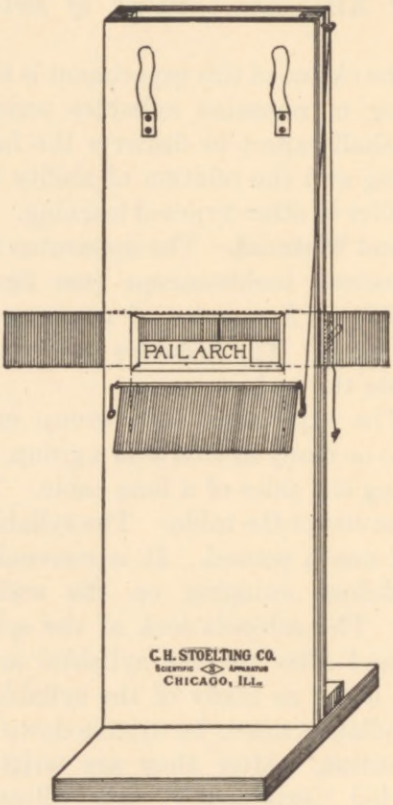

FIG. 29.—Jastrow tachistoscope.

the experiment is finished, the material is assembled, all the reports of the same subject being placed together. The papers are then scored. Credit is given only for syllables that are in their proper position or order. The first report of the first series is scored by marking on the paper the number of syllables that are there and in their

proper order. The second report is scored in a similar way, and so all the others. A subject's learning efficiency for the first series is represented by the sum of the syllables reported for the first four exposures. The other four series are similarly scored. The subject's efficiency for the whole experiment is represented by the sum of his

TABLE 42.—NONSENSE SYLLABLES

Subject	Sum of 5 series	Average 50
A	42	21
B	58	29
C	128	63
D	73	36
E	141	70
F	113	56
G	105	52
H	119	59
I	104	51
K	122	60
L	102	50
M	112	55
N	82	41
O	132	65
P	111	55
R	87	43
S	94	46
T	97	48
Average	101.2	50

TABLE 43.—CORRELATIONS—NONSENSE SYLLABLES

NONSENSE SYLLABLES WITH	r
Ball tossing	−.51
Mirror writing	.39
Manthanometer	.77
Card sorting	.59
Marble sorting	.54
Three motor combined	.65
Card retention	.58
Card inhibition	.74
Substitution	.38
Spot pattern	.34
Tach. poetry	.64
Quickness perception	−.09

scores for the five series. The scores for the whole class are then averaged and the individual scores reduced to the basis of a class average of 50. The scores for 18 subjects are shown in table 42.

Study and Interpretation of Results.—(1) Each student should keep careful notes of his method of learning. An abstract of these notes should be included in the note book. The abstracts of all members of the class should be studied in order to determine what methods seem most effective.

2. Make a study of individual variability.

3. Make a study of individual improvement from series to series.

4. Make a study of rapidity of learning. Do those having the highest scores learn the most from the first exposure? Correlate the results of the first exposure with the results from the second exposure, also with the results from the fourth exposure. What is your conclusion?

5. Interpret the correlation table.

Experiment XIII.—*Learning series of meaningful words.*

Object of Experiment.—The object of this experiment is to make a study of the learning of series of meaningful words and to compare the results with the learning of nonsense syllables and with other types of learning.

Apparatus and Material.—The apparatus used is the Jastrow tachistoscope, as in the preceding experiment. The material consists of five series of meaningful, one-syllable words, printed on pieces of cardboard which fit the exposure apparatus.

Method.—The method is the same as in the preceding experiment except that only four exposures are made. In determining efficiency, only the first two exposures of each series are counted.

Results.—The results are shown in table 44 and the correlations in table 45.

Study and Interpretation of Results.—(1) Make a careful comparison of the results of this experiment with those

TABLE 44.—LEARNING MEANINGFUL WORDS

The first column of figures gives the sum learned for the five series in two exposures for each. The second column of figures gives the scores reduced to the basis of a class average of 50.

Subject	Score	To average 50
A	45	35
B	49	38
C	78	61
D	60	47
E	78	61
F	56	44
G	68	53
H	59	46
I	63	49
K	72	56
L	67	52
M	67	52
N	55	43
O	81	63
P	67	52
R	67	52
S	57	44
T	67	52
Average	64.2	50

TABLE 45.—CORRELATIONS MEANINGFUL WORDS

MEANINGFUL WORDS WITH	r
Ball tossing	−.54
Mirror writing	.55
Manthanometer	.21
Card sorting	.48
Marble sorting	.47
Three motor combined	.53
Card retention	.54
Card inhibition	.67
Substitution	.34
Spot pattern	.34
Tach. poetry	.69
Quickness perception	.38
Nonsense syllables	.83

of the preceding experiment in order to learn whether the same factors operate in both types of learning.

