**Interference and adaptability : an experimental study of their relation with special reference to individual differences / by Arthur Jerome Culler.**

# INTERFERENCE AND ADAPTABILITY

## AN EXPERIMENTAL STUDY OF THEIR RELATION WITH SPECIAL REFERENCE TO INDIVIDUAL DIFFERENCES

BY
ARTHUR JEROME CULLER, PH.D.

ARCHIVES OF PSYCHOLOGY
EDITED BY
R. S. WOODWORTH

No. 24, JULY, 1912



COLUMBIA CONTRIBUTIONS TO PHILOSOPHY AND PSYCHOLOGY
VOL. XXI, NO. 2

NEW YORK
THE SCIENCE PRESS

## ARCHIVES OF PSYCHOLOGY

Editorial communications should be addressed to PROFESSOR R. S. WOODWORTH, Columbia University, New York City.

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PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA

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## ACKNOWLEDGMENTS

THE writer wishes to express his deep indebtedness to all of those who acted in the capacity of subjects, many of whom sacrificed for the sake of the experiment. He is under obligations to Professor Bergström, whose various articles suggested the use of cards as material. For the material in one of the discrimination reaction experiments he is indebted to Margaret Hart Strong and Dr. Hollingworth. For many suggestions as to methods of treatment and conduct of the experiments, thanks are due to Professor R. L. Woodworth and Professor E. L. Thorndike. For the suggestion of the study, for continual supervision and guidance of the work, the writer is most deeply indebted to Professor J. McKeen Cattell. For assistance in the final arrangement of material the author's thanks are due to his wife.

# INTERFERENCE AND ADAPTABILITY

## CHAPTER I

### INTRODUCTION

### 1. *Statement of Problem*

THE previous work upon interference of associations has given rise to some definite problems. Münsterberg asked whether a given association can function automatically, while some effect of a previous and different association with the same stimulus remains. Also in case the new association becomes automatic, what is the condition of the former association with the same stimulus? Does it disappear or can the two entirely different movements be connected with the same sensation complex, and either of them be called up independently?[1] Müller and Schumann worded their problems thus: "When a series of nonsense syllables has been learned until the first correct repetition is possible, and is then relearned to the same extent after a certain interval, will more repetitions be required if in the meantime the syllables of the series have been associated with another set of syllables?"[2] Bergström devotes his attention to the question whether the interference effect is equal to, greater or less than the practise effect.[3] Among the purposes of Bair's experiments was "to determine . . . the increasing amount of interference, first, when there is an alteration in the serial order of stimuli, and secondly, when there is an alteration of particular responses to particular stimuli associated by preceding practises."[4] These investigators have asked the following questions. Is there such a thing as true interference, and if so how can it be measured? What is the effect of a well-fixed association on the formation of a new one with the same stimulus, how great is this effect, and can it be overcome? When

[1] Hugo Münsterberg, "Gedächtnisstudien, Beiträge zur Experimentellen Psychologie," **1**, **4**, 70, 1892.

[2] Müller and Schumann, "Experimentellen Beiträge zur Experimentellen Untersuchung des Gedächtniss, *Zeitschrift f. Psych. und Phys. der Sinnesorgane*, **6**, 173, 1893.

[3] John A. Bergström, "The Relation of the Interference to the Practise Effect," *Am. Jour. Psych.*, **6**, 434, 1894.

[4] J. H. Bair, "The Practise Curve," *Columbia Univ. Contributions to Philosophy, Psychology, and Education*, **5**, **9**, 5, 1902.

the new association has become established what is the condition of the former? And finally, can both of them become automatic and either be called up without the appearance of the other?

This paper is concerned with the problem of individual differences in interference. It is concerned not primarily with the fact or amount of interference when two conflicting associations are opposed, but rather with the rapidity and extent to which the interference is overcome by a new association, and with the adaptation of the individual to the new association. This of course has special interest for the study of individual differences.

There are two phases of the problem to which the two experiments will apply. The first is the interference effect of a well-established and long-practised habit association of a series of simple stimuli with equally simple reactions. At the end of the long period of practise other reactions are substituted for the same stimuli or series of stimuli, and a measure is then obtained of the adaptability of the individual to the new association and of the interference effect of the previous association upon the new one. The second type is that in which two mutually opposing associations are alternated. The interference of the one against the other is measured by its resistance to the tendency of the opposing one to become automatic. This is studied with special reference to individual differences. The first of these experiments aims to measure the modifiability of the individual, or the building up of a new association against the opposing and well-fixed former association. The individual differences will be differences in adaptability to a new situation. The second is the same question with which Münsterberg was concerned. The experiment, however, is performed under laboratory conditions, with many subjects, and viewed from the standpoint of individual differences. This second phase nicely supplements the first in a study of interference and adaptability. The paper will also consider the question of the most economical methods of making the two associations automatic. In order to determine more specifically what relation the interference effect holds to the practise effect, the results will be considered in relation to Bergström's contention that the interference effect is equal to the practise effect[5] and Münsterberg's conclusion[6] that the two opposing associations can become automatic.

The question of adaptability is one of great practical importance. Yoakum says: "The biologist tells us that the specialist as a mere individual must fail in the great life functions. The scientists not only demand habits but the power to break those habits. Each and

[5] Bergström, *loc. cit.*, p. 441.

[6] Münsterberg, *loc. cit.*, p. 71.

all abjure over-specialization.''[7] Professor MacDougall says: ''The general character of mental development may be described as adaptation. At all stages and in every phase of its activity the change from the earlier to the later form is a reconstruction which tends to establish more harmonious relation between the individual and his environment. . . . Adaptive reconstruction constitutes the general form of change whether the origin of determination be conceived as lying in the environment and producing adaptive modification, or the element of initiative be considered in the utilization of materials for ideal ends. Such adaptation is incessantly renewed so long as the individual continues to live. . . . Adaptation involves two factors, a form of response already elaborated and an action tending to modify the adjustment in conformity with a variation in the system of stimuli. The former represents the level of adaptation already attained by the organism, the latter represents the increment of advance in which the fact of development consists. The first of these two factors we call Habit, the second Accommodation. Habit constitutes the response of the organism to its environment in so far as the system of stimuli possesses permanence in the course of experience. Accommodation constitutes the organism's response to variations appearing within this system of stimuli.''[8]

Professor MacDougall well describes habit and adaptation in the development of the organism. One of my experiments, that on the typewriter, aims to fulfil under experimental conditions, his outline of habit as a form of response to a system of stimuli already attained, with a change in the environment such that a new level of adaptation is necessary. What I have done in the typewriting experiment before the break is what he calls habit, the development after that break is what he calls accommodation. I am calling it adaptation in a more specific sense.

Adaptation to environmental variations has a very wide significance. Sociologists have long pointed out that the races which can most readily change their customs when thrown into new surroundings are the ones which survive. Le Bon says that one of the fundamental differences between the savage and the civilized races is that of adaptability. Brinton says the same thing and claims that only as there are variations in this respect will the race survive and that the most adaptable are the fittest. Bagehot says that the lowest races

[7] C. L. Yoakum, ''An Experimental Study of Fatigue,'' *Psy. Rev. Mon. Suppl.*, **46**, 116, 1909.