2. Each student should keep, as in the preceding experiment, a record of his methods of learning, with notes on difficulties of learning, easy aspects, and all other points that throw light on the proper interpretation of the results.

3. Make a study of variability.

4. Make a study of improvement from series to series.

5. Do the best learners learn most from the first exposure? Correlate first exposure with second. Explain results.

6. Compare the correlations of the results from this experiment with those of the preceding experiment. Correlate the two columns of correlations. Interpret the results.

Related Experiments.—Series of meaningful words can be learned from auditory presentation and the results compared with those from visual presentation. Similar studies can be made by presenting series of objects, or series of pictures of objects. In each case, the subject reproduces the series.

CHAPTER X

ASSOCIATIVE LEARNING

Experiment XIV.—*Simple associative learning—Couples.*

Object.—The object of this experiment is to study one of the most common forms of learning in man, the association of two things, the one with the other. This is the most common form of ideational learning. It is the type of learning we have in the association of a thing with its name, or in the association of a thing with its functions. We shall be especially interested in comparing this type of learning with serial learning, as well as with the other forms of learning studied in this course.

Material.—The material for this experiment consists of four sets of couples, with twelve couples in a set. The couples are drawn on pieces of cardboard five inches square large enough to be seen by all the members of a class of 20 or 25 students. The sets are known as the 1–12 set, the 13–24 set, A–L set, and the M–Z set. In the 1–12 and 13–24 sets, the numbers are represented by simple figures. In the A–L and M–Z sets, the letters are represented by simple figures.

Method.—The experiment consists of four parts, one part for each set of couples. The procedure is exactly the same for each set, and is as follows: The students are told that they will be shown 12 cards, on each of which there is a number together with a symbol. Each card will be shown long enough to be clearly seen. The subjects are to associate the symbols with their corresponding numbers. The students look carefully at each card as it is shown till the 12 of the set are shown. The experimenter then shuffles the cards and shows their backs to the class. On the backs the numbers alone are represented. As the numbers are shown, the students write down the numbers and as many of the symbols as they can remember. Their

reports are then collected or put out of sight, and the experiment repeated till the cards have been shown four times. The couples are never to be shown in serial order, 1, 2, 3, etc. and are always to be shuffled so as to be shown in a different order every time. The object of the above precautions is to prevent serial learning. Each symbol is to be associated only with its appropriate number and not with the preceding or following symbol.

Results.—For comparison with other experiments only the results of the first two exposures of each set are used. After the experiment is finished the reports of each student are assembled and scored. The number of correct associations for each series of exposures is ascertained. The notebook should contain a detailed report of the number of associations correct for each student for each series of exposures. A student's score for the whole experiment is determined as follows: For series 1–12, find the total number of couples correct for the first and second exposures. Treat the other series in a similar way, then add the four scores, of the four series of couples. For example, in the experiment as reported here student A got 4 couples correct for the first exposure of series 1–12, and 6 correct the second exposure. This gives him a score of 10 for this series. For series 13–24, he got 1 and 2 for the first and second exposures, giving him a score of 3 for this series. For A–L, he got 4 and 3, giving him a score of 7. For series M–Z, he got 0 and 1, giving him a score for this series of 1. His total score is $10 + 3 + 7 + 1 = 21$.

Discussion and Interpretation.—(1) The reliability of the test should be determined by finding the inter-correlation between the different pairs of the four experiments. What is the average of the inter-correlations? Combine the results of the first two experiments and correlate with the combined results of the last two experiments.

2. Study the correlation table to see what can be discovered about the relationships of this type of learning.

3. Make a special study of individual differences. Study the previous records of the two or three subjects who stand

TABLE 46.—COUPLES

The first column of figures gives the sum of the scores for the first and second exposures for set 1–12. The second column gives the scores similarly for set 13–24. The third column gives the scores similarly for set A–L. The fourth column gives the scores similarly for series M-Z. The fifth column gives the sum of these scores. The average of the last column is approximately 50.

A	10	3	7	1	21
B	5	9	16	9	39
C	4	6	14	12	36
D	7	10	16	9	42
E	8	17	13	13	51
F	7	12	19	8	46
G	7	14	16	14	51
H	5	14	18	18	55
I	8	14	24	18	64
K	10	20	23	18	71
L	8	10	20	16	54
M	18	13	24	20	75
N	10	11	10	8	39
O	5	13	19	13	50
P	10	13	19	16	58
R	4	15	17	12	48
S	5	11	7	11	34
T	12	10	23	16	61
Average.....	7.5	11.9	16.9	12.9	49.7

TABLE 47.—CORRELATIONS—COUPLES, WITH PRECEDING EXPERIMENTS

COUPLES WITH	r
Ball tossing	−.35
Mirror writing	.02
Card sorting	.34
Manthanometer	.32
Marble sorting	−.35
Average motor	.53
Substitution	.26
Retention	.47
Inhibition	.48
Spot pattern	.02
Tach. poetry	.55
Quick perception	.09
Nonsense syllables	.55
Meaningful words	.49

highest in this experiment. Similarly study the previous records of the students who stand lowest in this experiment.

4. During the progress of the experiment the students should make a record of their methods of learning the couples. These records should be examined and compared. What methods are used by the students making the best records? Are the differences between students in this experiment due to difference of method or to other causes?

Related Experiments.—If there is time, many interesting related experiments can be performed: (1) Pictures can be associated with names. Cut pictures from magazines, paste them on stiff cardboard. Underneath the picture write in large letters a name for each picture. Hold them up before the class, each picture for one second. Have twelve pictures in a series. After one exposure show the pictures with the names hidden and require the subjects to write the corresponding names. Then give a second exposure and take a second record, and so continue as long as desired or till all have completed the learning. For each exposure and for each record, the cards containing the picture should be shuffled, so the pictures may not appear twice in the same serial order. The experiment can be varied by speaking the name instead of showing it visually. Compare the results with the couples experiment as above performed.

2. Colors can be associated with geometrical forms. The material can be prepared by drawing on cardboard triangles, squares, circles etc., each different form being painted a different color. First show the series of colored forms. Then show the forms without the color and require the subjects to write down the name of the color. Continue the experiment as long as desired or till all have completed the learning. The test should be varied by the experimenter showing a square patch of the colors and requiring the subjects to draw the forms. Many other variations of this type of learning can be devised by the instructor. The results of the supplementary experiments should be compared with the results of the standard experiment.

CHAPTER XI

VERBATIM LEARNING OF POETRY

Experiment XV.—*Visual method.*

Object.—In this chapter we shall make an extensive study of committing to memory, a type of learning in which the ideas must be reproduced in the exact words used in the copy studied. The results are to be compared not only with preceding experiments but especially with the results of the experiments in the next chapter.

Material.—Four short poems are used in this experiment. They shall be here designated as *A*, *B*, *C*, and *D*. The poems are printed on sheets of paper so that each subject may have a copy. A Whipple time clock is used to keep the time.

Method.—Before beginning the experiment, the experimenter should explain the object and procedure to the subjects. They are to study the copy till they think they can reproduce it. Each student, when he thinks he can reproduce the poem, notes the time he has been studying, and proceeds to reproduce the poem. When the poems are distributed to the subjects, they are placed printed side down on the table and must not be turned over till everything is ready for the experiment to begin. When all is ready, the poems are turned over and the experimenter starts the Whipple time clock. After a student has once stopped studying and attempted to write the poem, he should not look at the copy again. In reproducing the poem each student is allowed time enough to write all that can readily be recalled. After a student has done the best he can at the reproduction, his work is collected by the experimenter.

After poem *A* is learned, proceed in turn with *B*, *C*, and *D*. Finish all the poems at one laboratory period. The results are scored by counting the number of words correctly

reproduced. The scores are then reduced to speed per minute. The formula for this computation is to multiply the total number of words correctly reproduced by 60 and divide this product by the time in seconds. The scores for the four poems should be combined and the combined score reduced to the basis of a class average of 50. The raw data for the different poems should be recorded in the notebooks.

Results.—The results obtained from 18 subjects are shown in table 48.

Discussion and Interpretation.—(1) Compute the intercorrelations between the pairs of results from the four poems.

TABLE 48.—VISUAL VERBATIM LEARNING OF POETRY

The number of words learned per minute for each poem by each subject is shown in the first four columns of figures under the letters *A*, *B*, *C*, and *D*. The sum of the scores for the four poems is shown in the fifth column. The last column shows the combined scores reduced to the basis of a class average of 50.