[8] R. MacDougall, ''The System of Habits and the System of Ideas,'' *Psych. Rev.*, **18**, 325, Sept., 1911.

are enclosed in a cake of custom and the first step of progress is to break this preservative habit.[9]

This is also true of smaller groupings of individuals. Giddings[10] makes a classification of religions on the basis of their tendency to break away from hidebound custom. Conversion is a distinct type of changed reaction to life and often presents marked interference. In every condition of life there are interferences of the old situation and adaptability to the new. A strange citizen in a new country, a boy from the farm in the city, the freshman in the college, and the institutional lad on the streets are all familiar examples. A perfect adaptability to all situations is the result of long and varied experience. Adaptations are thus a large part of the activity of any expanding organism.

## 2. *Investigations on Interference*

The problems of association are among the oldest in psychology, both among the philosophers and among those taking a more experimental attitude toward mental facts. The associationist school attempted to find the unit of their psychology in the discrete ideas and their cohesions, repulsions, and forms of succession: Wundt, Ebbinghaus, Müller, Schumann, Galton, and many others of the pioneers experimented largely with memory, learning, association practise, and other related problems. I shall consider only such investigations as bear directly on some phase of the present problem.

The work that inspired much of later research in interference was an investigation of Münsterberg's published in 1892.[11] He raises the question whether a habit associated with a given sensory stimulus can function automatically while some effect of a previous and different habit association with the same stimulus remains. What is the condition of the old habit when the new one functions automatically? Does it disappear or can the two entirely different movements be connected with the same sensation complex, and either of them be called up independently? He concluded that both can become automatic and need only a slight momentary advantage in order to function. The sensori-motor impulse need not pass out through both pathways of discharge, like an electrical current in-

[9] See Giddings, "Principles of Sociology"; Brinton, "Basis of the Social Mind"; Le Bon, "Psychology of Peoples"; and Bagehot, "Physics and Politics."

[10] F. H. Giddings, "Psychological Classes of Population," *Psych. Review*, Vol. VIII., 337, 1901.

[11] Münsterberg, "Gedächtnisstudien, Beiträge zur Experimentellen Psychologie," 1, 4, 70, 1892.

versely proportional to the resistance, but it can go along either one and leave the other undisturbed. Neither is effaced by the repetition of the other but both are retained and can quickly function automatically.

For the investigation of this question he pointed out three experimental conditions: (*a*) The movements must be entirely mechanical so as not to call in the attention; (*b*) they must be easily varied, and (*c*) they must call in the attention whenever a false movement is made or when the reaction is to the previous association. Because of the first requirement the experiments could not be performed in the laboratory.

He therefore performed the experiment upon the simple actions of his daily life. He had been accustomed to carry his watch in his left vest pocket. On the first of the month he put it into his right trousers pocket. He noted the number of false movements and beginnings. On the first of the next month he replaced it in the left vest pocket. During the interval he automatically took it out of the right trouser's pocket. He then found that to relearn taking it out of the left vest pocket took less practise than it previously did to learn to take it from the right trouser's pocket. From this fact he concluded that some traces of the old habit remained. He found that if this alternating process was repeated, the time for each relearning grew less, that both habits constantly grew stronger, and that both became automatic. In fact after the third change there were no wrong reactions.

He also made similar experiments with the inkstands on his writing table, during one period having the right side bottle and during the next the left side bottle filled. He noted the false movements during each period. His third experiment was the alternating use of two doors from his study to the corridor, keeping the one not in use locked, and noting again the number of mistakes until each became automatic.

Müller and Schumann's[12] problem was whether it will require more repetitions to relearn a series of nonsense syllables if in the meantime the syllables of the series have been associated with another set of syllables. They had two series of twelve syllables, each of which was relearned in an average of 7.29 and 7.89 repetitions respectively. The second of the series had been united with twelve new syllables in the meantime. While relearned almost as quickly, interference may have been present, for the second series had been repeated about twice as often as the first, and as considerable part of the work of

[12] Müller and Schumann, *loc. cit.*, 173.

learning the series is in learning the individual syllables, the interference effect was offset by the greater practise effect.

Bergström made several researches on the relation of interference and practise.[13] His first experiment was to study the rate of decrease of interference with the increasing intervals of time between the first and second sorting of cards. His subject sorted a pack of eighty cards into ten piles, eight in a pile, each card of a given pile containing the same picture. In sorting the pack a second time each card might be placed in the same position it occupied before or in any one of nine other positions. If the former happened there would be simple practise, whereas in the latter case the cards enter into associations which would exclude the former associations and there would be interference effect. The subject first sorted the cards, then after a given interval sorted them into ten piles of different positions. The intervals used were 3, 15, 30, 60, 120, 240, 480, and 960 seconds. Bergström found that the average difference between the 3-second and the 8-minute interval was 14.28 seconds, and between the one minute and eight minute interval 4.72 seconds, showing that about two thirds of the decrease took place in the first minute. In twenty-four hours the subject can sort the cards as rapidly as at first. Bergström did not interpret this as meaning that the neural habit of the first association had vanished, but that the second was temporarily raised above it. The time for the first sorting was about 65 seconds and for the one immediately afterwards 85 seconds. From the false movements which were made he concluded that a strong association had been formed.

The second experiment reported about a year later is more elaborate and contains a fuller discussion of the subject of interference.[14] After quoting the problems of Münsterberg and Müller and Schumann he asks what relation the interference effect holds to the practise effect. It must either be equal to, or greater or less than, or hold a variable relation thereto. He used the same number of cards and methods of sorting them as in the previous experiment. The cards for the test proper were sorted in the following manner:

$$A_1^1 A_2^1 A_1^2 A_2^2 \ldots A_1^8 A_2^8.$$

The comparison series was composed of two sets of cards differing both from $A$ and from each other, and these, with consequently no

[13] John A. Bergström, "Experiments upon Physiological Memory by Means of the Interference of Associations," *Am. Jour. Psych.*, **5**, 356, 1893.

[14] Bergström, *loc. cit.*, 433.

opposing associations, were sorted in like manner eight times. Three minutes for each sorting were given, thus allowing forty-eight minutes for each test, and giving an interval of nearly two minutes between the sortings.

Bergström took eight records for each of the tests, the interference test and the comparison test. For the interference test he used either a different set of cards or allowed several weeks to elapse so that no practise effect from the previous experiment remained. He had one subject and averaged the records for this subject. The comparison test shows a regular practise curve but the $A_1A_2$ series is a horizontal line. Bergström did not interpret this as indicating that the interfering associations tended to efface one another. This conclusion was verified by the fact that a third arrangement of $A$ showed the same interference effect as either of the other arrangements. He concluded that the interference effect is constant to the practise effect and is in fact equivalent to it.

Bair's experiments were devised to determine the quantitative relation between the increasing permanency of an association and the succeeding practises, and also the increasing amount of interference, first, when there is an alteration in the serial order of stimuli, and second, when there is an alteration of particular responses to particular stimuli. He practised a particular order of stimuli until they became automatic, then changed the serial order of stimuli, or substituted new responses to the old stimuli. The experiments were made on a typewriter with several series or colors arranged in serial order. A certain key was to be associated with each color, and when the color appeared the key was to be struck. The series of colors were then changed or a different set of keys associated with the colors.[15]

He also sorted cards following Bergström's method but did not find nearly as much interference. Taking a lesser number of cards he sorted them into six positions. He had them sorted a varying number of times and then sorted with an opposing arrangement. He found that the difference in time between the last sorting of the first arrangement and the first sorting of the second arrangement increased with the greater number of practises of the first order. He concluded that this greater difference is due to the increased speed of the first arrangement and not to interference.[16]

On the typewriting experiment he sums up as follows: "By practising a particular reaction or series of reactions to a certain stimulus

[15] J. H. Bair, *loc. cit.*, 5, 14.