Subject	*A*	*B*	*C*	*D*	Sum	Av. 50
A	8	4	7	9	28	19
B	12	3	7	9	31	21
C	19	18	24	48	109	63
D	9	3	6	7	25	17
E	34	14	17	24	89	59
F	17	3	4	7	31	21
G	22	5	13	24	64	43
H	18	13	11	16	58	39
I	27	9	18	30	84	56
K	35	20	17	48	120	80
L	26	7	17	19	69	46
M	33	17	32	51	133	88
N	3	4	16	5	28	19
O	37	17	15	4	113	75
P	21	8	12	22	63	42
R	23	6	17	12	58	39
S	42	26	13	33	114	76
T	10	6	20	17	53	35
Average.....	22.0	10.2	14.8	23.6	71.1	50

TABLE 49.—CORRELATIONS—VERBATIM LEARNING

VERBATIM LEARNING WITH	r
Ball tossing	−.41
Mirror writing	.24
Card sorting	.60
Manthanometer	.42
Marble sorting	.57
Average motor	.71
Substitution	.61
Retention	.59
Inhibition	.43
Spot pattern	.28
Tach. poetry	.67
Quick perception	.61
Couples	.51
Nonsense syllables	.63
Meaningful words	.61

What do the results show as to the reliability and constancy of the test?

2. Study the correlations with preceding experiments. What do you learn about the relationships of this type of learning?

3. Study individual differences. Especially investigate the records in preceding experiments of the best and poorest in this experiment. What type of student is good at this kind of learning? Study the results in the light of the courses the subjects have specialised in. Compare science students with literary students.

4. To what extent do the individual differences depend upon the subject matter of the poem?

5. To what extent is much previous experience in committing to memory a factor in the results of this experiment?

Related Experiments.—Variations can be made of both the method of the experiment and the kind of poems used. (1) All the subjects can be allowed to study for the same length of time.

2. The learning of longer poems can be compared with the learning of short ones.

3. Each student can be allowed to use his own method of learning or the method can be prescribed. For example

all students can be required to study the poem by reading it entirely through each time.

4. The effects of subject matter can be studied by using several different types of poems—descriptive, narrative, dramatic, etc.

Experiment XVI.—*Verbatim learning of poetry—Auditory presentation.*

Object.—The primary object of this experiment is to compare the auditory with the visual presentation in verbatim learning.

Material.—The material used in this experiment consists of a poem of nine stanzas, four lines to the stanza.

Method.—The poem is read to the class one stanza at a time. After the reading of a stanza, each member of the class writes as much of the stanza as he can readily recall. After the first stanza is finished, the written reports are collected or put out of sight and are not to be further added to or corrected. The succeeding stanzas are given similarly. After all the stanzas have been read to the class and the reports written, the papers are assembled and scored. In scoring, one credit is given for each word in its proper place. To facilitate correct scoring, omitted words should be indicated by dashes. A subject's score is the total number of words correctly reproduced for the nine stanzas.

Results.—The student's notebook should contain each student's score for each stanza, the sum for all the stanzas, and the sum reduced to the basis of a class average of 50. The average scores for the different stanzas made by 18 students are as follows:

Stanza	Score	Stanza	Score
1	21.5	6	19.8
2	18.1	7	16.1
3	23.1	8	17.0
4	23.1	9	15.9
5	13.2		

TABLE 50.—VERBATIM LEARNING OF POETRY—AUDITORY

The first column of figures gives the sum of the scores for the nine stanzas for each subject in a class of 18 students.

Subject	Total score	Average 50
A	90	26
B	99	29
C	214	61
D	162	46
E	160	46
F	168	48
G	178	51
H	194	55
I	164	47
K	229	65
L	171	49
M	202	58
N	153	44
O	204	58
P	139	40
R	220	63
S	204	58
T	185	53
Average.....	174.2	50

TABLE 51.—CORRELATION OF AUDITORY VERBATIM LEARNING WITH PRECEDING EXPERIMENTS

AUDITORY VERBATIM LEARNING WITH	r
Ball tossing	−.67
Mirror writing	.24
Card sorting	.28
Manthanometer	.01
Marble sorting	.41
Average motor	.41
Substitution	.18
Retention	.38
Inhibition	.72
Spot pattern	.12
Tach. poetry	.84
Quick perception	.36
Nonsense syllables	.64
Meaningful words	.69
Couples	.51
Visual poetry	.65

Study and Interpretation.—(1) From every point of view, compare the auditory with the visual presentation. Does the auditory method give some subjects an especial advantage? If so, how do you explain the fact? Is such a result, when found, due to previous experience or to some difference in native endowment?

2. Make a special study of the students showing the greatest difference between visual and auditory learning. Study their records in other experiments. Devise simple experiments in order to determine whether the difference holds with various kinds of material. For example, prepare several lists of words for visual presentation and several lists for auditory presentation, and compare the relative standing of these students in the two types of experimentation.

3. Study the correlation table. Compare with the table in the preceding experiment. Correlate the two arrays of correlation co-efficients representing the correlations of visual learning and the correlations of auditory learning. Interpret the result.

4. Does the highest type of learner show up best in the auditory presentation or in the visual presentation?

5. Is visual or auditory learning most in demand in school work?

6. Can experience and practice much affect one's relative ability in the two methods of learning?

Related Experiments.—If there is time it will be profitable to make an extensive study of the difference between visual and auditory presentation. The instructor can devise experiments with all the different types of material in ideational learning.

CHAPTER XII

IDEATIONAL LEARNING

The experiments of this chapter differ from those of the preceding chapter as follows: In verbatim learning the subjects learned words. In the experiments of this chapter, the subjects are not required to learn the words in the material presented. They are required to get the meaning and give this meaning in their own words. This is the highest type of learning and the most important of all types of learning. The important thing in our life in this world, as far as learning is concerned, is to get the *meaning* of things, to get this meaning in such a way as to be able to express it clearly in our own words.

Experiment XVII.—*Ideational learning, visual presentation.*

Object.—While our object in this experiment is to compare visual ideational learning with all other forms of learning, we shall be especially interested in comparing the results of this experiment with the results of verbatim learning and with the results of the following experiment.

Material.—The material for this experiment consists of printed copies of four different pieces of prose material. Each piece is a different type of material from the others.

Method.—It must be clearly understood by the students that in this experiment they are to learn the ideas so that they can express them in their own words, and that they will be scored on the number of ideas that they correctly reproduce. After all is clearly understood, the subjects are provided with copies of selection *A*, which are placed printed side down on the table. At the signal from the

experimenter, the subjects turn the copies over and study them for 90 seconds. At the end of 90 seconds, the experimenter announces the time and all study ceases. The copies are collected and each subject writes down the material in his own words, trying to get every idea of the original. The report should be a continuous, connected statement giving the material as fully and accurately as possible. It is not required that the ideas be reproduced in the same order as in the original. The time for writing the report is not limited. All are allowed a reasonable amount of time and each is allowed to do it in his own way. However, when all have written what can readily be recalled, the papers are collected. The subjects are then required to write answers to definite questions based on the copy. When the answers to the questions are collected, the experimenter proceeds with copy *B*, which is given in a similar way, as are also copies *C* and *D*.

The written reports are scored by being marked with one credit for each idea correctly reproduced. The same standards must be applied to every paper. The answers to the questions are scored by being given one credit for each correct answer. The scores from the written reports and from the answers to the questions are combined for each experiment and the results from the four copies are added together to give the total score which is then reduced to a class average of 50.

Results.—The averages from 18 subjects for the four experiments are as follows:

Copy	Report	Questions
A	14.9	8.2
B	9.1	7.4
C	13.1	8.4
D	23.1	10.4

TABLE 52.—VISUAL IDEATIONAL LEARNING

Subject	Total score	Average 50
A	61	32
B	59	31
C	113	60
D	54	29
E	103	56
F	78	41
G	102	54
H	90	48
I	115	61
K	139	74
L	87	46
M	110	58
N	106	56
O	112	59
P	88	47
R	100	53
S	91	48
T	92	49
Average	93.3	50

TABLE 53.—CORRELATIONS—VISUAL IDEATIONAL LEARNING

VISUAL IDEATIONAL LEARNING WITH	r
Ball tossing	−.45
Mirror writing	.49
Card sorting	.40
Manthanometer	.22
Marble sorting	.76
Average motor	.36
Retention	.47
Inhibition	.50
Substitution	.36
Spot pattern	.09
Tach. poetry	.89
Quick perception	.44
Nonsense syllables	.71
Meaningful words	.76
Couples	.59
Visual poetry	.51
Auditory poetry	.67

Discussion and Interpretation.—(1) Study the reliability and constancy of the test by computing the six intercorrelations and determining the individual variability.

2. Study the table of correlations with preceding experiments. What inferences can you draw as to the relationships of this test?

3. Make a study of individual differences, noting especially marked changes of rank from this to other experiments. Try to explain the exceptional changes of rank.

4. Make a careful study of the best and poorest learners in this experiment. Note their standing in all other experiments.

5. The material and method of this experiment come nearest to being like the material and method in ordinary school work. It ought therefore to be profitable to compare standing in this experiment with previous achievement in school work. The instructor should make such a study and give the general results to the class. A perfect correlation between ability as shown by this test and achievement as shown by university standing in class work will not be found. How high is the correlation? Why is it not perfect? Compare the college or university records of the very best learners with the very poorest learners.

6. In this experiment, the type of material is important. The kind of material used makes a different appeal to different subjects, largely because of interests and funds of knowledge which depend upon previous experience. There are probably also large sex differences in interest. All these differences materially affect the results. If there is time, the class should make a special study of the effects of different kinds of material.

7. The question of method may also be investigated. Instead of giving the same limited time for study to all, each may be allowed to study till he thinks he has learned all the ideas, and then be tested as in the experiment above. The score should be the number of ideas learned per minute. The scoring should be very carefully and uniformly done.