[16] J. H. Bair, *loc. cit.*, 34.

or series of stimuli, until these responses become automatic, and then associating the same response or series of responses with a different stimulus or series of stimuli, or a different order of responses to the same set of stimuli until the new order becomes automatic, and then returning to the first order, going from one order to the other, every time the order practised becomes automatic, the time becomes continually less for the subsequent adjustments until finally after a sufficient number of alternating adjustment practises, either order can be responded to automatically, one needing but voluntarily to start the response impulse in one direction or the other, and the whole series of responses proceed as though that were the only order acquired.'' His results show that both associations become automatic and that the neural disposition of an old habit does not vanish when a new one is formed. He claimed that there is not as much interference as Bergström finds, and that it is due to indisposition rather than inability.

Mr. W. O. Beazley's problem was to determine the causes of interference and to analyze its elements with the purpose of determining of what it consists.[17] He paid particular attention to interference in relation to motor coordination. In one of his experiments the subject was required to strike five keys in a certain order. The five keys were of the shape and appearance of piano keys, and were constructed in a small box, each key having electrical connections with the kymograph. The first and last keys were connected with a Hipp chronoscope thus giving the time of the entire reaction. Each of the keys had a small picture pasted upon it and the subject had before him a paper on which were the same pictures arranged in the order in which the keys were to be struck. At the given signal the subject struck the keys in the required order, the time was taken by the chronoscope and the objective record was made on the kymograph. Two hundred records were taken, then the arrangement of the three middle keys was changed. The first and last were not altered as they were connected with the chronoscope. With this arrangement two hundred reactions were taken. The second arrangement was then used with a different order for two hundred reactions, and finally the first arrangements was resumed for this second order. Four subjects were used. Practically no interference was found after the changes.

The second part of the experiment was similar to the first except that the two orders were before the subject, and he was instructed

[17] W. O. Beazley, unpublished research work done at the University of Pennsylvania, 1911–12.

to react first to the one, then to the other, alternating through the entire experiment. Very little interference was found. Mr. Beazley concluded that there is no true interference of the old association. The only interference is that due to becoming used to the experiment. These unpublished conclusions are given only as his tentative opinion.

The other works which will be referred to are not directly on the problem but will be used in the discussion, at which time their results will be mentioned.

## CHAPTER II

### The Typewriting and Discrimination Reaction Experiments

The problem as outlined in its broader relations requires a wide field of investigation and observation. The changes in reaction which a community of foreigners undergo on coming into the new conditions of American life, of the American as he goes abroad, or of the country lad going into the city furnish interesting observation. Mathematical problems in which a new element is introduced, a new factor in a problem of logic, a stubborn fact in a theory, a shift in economic conditions, all present situations for a broad study of adaptability. A study of religious conversion presents a distinct type of changed reaction.[1]

The method of the experimental psychologist however is to take processes in as simple a form as he can find them. The aim is, under laboratory conditions, to exclude all factors except the one which is being investigated. Should not the student of individual differences do the same thing? The school of Binet and Henri have contended that the study of individual differences should be concerned with the more intellectual and complex processes because in these the variations are more pronounced.[2] Max Brahn in a criticism of their work says that the problem of individual psychology can only be investigated in the simplest forms of psychical activity.[3] To this latter principle of method the German and American school has generally adhered.

In all the experiments I have used as simple methods as possible in the endeavor to isolate the factor under consideration. Only in an auxiliary study of character by the method of average judgment is the present study concerned with the more general and intellectual differences. This study was made for the purpose of correlation with the results of the typewriting experiment.

#### (*a*) *Preliminary Group of the Typewriting Experiment*

The first series of experiments were those made on a typewriter and will be referred to as the *typewriting* experiments. There were

[1] See especially E. D. Starbuck, "Psychology of Religion," Chaps. 5 and 13.

[2] Most clearly set forth in "Etude de Psychologie sur les Auteurs dramatique," by A. Binet et J. Passy, *Annee Psychologie, I. S.* 60–118, 1895.

[3] Max Brahn, "Review of the Work of Binet and Passy," *Zeitschrift für Psych. und Phys. der Sinnesorgane,* **12**, 280, 1896.

two experiments, the preliminary, and the regular. In these two the procedure was slightly different. The preliminary experiments were made to familiarize the writer with the subject and to suggest methods for further work.

The preliminary experiments were made during the winter of 1909–10. They were made on an Oliver typewriter, using only the middle row of nine keys. A small stand placed beside the machine held a cover over the keyboard, high enough so as not to hinder the finger or hand movement, yet preventing the subject from seeing the keyboard. This cover also held the copy which was to be written conveniently before the subject. Each key of the row was assigned to a definite finger and was not to be struck by any other finger. The fingers of the left hand manipulated the four keys to the left and those of the right hand the five keys to the right, the index finger manipulating two keys. The experimenter always required that the fingers be in their proper position before the separate repetitions of the copy. The thumb was used for spacing.

For the sake of simplicity numerals instead of letters were written. The keys were numbered from 1 to 9 beginning at the left. The subject could easily remember the number associated with each finger because the numbers came in order from left to right. Each number was associated with a particular finger and that finger was to strike a particular key. The work of the subject was to make the reaction automatic as quickly as possible.

The following three-place numerals were on the copy before the subject and were to be written.

174 479 853 639 751 628 392

The objective record was in letters but these were easily checked up by a key.

The subject's hand and fingers were placed ready to write when the signal was given. The time was taken with a stop watch. It was started on the signal to write and stopped after the last stroke. Thirty seconds rest were given between each trial.

In the preliminary experiment no given number of repetitions were given, as was the case in the later experiments. The purpose was to practise the series until the subjects had reached their maximum speed, and the association had become automatic. This matter will be discussed later.

At this point of practise there was a definite change made in the association of the numerals, and this change will be referred to as the *break*. It was simple but definite. Numbers 2 and 3 which had been

written by the middle and third fingers of the left hand were hereafter to be written by the middle and third fingers of the right hand, and numbers 7 and 8 were to be transposed to their position on the left hand. The number written by the middle finger of one hand was to be written by the middle finger of the other and vice versa, and the same thing is true of the third finger. The copy was not disturbed in the least, only the reaction to the numerals mentioned. The other associations were not disturbed. The change was made to the opposite hand so that the discharge had to follow an entirely different channel, and so that there could be no mistake about *relapses, i. e.,* reacting to the former associations. Had the change been made from one finger to another of the same hand, one could not always tell whether a certain error was due to a bungling of the fingers or to the former association. After the break the subjects again practised until they attained their former efficiency or approximated it as closely as possible.

### (*b*) *Regular Group of the Typewriting Experiment*

The procedure in this was the same as in the preliminary experiment except that it was more rigorous and uniform. The same numerals were written under the same conditions up to the break. But the number of repetitions was the same for all the subjects regardless of the point of efficiency reached. Each subject practised the series 130 times. This number of repetitions had been found sufficient for the great majority of the subjects in the preliminary group. The associations seemed well fixed and automatic by the 130th trial. It was also found in the preliminary group that the only safe measure of the strength of the association was the number of repetitions and not the point of efficiency reached. The more rapid subjects could soon attain a speed never reached by others. But to have introduced the break sooner would have made the strength of the associations unequal.