Experiment XVIII.—*Auditory ideational learning.*

Object.—The object of this experiment is to compare this type of learning with all the preceding types and especially with visual ideational learning.

Material.—An article entitled "Painless Thinking" and other similar material which the instructor may select or prepare.

TABLE 54.—AUDITORY IDEATIONAL LEARNING

The first column of figures gives the scores for each of 18 subjects. The score is obtained by combining the scores of the written reports and answers to questions. The second column of figures gives the scores reduced to the basis of a class average of 50.

Subject	Score	Score to average 50
A	19	29
B	22	33
C	35	53
D	19	29
E	39	59
F	35	53
G	22	33
H	40	61
I	47	71
K	60	91
L	39	59
M	30	46
N	20	30
O	46	70
P	30	46
R	31	47
S	19	29
T	40	61
Average.....	32.9	50

Method.—The article is read once to the class. The subjects then reproduce the ideas in their own words. The reproduction is to be as complete and detailed as possible. It should be straight-forward, consecutive, not

merely topical or in outline. Each subject is to have a reasonable amount of time to reproduce all the ideas that can be readily recalled. When the reports are all written they are collected and the subjects are required to answer questions based on the article as in the preceding experiment. The score is the combined number of points made in the written reproduction and in the answers to the questions. One credit is given for each idea adequately reproduced. The answers are scored as directed.

Results.—The results are shown in the accompanying tables. The average score made by 18 subjects on the written report was 21.0; the average on the questions was 11.9.

TABLE 55.—CORRELATIONS—AUDITORY IDEATIONAL LEARNING WITH PRECEDING EXPERIMENTS

AUDITORY IDEATIONAL LEARNING WITH	r
Ball tossing	−.56
Mirror writing	.47
Card sorting	.49
Manthanometer	.29
Marble sorting	.71
Average motor	.66
Retention	.57
Inhibition	.44
Substitution	.57
Spot pattern	.12
Tach. poetry	.69
Quick perception	.20
Nonsense syllables	.67
Meaningful words	.60
Couples	.60
Visual poetry	.60
Auditory poetry	.48
Visual ideational	.68

Study and Interpretation.—The results of this experiment should be studied in much the same way as were those of the preceding experiment. If there is time the experiment should be repeated with at least four different types of material, and the results studied with reference to their constancy and uniformity.

1. Study the correlation table. Compare with that of the preceding experiment. The two arrays of co-efficients should be correlated and the result interpreted.

2. Make a special study of individual differences with particular reference to the best and poorest learners, as in the preceding experiment.

3. Which type of ideational learning—visual or auditory—seems to be the most significant measure of ability to learn? Which gives the highest average correlation with other experiments? Which gives the highest correlation with school standing?

4. Each subject should give as good account as possible of his method of learning. These reports should be compared. What do they show with reference to the best and poorest learners?

CHAPTER XIII

COMPARATIVE STUDY OF ALL THE EXPERIMENTS

Each student should prepare a table showing the individual scores in all experiments. The scores shown should be those reduced to the basis of a class average of 50. In table 56 are shown the results of the same 18 subjects in

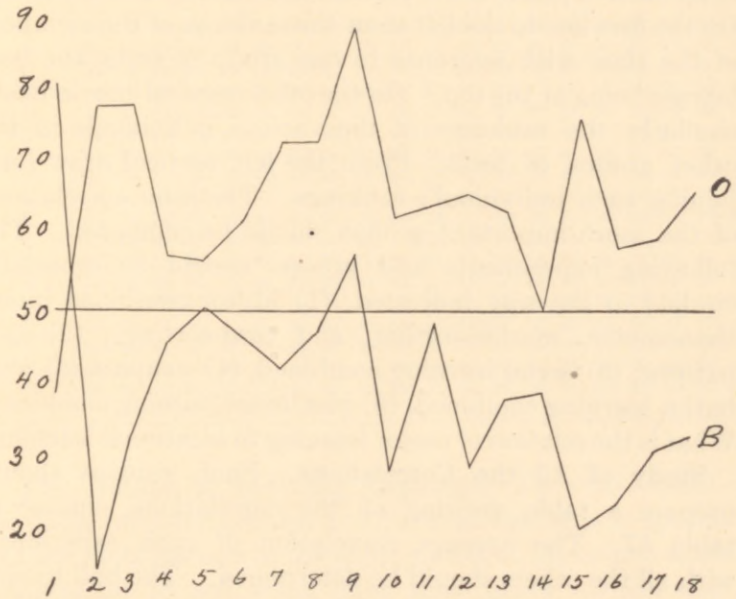

FIG. 30.—Graphical representation of the standing of subjects B and O in the various experiments. The scores are reduced to the basis of a class average of 50.

all the experiments, reduced to a class average of 50. In table 57 are shown all the correlations based on the records of table 56.

Each student should make a graph showing his own standing in each of the experiments. The graph should be made as follows: Draw a straight horizontal line repre-

senting the class average. Represent the various experiments from left to right and let your own graph show how much above or below the class average you are in the various experiments, as illustrated in figure 30. The graphs for the best and poorest learners might also be shown. Each student should write up a comprehensive discussion and interpretation of his own results.

The experimental results should be grouped. The results of those experiments most similar should be combined and averaged and studied comparatively. The more important groups should be represented graphically as follows: On cross section paper draw vertical lines about an inch apart. On the first line to the left show the rankings of the members of the class with reference to one group of tests, the best learner being at the top. On the other vertical lines indicate similarly the rankings of the various individuals in the other groups of tests. From the left vertical draw lines joining each individual's rankings. The inter-correlations of the more important groups should be computed. The following experiments and groups should be especially studied in the way indicated: (1) Motor combined (manthanometer, marble-sorting, and card-sorting), (2) spot pattern, (3) serial learning combined, (4) couples, (5) verbatim learning combined, (6) ideational learning combined. What is the relation of motor learning to ideational learning?

Study of All the Correlations.—Each student should prepare a table showing all the correlations, similar to table 57. The average correlation of each experiment with all the others should be determined. The ball tossing correlations should be omitted from this average. Why? Make a special study and comparison of the ball tossing correlations. Write up a full discussion of the correlation table.

Each student should write up a full discussion of what he has learned about himself in the experiments. The facts should be systematically numbered, discussed and interpreted.

Each student should write a comprehensive essay setting forth the facts learned in general about the psychology of

learning. These facts should be systematically numbered and orderly arranged. A numbered list of the facts of important practical application in teaching or in life should be made. The particular use to be made of the facts should be specifically stated.

TABLE 56.—ALL EXPERIMENTS REDUCED TO A CLASS AVERAGE OF 50

Subject	Ball tossing	Mirror writing	Card sorting	Manthanometer	Marble sorting	Average motor	Substitution	Retention	Inhibition	Spot pattern	Tach. poetry	Quick perception	Nonsense series	Word series	Couples	Visual poetry	Auditory poetry	Visual ideas	Auditory ideas	Average
A	83	55	45	54	41	45	56	43	36	41	38	50	21	35	21	19	26	32	29	38
B	80	15	32	45	50	40	46	41	46	57	28	49	29	38	39	21	29	31	33	37
C	45	82	42	44	59	52	41	45	54	63	54	51	63	61	36	63	61	60	53	55
D	42	33	42	49	34	39	38	45	38	39	37	48	36	47	42	17	46	29	29	38
E	35	88	62	55	63	60	67	51	58	43	51	44	70	61	51	59	46	56	59	58
F	54	25	57	51	47	54	45	52	56	48	49	33	56	44	46	21	48	41	53	45
G	77	36	50	51	48	49	62	54	61	63	55	60	52	53	51	43	51	54	33	52
H	35	53	41	48	51	44	48	47	49	51	49	42	59	56	55	39	55	48	61	50
I	29	36	47	44	64	53	44	54	53	51	53	50	51	49	64	56	47	61	71	53
K	42	74	64	61	76	68	70	57	54	36	73	72	60	56	71	80	65	74	91	67
L	32	90	64	46	66	57	53	57	56	71	45	41	50	52	54	46	49	46	59	56
M	51	32	57	60	71	64	58	57	61	54	56	50	55	52	75	88	58	58	46	58
N	54	72	39	45	49	46	31	43	38	43	47	43	41	43	39	19	44	56	30	42
O	38	77	77	57	56	66	64	74	74	87	62	63	65	63	50	75	58	59	70	67
P	77	20	53	45	..	46	39	47	48	57	42	42	55	52	58	42	40	47	46	46
R	32	38	31	37	47	35	36	37	39	24	62	44	43	52	48	39	63	53	47	44
S	42	23	55	53	48	51	56	48	40	43	47	68	46	44	34	76	58	48	29	48
T	48	53	42	60	60	53	44	49	43	29	50	50	48	52	61	35	53	49	61	49

The Nature of Learning Capacity.—To what extent is learning capacity general and to what extent is it specific? All the facts learned in the experiments of the course should be studied to see what light they throw on the above question. In particular, study table 56 giving all the scores and table 57 giving all the correlations.

What evidence is there that there is a general factor in all learning? What evidence is there that there is always a specific factor? How can the specific factor be best measured? How can the general factor be best measured?