At the end of the 130th repetition the break was introduced. Instead of alternating the fingers writing 2 and 3 with those writing 8 and 7 as in the preliminary experiment, the fingers writing 1 and 3 were alternated with 9 and 7 respectively. This change in the association was explained to them and they were immediately set to writing. Other conditions remained the same as before the break. This new set of responses was then practised fifty times and the experiment closed.

The experiment took six sittings of one half hour or more each. Thirty repetitions were given at each sitting. The first four sittings

gave 120 repetitions. On the fifth day ten repetitions refreshed the habit at which time the break was introduced. Twenty repetitions of the new responses were then given on that day and thirty on the day following. The experiments were all held in the afternoon or early evening and at approximately the same hour each day of the experiment.

Simple errors in writing before the break were counted, grouped, and studied for their own interest. But the errors after the break in which the old associations persist were separately treated and were the direct material for the study of individual differences. These will be referred to as *relapses* and are always to be distinguished from errors.

### (*c*) *First Group of the Discrimination Reaction Experiments*

The results reported in this group are only a by-product of the experiments on the influence of caffein on the various mental functions held under the direction of Dr. Hollingworth in the early months of 1911.[4] The writer was one of the assistants in those experiments and secured permission to use these results for a study of individual differences in interference. The data here given are those secured during the first week before caffein was used.

The experiments are those of color discrimination reactions on a Forbes chronoscope. The subjects reacted to "red" with the right hand and to "blue" with the left. Only reactions of the right hand are recorded, while the left set a buzzer going. Mistakes were noted as well as double reactions. The data are for 15 subjects, 10 men and 5 women. There were 140 reactions for each hand taken in fourteen sittings of ten reactions each for each hand. At the end of this practise period the associations were reversed, blue now being reacted to with the right hand and red with the left. The time and errors of the right hand were recorded. This association was then practised for three periods of ten reactions each. Interference is measured by the difference in reaction time of discrimination due to the change. The greater frequency of errors after the change is also a measure of interference.

Later on when the subjects had become well practised on the Color Naming Test, the Opposites test and the Calculation test, Dr. Hollingworth had the correct responses for each of these tests written out, and ascertained the time it took the subjects to merely read the answers to the tests. The average time was taken as approximately

[4] H. L. Hollingworth, "The Influence of Caffein," ARCHIVES OF PSYCHOLOGY, **22**, April, 1912.

the time required for the perception and pronunciation of the words. This average measure of the perception and pronunciation time was taken from the average records of the subjects for the test proper. This is perhaps as fair a measure of the individual's ability in these subjects as can be obtained, for it reduces the time to the "psychological limit" if there is such a thing. The results obtained on the chronoscope experiments were then correlated with these various tests along association lines.

The chronoscope experiments were conducted by Margaret Hart Strong, of the department of psychology of Barnard College, under the direction of Dr. Hollingworth.

### (*d*) *Second Group of the Discrimination Reaction Experiments*

This series is similar to the first group except that the reaction times for both red and blue were recorded and that only sixty records of each were obtained before the color associations were changed. After the change thirty reactions with each hand were taken. Before the change the right hand reacted to "red" and the left to "blue"; after the change the reactions were reversed. The group was composed of twelve men and seven women, all of them subjects in the typewriting experiments. The data were secured for the purposes of correlation with the results of the typewriting experiments.

### (*e*) *Character Judgments*

This is the only part of the investigation which is not of an experimental nature, and which deals with the more general and intellectual qualities. Determination of character by the method of average judgments is most fully discussed by Professor Norsworthy.[5] This is the method here used.

An attempt was made to secure competent judgments on the following qualities or traits of character: mental balance, intellect, emotions, will, quickness, originality, individuality, independence, and persistency of habits. Only three of these qualities are discussed with reference to our problem, viz., independence, originality, and individuality. Sheets were prepared giving the names of the subjects in a horizontal column at the top and a vertical column giving the qualities in which they were to be rated. These sheets were sent to twelve men who were well acquainted with all the subjects to be rated. Judgments were secured upon the eight men of the preliminary type-

[5] Naomi Norsworthy, "Judgments of Character," Volume to William James, 551, 1908.

writing experiment. Their rating in these qualities was correlated with the results of the typewriting experiments.

The observers were instructed to rate each of the subjects in the given traits on the basis of 10. The individual being the most fully developed in the trait was to be rated 10 and the lowest conceivable was to be rated 1. The most important consideration was to secure the same standard of judgment. For this purpose it was felt better to make the highest individual conceivable the basis of 10 rather than the highest in the group. The writer realizes at the present that greater individual differences would have been secured had 10 and 1 been made the highest and lowest of the group rather than the given standards.

A letter of instruction was given to each of the observers, in which the comparative rating of the men was emphasized. Whether a man is rated higher or lower is not as significant as whether he is in the correct relative position. Only ten judgments were secured, as two of the observers did not rate all the men. The judgments for a single trait were averaged for each individual and his place in the group determined by that average. The method of position in the group could not be used because two or three subjects might have the same marking, which would introduce too great an error.

### (*f*) *Subjects*

The subjects in the typewriting experiments range in age from 20 to 35. Only one of them had special training in psychology. None of them had had appreciable practise on a typewriter.

The designations for the different subjects are as follows:

In the preliminary group: Hf, Co, Sa, Lo, Ja, Se, Hi, St, all students of Union Theological Seminary.

In the regular group: Men, Ha, McC, Br, De, La, Cl, students at Union Theological Seminary. Ru, clerk in the seminary.

Women: Mrs. Hf and McC, wives of students in Union Seminary, Wh, instructor in psychology in Teachers College. Mo, Gr, Wa, Ta, Og, and Ha, students at Teachers College.

The subjects of the first group of discrimination experiments will not be referred to individually. Those of the second group are all included in the typewriting groups. In order to facilitate matters for the reader all men will be referred to by the designations given while the designations of women will be prefixed by Mrs. or Miss. The context or definite statement will indicate in what experiment. There were twenty-four subjects in the typewriting experiments.

## II. Statement of Results

To make the treatment more coherent a number of questions will be discussed in Chap. IV., on "Individual Differences," which will embody direct statement of results. Such results as will not be needed to make this chapter clear will be given there.

### (a) *The Typewriting Experiments*

Table I. gives in condensed form the results of both the preliminary and regular groups. The individual records of the 130 repeti-

TABLE I

Table I. gives first trial before and after the "Break" in the first two columns; the average of the first five likewise in the second two columns; then the average of last five. The next two columns give the absolute gain and following the percentage of gain before and after "Break." The last column gives the difference between the last five before the "Break" and the last five after it. A negative sign indicates poorer efficiency after "Break" than before, positive better record than before "Break."

| Subject | First Trial | | Average of First Five | | Last Five | | Absolute Gain | | Percentage Of Gain | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After | Before | After | |
| Ha .... | 36.0 | 48.4 | 28.8 | 29.4 | 6.6 | 9.8 | 22.2 | 19.6 | .77 | .66 | —3.2 |
| Mo .... | 75.0 | 36.0 | 49.0 | 26.0 | 8.8 | 9.6 | 40.2 | 16.4 | .82 | .63 | — .8 |
| Ta .... | 54.0 | 37.4 | 39.4 | 29.4 | 10.0 | 10.2 | 29.4 | 19.2 | .76 | .61 | — .2 |
| Hf .... | 35.2 | 19.6 | 28.8 | 20.0 | 11.0 | 11.0 | 27.8 | 9.0 | .62 | .45 | .0 |
| McC ... | 96.0 | 39.0 | 44.6 | 32.6 | 10.6 | 10.4 | 34.0 | 22.2 | .75 | .69 | .2 |
| Wa ... | 69.8 | 28.0 | 41.4 | 26.6 | 9.8 | 15.0 | 31.6 | 11.6 | .76 | .45 | —5.2 |
| Wh ... | 22.4 | 27.8 | 20.8 | 18.4 | 6.6 | 8.0 | 14.2 | 10.4 | .69 | .56 | —1.4 |
| Og .... | 54.0 | 32.2 | 34.8 | 24.6 | 6.8 | 12.2 | 28.0 | 12.4 | .79 | .51 | —5.4 |
| Gr .... | 57.0 | 41.0 | 44.6 | 29.4 | 12.4 | 12.2 | 32.2 | 17.2 | .72 | .58 | .2 |
| Cl .... | 33.2 | 24.2 | 24.4 | 18.8 | 6.6 | 9.4 | 17.8 | 9.4 | .73 | .51 | —2.8 |
| Ru .... | 77.4 | 57.0 | 47.0 | 35.0 | 16.8 | 13.8 | 30.2 | 21.2 | .64 | .60 | 3.0 |
| Ha .... | 131.0 | 32.6 | 58.0 | 26.6 | 12.8 | 14.8 | 45.2 | 11.8 | .78 | .45 | —2.0 |
| Br .... | 55.6 | 37.0 | 41.8 | 25.6 | 10.6 | 14.6 | 36.2 | 11.0 | .77 | .44 | —4.0 |
| De .... | 37.0 | 33.0 | 28.0 | 28.0 | 9.8 | 10.4 | 28.2 | 17.6 | .65 | .63 | — .6 |
| La .... | 47.0 | 28.0 | 33.4 | 25.8 | 11.2 | 13.0 | 22.2 | 12.8 | .70 | .50 | —1.8 |
| McC ... | 71.8 | 35.4 | 52.4 | 31.8 | 14.0 | 20.0 | 38.4 | 11.8 | .74 | .38 | —6.0 |
| Hf .... | 46.2 | 31.0 | 47.0 | 26.8 | 17.0 | 17.2 | 30.0 | 9.6 | .64 | .36 | — .2 |
| Co .... | 51.0 | 72.0 | 38.6 | 42.8 | 13.0 | 11.6 | 25.6 | 31.2 | .67 | .73 | 1.4 |
| Sa .... | 49.2 | 29.6 | 35.8 | 21.8 | 11.6 | 12.0 | 24.2 | 9.8 | .68 | .46 | — .4 |
| Lo .... | 60.0 | 36.0 | 35.0 | 30.6 | 11.6 | 11.2 | 23.4 | 19.4 | .67 | .63 | .4 |
| Ja .... | 40.0 | 44.0 | 32.0 | 35.8 | 9.4 | 11.6 | 22.6 | 24.2 | .74 | .68 | 2.2 |
| Se .... | 45.8 | 31.0 | 30.2 | 21.6 | 10.4 | 10.0 | 19.8 | 11.6 | .65 | .55 | .4 |
| Hi .... | 41.0 | 24.2 | 28.4 | 17.6 | 9.0 | 12.4 | 19.4 | 15.2 | .68 | .31 | —3.4 |
| St .... | 28.0 | 25.0 | 23.6 | 20.4 | 9.6 | 9.8 | 14.0 | 10.6 | .60 | .51 | — .2 |

tions are not given as they constitute a simple practise curve, fairly regular and reaching, for most subjects, the physiological limit. The table gives the times of the first performance, the average of the first five and last five performances, the absolute gain in seconds and the percentage of gain. All these are given both before and after the break. Plate I. gives the curves for the men and women of the regular group. The curves of the preliminary group are not given. Both the curves and the table show the practise before the break and its effect. The break, it will be recalled, was transferring 1 and 3 from the fingers of the left hand to the respective fingers of the right hand, and vice versa.

The initial records of the practise curve are very high because the subjects were not familiar with the typewriter, and were very awkward at first. They improved rapidly because of the simplicity of the experiment. That the subjects do not rise as high after the break as in the initial performance of the practise curve is due to the great gain made in learning to use the machine. Four subjects, Co, Ja, Misses Ha and Wh, do actually rise higher after the break than at the beginning. The curves clearly show that in the fifty repetitions after the break the subjects did not attain the level of efficiency before the break. An extra column is therefore given in Table I. showing the difference between their final performances in the two curves. This is obtained by subtracting the average of the last five performances after the break from the average of the last five before the break. A negative sign indicates that they did not reach their practise level by the given number of seconds and a positive sign indicates that they surpassed it. By this column we find that among the women McC, Hf, and Gr, equalled or surpassed their record before the break, while the rest did not equal it. Among the men of the preliminary group Se, Lo and Co, and among those of the regular group, Ru surpassed their previous record, while the rest did not equal it. Miss Wa and Mr. McC show the largest difference, they being six seconds or more behind their former record. The rate of improvement will be dealt with in Chap. IV.

Perhaps the best index of interference of the old association and of its persistency is that of its recurrences. Whenever 1 or 3, and 7 or 9 were struck with the fingers with which they had been associated, the errors were treated as a recurrence of the former association, and as such were used as an index of interference. These recurrences are called *relapses*. Table II. shows the distribution of the relapses in periods of ten trials and the total number for each subject.