Try to characterise the general learning factor. Characterise specific factors concerning which you have evidence.

TABLE 57.—CORRELATION OF EACH TEST WITH ALL OF THE OTHERS

Substitution	Ball tossing	Mirror writing	Card sorting	Manthanometer	Marble sorting	Substitution	Card retention	Card inhibition	Spot pattern	Tach. poetry	Tach. letters	Nonsense series	Word series	Couples	Visual poetry	Auditory poetry	Visual ideas	Auditory ideas
Ball tossing		−43	−25	03	−38	−03	−28	−20	−08	−49	−02	−50	−48	−35	−41	−67	−45	−56
Mirror writing	−43		40	17	43	31	34	36	22	38	08	42	54	02	24	26	45	46
Card sorting	−25	40		55	46	71	89	66	52	42	31	57	53	34	60	28	40	50
Manthanometer	03	17	55		37	67	46	27	00	28	42	23	19	31	41	16	21	29
Marble sorting	−38	43	46	37		45	48	54	15	53	42	55	52	68	61	42	71	71
Substitution	−03	31	71	67	45		64	52	50	38	51	45	35	25	60	19	35	39
Card retention	−28	34	89	46	48	64		78	65	48	34	57	56	47	56	34	45	57
Card inhibition	−20	36	66	27	54	52	78		74	61	20	75	73	40	58	39	51	52
Spot pattern	08	22	52	00	15	50	65	74		−03	08	34	33	02	27	−03	09	11
Tach. poetry	−49	38	42	28	53	38	48	61	−03		37	63	66	53	65	82	86	68
Tach. letters	−02	08	31	42	42	51	34	20	08	37		08	21	06	45	32	37	18
Nonense series	−50	42	57	23	55	45	57	75	34	63	08		10	64	74	76	82	79
Word series	−48	54	53	19	52	35	56	73	33	66	21	10		47	63	66	69	60
Couples	−35	02	34	31	68	25	47	40	02	53	06	64	47		51	48	58	66
Visual poetry	−41	24	60	41	61	60	56	58	27	65	45	74	63	51		60	73	50
Auditory poetry	−67	26	28	16	42	19	34	39	−03	82	32	76	66	48	60		68	51
Auditory ideas	−56	46	50	29	71	39	57	52	11	68	18	79	60	66	50	51	68	
Visual ideas	−45	45	40	21	71	35	45	51	09	86	37	82	69	58	73	68		68
Averages	−32	30	51	31	50	45	54	54	25	52	28	53	49	40	54	43	54	51

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APPENDIX

LIST OF MATERIAL AND APPARATUS FOR ALL THE EXPERIMENTS

For the mathematical treatment of the data in all the experiments, the following are needed: Slide rule, Barlow's tables, and Crelle's Calculating tables.

Experiment 1. (1) Ball-tossing bag, (2) 50 rubber balls, $^{15}/_{16}$ inch in diameter.

Experiment 2. (1) Mirror drawing apparatus, (2) Pyle's mirror drawing form, (3) Whipple time clock or an interval timer.

Experiment 3. (1) Card tray, 15 pigeon holes on each side, (2) set of cards numbered from 11 to 40, (3) Whipple clock.

Experiment 4. (1) Pyle's marble sorting apparatus, (2) 90 colored marbles, (3) Whipple clock.

Experiment 5. (1) Pyle's manthanometer, (2) Ranschburg apparatus, (3) telegraph key, (4) 6 dry batteries, (5) Whipple clock or a stopwatch.

Experiment 6. (1) Pyle's digit-letter substitution test blank, (2) key (3) Whipple clock.

Experiment 7. Material same as in experiment 3.

Experiment 8. Material same as in experiments 3 and 7.

Experiment 9. (1) Whipple tachistoscope, (2) Five seven-spot patterns.

Experiment 10. (1) Whipple tachistoscope, (2) set of letter exposure cards.

Experiment 11. (1) Whipple tachistoscope, (2) set of poetry exposure cards.

Experiment 12. (1) Jastrow tachistoscope, (2) five sets of nonsense syllables arranged on cardboard.

Experiment 13. (1) Jastrow tachistoscope, (2) Five sets of meaningful one syllable words, arranged on cardboard.

Experiment 14. Four sets of couples, 12 paired associates in each.

Experiment 15. Four poems, labeled A, B, C, and D, for visual learning.

Experiment 16. A poem of nine stanzas for auditory learning.

Experiment 17. Four selections of prose for ideational learning, labeled A, B, C, and D.

Experiment 18. "Painless Thinking," a prose selection for auditory ideational learning.

All the material and apparatus listed above can be procured from the C. H. Stoelting Co., Chicago, Illinois.