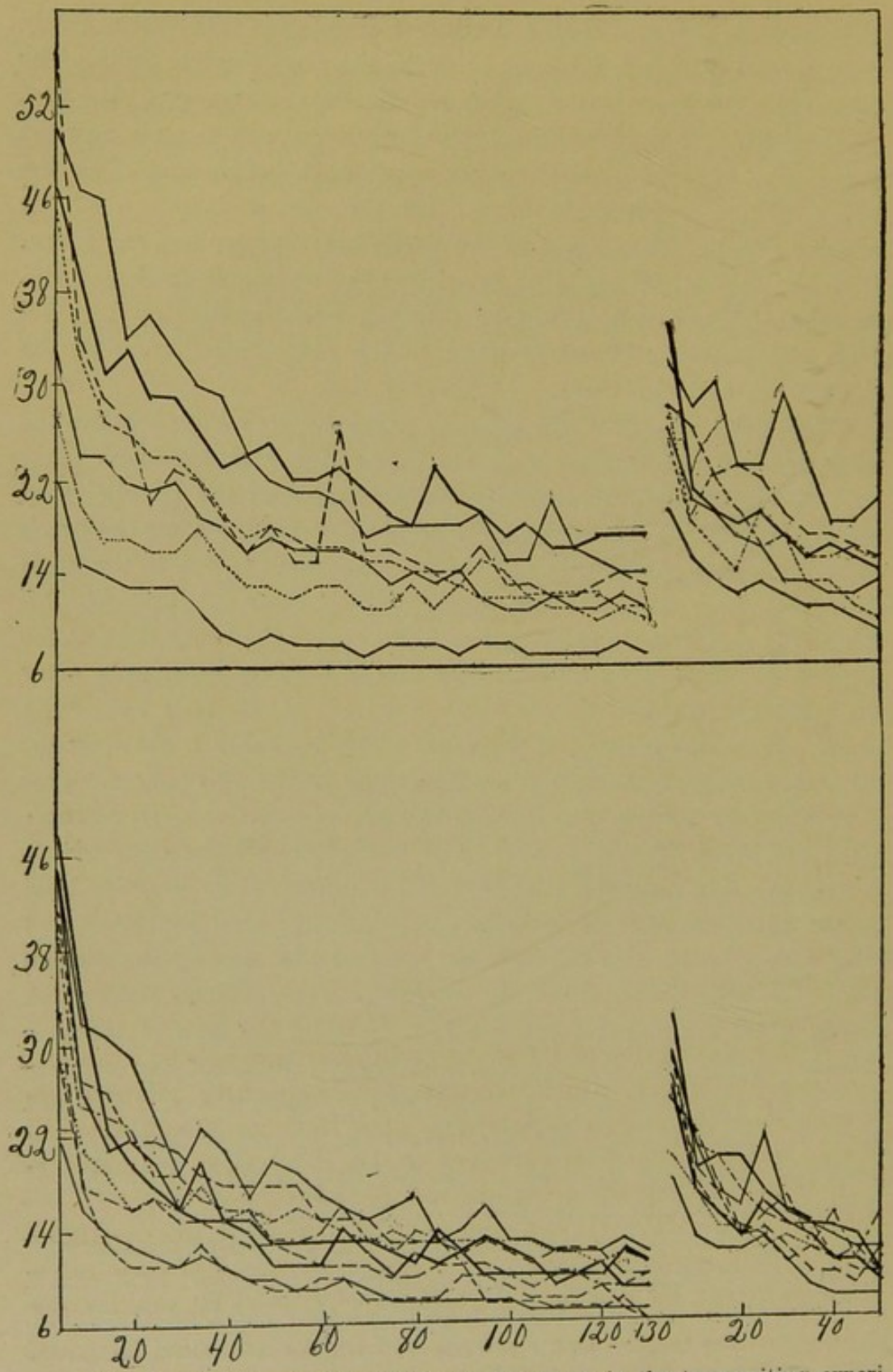



Plate I. gives the records of the regular group in the type-writing experiment. The ordinates give time in seconds and abscissas the number of repetition. The curves are made out on the basis of average of five reactions. The individual variations are due largely to confusion, errors, etc., and are not important for

TABLE II

The distribution of relapses is shown for every ten repetitions after the break. Two of the subjects of the preliminary group had more than fifty repetitions after the break, thus giving a wider distribution of their errors.

| | 1–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | Total |
|---|---|---|---|---|---|---|---|---|
| Women | | | | | | | | |
| Ha ..... | 5 | | | | 1 | | | 6 |
| Mo ..... | 12 | 1 | 1 | 1 | | | | 15 |
| Ta ..... | 8 | 2 | 1 | | | | | 11 |
| Hf ..... | 6 | 2 | 4 | | | | | 12 |
| McC ..... | 11 | 25 | 16 | 11 | 3 | | | 66 |
| Wa ..... | 16 | 2 | 13 | 16 | 12 | | | 59 |
| Wh ..... | 1 | | | | 1 | | | 2 |
| Og ..... | 39 | 3 | 6 | 3 | 3 | | | 54 |
| Gr ..... | 15 | 14 | 24 | | 3 | | | 56 |
| Men | | | | | | | | |
| Cl ..... | 13 | | 2 | 1 | | | | 16 |
| Ru ..... | 15 | 2 | 3 | | | | | 20 |
| Ha ..... | 16 | 9 | 10 | 3 | 1 | | | 39 |
| Br ..... | 8 | 12 | 5 | 3 | 5 | | | 33 |
| De ..... | 5 | 7 | 2 | 1 | | | | 15 |
| La ..... | 2 | 4 | 2 | 3 | 7 | | | 18 |
| McC ..... | 3 | 2 | 14 | 10 | 13 | | | 42 |
| Ja ..... | 3 | 2 | 4 | 2 | 1 | | | 12 |
| Se ..... | 7 | 1 | 4 | | | | | 12 |
| Hf ..... | 22 | 7 | 6 | 5 | 9 | 24 | 7 | 80 |
| Hi ..... | 5 | 6 | 8 | 1 | 3 | | | 23 |
| Co ..... | 1 | 1 | | | 1 | | | 3 |
| St ..... | 6 | 4 | | | | | | 10 |
| Sa ..... | 5 | 1 | 2 | | 1 | 2 | | 11 |
| Lo ..... | 10 | 4 | 1 | 1 | | | | 16 |

With the exception of Hf of the preliminary group who continued two periods longer, which accounts for his eightly relapses, the women show the greater variability. Mrs. McC has 66 and Miss Wh has 2; among the men the extremes are De 15, McC 42. Among the men of the preliminary group the number of relapses ranges from 3 for Co to 80 for Hf. Hf however made 31 of those in the repetitions beyond fifty which was the total number of repetitions for all of subjects except Hf and Sa. With the exception of Hf the distribu-

our purpose, and to give them would require many charts or cloud the general curve. After 130 repetitions the break is shown and the record for the 50 repetitions after the break with the variations in performance. While some of the curves have similar lines they are well enough separated so as not to be confused.

tion in the preliminary group is very regular, 3, 10, 11, 12, 12, 16 and 23. Among the men of the regular experiment there are two groups one of 15, 16, 18, and 20, and the other of 33, 39, 42. Among the women there are also two groups, the first 2, 6, 11, 12, 15, then a wide gap to 54, 56, 59, 66. That this distinct separation into groups should exist does not seem to the writer to justify any other statement than that there is a very wide range of individual differences. There is no correlation between the rate of improvement and the number of relapses so that those making the greater number of relapses did not do so in a sacrifice to speed. The differences in the number of relapses are far greater than the differences in rate of improvement or of speed before the break.

There were many expressions of difficulty after the break, and these were noticeable among the four women making the most relapses. One quivered and gritted her teeth, another started to cry, the two others claimed they tried hard and one said that it felt so funny to start to put one finger down and then stop and put the other down. These were the four who made 54, 56, 59 and 66 relapses. The number of subjects does not warrant one in concluding that there are two types among the women, yet the results do tend to show that there is not a single type to which women conform when put under such a situation of adaptation to a new element. While the men arrange themselves in groups the differences are not so great.

The men in the preliminary group with the exception of Hf conform closely to a type. Hf, whose time record was poor and who thought he had no associations firmly fixed, nevertheless shows an abundance of relapses after the break.

A glance at the table will show interesting differences as to the stage at which the relapses occur. The first twenty trials were on the day of the break and the other thirty on the day following. With most of the subjects the majority of the relapses were made during the first ten trials but with some this was not the case. Ha, Mo, Ta, and Og, among the women, and Cl, Ru, Se, St, Sa, and Lo among the men, had a majority of their relapses during the first ten trials and thereafter a rapid decrease. But this is not true of Mrs. McC, Misses Wa and Gr, nor of Ha, Br, De, McC, Ha, Ja, and Hi among the men. They had more relapses during the later periods. Mrs. McC made more relapses in each of the following three periods than in the first one. McC's relapses rise very decidedly on the second day though he had a good record on the first. On the third day Hf shows more errors in the first period than on either of the two previous days. On the second day he had apparently acquired good con-

trol, but on the third day he had 6, 3, 1, 4, 4, 4, and 2 relapses per trial in consecutive trials. Although he thought he had no habit formed it proved to have greater and more persistent effect on him than on any other individual of the entire group. Miss Gr had nearly as many relapses during the first ten trials of the second day as on the twenty trials immediately after the break. The comparative ease with which some of the subjects rose to the situation immediately after the break, and the relapses to which they were subject later on was very noticeable. This is especially true of Hf and McC, Misses Wa and Gr, and Mrs. McC. On the other hand Miss Og had 39 relapses during the first ten trials, then a very rapid falling off. These pronounced differences show that with some the effect is more immediate than with the others. The subjects were always cautioned on the second day to give their attention to the work so as not to make any relapses. In some cases the attention was not so well sustained as immediately after the break. Hi who made more relapses on the first period of the second day than before admitted wavering attention. But as a general rule those who made the most errors seemed to try the hardest. This was especially true among the women. On the other hand St, who was very rapid and had no relapses on the second day had much wavering of attention. De was more attentive, less nervous, and had better control after the break than before.

The only three-place number not having a digit affected by the break was 628. The 2 and the 8 were however transferred several times. The 8 was transferred from the third finger of the right hand to the third finger of the left and *vice versa* with the 2. This was done because of the third finger being between the two fingers whose associations were transferred. Miss Wa who did this several times, said that it seems she must also transpose the other finger (pointing to the third finger) because the middle and fourth fingers had to change. The same subject also had a number of cases in which she struck with the correct finger and then with the other as before the break. This seems to be due to a sort of secondary impulse after the correct finger has responded. There were also a number of cases, especially Misses Ta and Mo, where the relapse was first made, then the correct association.

The correlations by the Pearson coefficient between the rate of improvement after the break and the relapses are as follows:

| | | | |
|---|---|---|---|
| | Women ..... | $r = -.09$ | P.E. .28 |
| Regular | Men ..... | $r = -.76$ | P.E. .10 |
| Preliminary | Men ..... | $r = -.69$ | P.E. .12 |

The correlations between the rate of improvement after the break and before are as follows:

| | | | |
|---|---|---|---|
| Regular group | Men ..... | $r = .13$ | P.E. .19 |
| | Women ..... | $r = .45$ | P.E. .17 |
| Preliminary group | Men ..... | $r = -.86$ | P.E. .06 |

These coefficients show a negative correlation between the rate of improvement and relapses among the men. Those with more relapses improve less rapidly and those with fewer relapses improve more rapidly. Among the women there is no correlation. This shows that speed was not purchased at the price of accuracy nor accuracy secured with unlimited time. The two elements of errors and time are difficult to adjust so as to secure a reliable measure. With unlimited time the subject would have made no relapses, with a given speed there would be very many. How can we measure the difference when both time and relapses are variable?

The fact is that in order to secure a measure of the ability of breaking the former association the speed could not be set for the various subjects, for with some the physiological limit of writing is so much lower than with others, that they could at a given speed have time to inhibit each tendency to relapse, while the others going at their normal speed would have many relapses. The effect of the association can be measured only when each subject is writing at his best possible speed. Nor can a standard of absolutely no relapses be set, for then each single reaction could be fully thought out and the new association correctly made. The only true measure is to have the subject write at his greatest possible speed and measure both time and relapses.

The negative correlation shows however that speed is not made at a sacrifice of accuracy, nor accuracy purchased at the expense of speed. This shows that the two elements do not annul each other as an index of interference, but rather emphasize the differences. The individual differences are greater than either the relapses show or than the rates of improvement show and to the extent to which the two are negatively correlated is the variability of the group increased. Again there is no correlation between the rate of improvement before and after the break except that of .45 P.E., .17 among the women. This shows that the rapidity of improvement after the break is not due simply to the general ability to improve, but that the differences are entirely due to interference. There is thus no relation whatever between the performance after the break and before, and the individual differences after the break are due to interference. The negative correlation between the relapses and the rate of improve-

ment shows that individual differences in adaptability to a new situation in the face of the persisting old association are greater than under the conditions of ordinary practise. And the negative or negligible correlations between the rate of improvement after and before the break shows that the differences are not due solely to the same qualities as make for efficiency in practise. These differences are further emphasized by the fact that the variability in the rate of improvement after the break, as expressed by the Pearson coefficient of variability, is 1.6 times as great as that before the break among the women, 2.11 times as great among the regular group of men, and 4.3 as great for the preliminary men.

(*b*) *Second Group of the Discrimination Reaction Experiments*

These are reported here because they were given directly for purposes of correlation with the results of the typewriting experiment. In this group there were given sixty reactions to each of red and blue to the right and left hand respectively. Then the order was changed and the colors associated with the opposite hand. The results of the twelve men and seven women are given in Table

TABLE III

Table III. gives in the first column of each hand the average of the thirty reactions previous to the change; in the second column the average of the thirty after the change. The third column gives the difference between the two. A negative sign indicates that the time was less after the change than before. All numbers represent sigmas.

| | *Right Hand* | | | *Left Hand* | | |
|---|---|---|---|---|---|---|
| | Before Red | After Blue | Difference | Before Blue | After Red | Difference |
| Miss Wh .... | 305 | 333 | 28 | 332 | 312 | —20 |
| Wa ..... | 345 | 347 | 2 | 371 | 375 | 4 |
| Ta ..... | 375 | 387 | 12 | 392 | 380 | —12 |
| Gr ..... | 398 | 376 | —22 | 372 | 337 | —35 |
| Mrs. McC ... | 443 | 494 | 51 | 488 | 400 | —88 |
| Ha ..... | 362 | 398 | 36 | 403 | 435 | 32 |
| Mo ..... | 431 | 444 | 13 | 461 | 456 | — 5 |
| La ..... | 349 | 303 | —46 | 353 | 298 | —55 |
| McC ..... | 476 | 478 | 2 | 477 | 476 | — 1 |
| Br ..... | 391 | 388 | — 3 | 391 | 429 | 38 |
| Ha ..... | 371 | 392 | 21 | 401 | 443 | 42 |
| Ru ..... | 276 | 292 | 16 | 281 | 310 | 29 |
| Cl ..... | 336 | 385 | 49 | 383 | 367 | —16 |
| De ..... | 316 | 343 | 27 | 349 | 331 | —18 |
| Hf ..... | 367 | 388 | 21 | 379 | 392 | 13 |
| Lo ..... | 226 | 233 | 7 | 231 | 191 | —40 |
| St ..... | 351 | 353 | 2 | 332 | 343 | 11 |
| Hi ..... | 308 | 293 | —15 | 309 | 291 | —18 |
| Co ..... | 283 | 370 | 93 | 337 | 348 | 11 |

III. The results are indefinite because of an insufficient number of associations before the change was made. The subjects had not reached their practise limit and consequently interference is clouded and in some cases the reactions are quicker after the changes than before.

A glance at the table will show that nearly half of the records after the change are better than those before. The only explanation seems to be that the practise limit had not been reached. The results are negative and there is no correlation with the typewriting experiment. I give the table in order to show all the experiments, those which show negative as well as positive results.

### (c) *Character Judgments*

Table IV. gives the rating of the eight men in the preliminary group of the typewriting experiment in the traits of *individuality, originality* and *independence*. These figures give the averages of ten ratings by friends who lived in the same dormitory with the subjects and associated with them in the class room. All the observers were graduate students. The observers were very conscientious in their work and the ratings seem as carefully prepared as any that could be secured. With the exception of Se in the trait *independence* no P.E. is over 1, and the median P.E. is .8. This is of course quite large considering the small individual differences. The tendency among most observers is to mark the individuals high and make very little difference between them, giving many of them the same rank.

TABLE IV

The average ratings of the character judgments with their probable errors are given under the appropriate headings. The fourth column gives the number of relapses in the typewriting experiment. The fifth column gives the number of mistakes in pronouncing "the" as "a" in a selection of prose of 300 words in which the word "the" occurred forty times. The subjects were required to read as rapidly as possible and pronounce every "the" as if it were "a."

| | Individuality | | Originality | | Independence | | Typewriting Relapses | Reading Mistakes |
|---|---|---|---|---|---|---|---|---|
| | Av. | P.E. | Av. | P.E. | Av. | P.E. | | |
| Se | 6.0 | 1.0 | 7.2 | .8 | 7.0 | 2.0 | 9 | 6 |
| Lo | 6.0 | 1.0 | 5.5 | .5 | 6.0 | 1.0 | 12 | 10 |
| Hi | 8.5 | .5 | 8.0 | .5 | 9.0 | 1.0 | 27 | 7 |
| Co | 6.5 | .5 | 6.0 | .0 | 7.5 | .5 | 5 | 8 |
| Ja | 8.0 | .0 | 7.0 | 1.0 | 7.5 | .5 | 13 | 8 |
| Hf | 5.5 | .5 | 5.0 | 1.0 | 5.8 | .2 | 80 | 17 |
| St | 9.0 | .5 | 9.2 | .8 | 9.0 | 1.0 | 13 | 6 |
| Sa | 6.5 | .5 | 6.0 | .8 | 8.0 | 1.0 | 11 | 19 |
| Av. | 7.0 | 1.0 | 6.6 | .6 | 7.5 | .5 | 22 P.E. 10 | 10 P.E. 4 |

The correlations of the rating in these traits with the results of the typewriting and reading experiments are given below. Since the number of errors and relapses is an inverse index of adaptability, the correlation will have an opposite sign from the relation which the two actually sustain to each other. Few mistakes and relapses must go with high rating and *vice versa* in order that there should be a positive correlation. The correlations are all negative in sign but are therefore given positive to show the real correlation of the abilities in breaking the old association.

| | | |
|---|---|---|
| Between Individuality and "Relapses," Pearson Coeff. | $=.40$ | P.E. .20 |
| Between Originality and "Relapses," Pearson Coeff. | $=.35$ | P.E. .21 |
| Between Independence and "Relapses," Pearson Coeff. | $=.50$ | P.E. .18 |
| Between Individuality and Reading Mistakes, Pearson Coeff. | $=.66$ | P.E. .13 |
| Between Originality and Reading Mistakes, Pearson Coeff. | $=.64$ | P.E. .14 |
| Between Independence and Reading Mistakes, Pearson Coeff. | $=.43$ | P.E. .19 |
| Between "Relapses" and Reading Mistakes, Pearson Coeff. | $=.53$ | P.E. .17 |

I was unable to secure competent observers for the subjects in the other group, because no sufficient number of observers could be secured who were acquainted with all the subjects.

### (*d*) *First Group of the Discrimination Reaction Experiments*

Table IX. embodies the results of the first group of the discrimination reaction experiments. These results are much more definite than those of the second group. The old habit was much better established, there being 140 reactions to red before the change to blue was made. In the second group there were only 60. Column *D* gives the interference, *i. e.*, the difference in sigmas between the average of the last thirty reactions to red, and the average of the thirty to blue after the change. This difference varies among the individuals from 2 sigmas to 107. Column *F* gives the percentage of this interference to the subject's practised reaction. Column *E* gives the number of errors due to interference of the old habit, calculated from the difference between the number of errors in the thirty reactions before and after the change.

The other columns give in seconds the "psychological limit" for the tests specified, the time for perception and pronunciation of the name being subtracted. There were four women and eight men in this experiment.

The correlation between *D* and *F* by the Pearson coefficient is .85 P.E., .05. We thus find that the individuals showing the greater interference in discrimination time also show greater interference in errors. This same thing was found true of the men in the type-

writing experiments, while among the women there was no correlation.

There is a slight correlation among some of the association tests and column *D*. Between *A* and *D* the correlation by the Pearson coefficient is .46 P.E., 15, by the method of unlike signs, $r = .70$. There is practically no correlation between *D* and either *B* or *C*.

TABLE IX

Table IX. gives the results of the first group of chronoscope discrimination experiments obtained under the direction of Dr. Hollingworth. The twelve subjects are numbered as reported in the caffein experiment. Nos. 3, 6, 11, 15 are women, the rest are men. Column *D* gives the difference in sigmas of the average of 30 reactions of the right hand to red, and the average of 30 reactions to blue, the subjects being long practised to red and then changed to blue. Column *E* gives the percentage of difference on the basis of their discrimination reaction time before the change. Column *F* is obtained by subtracting the wrong reactions in 30 trials before the change with the wrong reactions in 30 trials after the change, thus giving the greater number of errors under interference. Columns *A*, *B*, and *C*, respectively, give the difference in seconds required to take the color-naming test (100 colors), the opposites test, and the calculation test, less the time of pronouncing the answers to each of the tests when written out. It thus gives the time taken for each test, excluding individual differences in rapidity of enunciation. The individual records are the average of ten trials for each test.

| Subjects | *A* Color-Naming Test Difference between Naming and Articulation | *B* Opposite Test Difference between Associating and Naming | *C* Calculation Difference between Calculating and Naming | *D* Interference in Discrimination on Chronoscope | *E* Per Cent. of Interference | *F* Errors |
|---|---|---|---|---|---|---|
| 1 ..... | 31.8 | 19.3 | 63.2 | 7 | .022 | 1 |
| 3 ..... | 24.6 | 13.4 | 59.0 | 79 | .125 | 8 |
| 4 ..... | 14.7 | 9.5 | 57.4 | 32 | .120 | 3 |
| 6 ..... | 11.2 | 4.2 | 30.6 | 32 | .100 | 0 |
| 7 ..... | 9.6 | 8.9 | 32.2 | 2 | .006 | 1 |
| 8 ..... | 21.5 | 20.7 | 44.6 | 14 | .038 | 0 |
| 9 ..... | 14.4 | 13.1 | 45.8 | 52 | .164 | 4 |
| 10 ..... | 19.7 | 19.3 | 37.8 | 26 | .104 | 5 |
| 11 ..... | 23.5 | 17.2 | 52.7 | 38 | .122 | 3 |
| 13 ..... | 34.7 | 16.0 | 41.7 | 107 | .384 | 11 |
| 14 ..... | 20.6 | 10.3 | 46.0 | 35 | .102 | 4 |
| 15 ..... | 42.5 | 28.7 | 100.0 | 56 | .124 | 2 |
| Av. ..... | 22.4 | 15.0 | 50.9 | 40 | .118 | 3.5 |

There does seem to be a clear cut correlation between the performance in the color naming test and the interference in the chronoscope discrimination. The naming of colors has an element of inter-

ference, because the impression of the one color persists during the perception and attempted naming of the second, and the same ability that gives efficiency in changing easily from one reaction to another would give a high efficiency in naming one hundred colors on the color chart.

The correlation between $D$ and $F$ shows that here as elsewhere those having greater interference in time also have greater interference in errors and those having less in the one have less in the other.

## CHAPTER III

### The Card-sorting Experiment

#### I. *Description of the Experiment*

This experiment was made during the winter and spring of 1911 and the fall and winter of 1912. There were 34 subjects, 17 men and 17 women. The experiment took six periods of about 35 minutes each for each subject.

The experiment is an enlargement and modification of the card sorting experiment which Bergström used.[1] Instead of using cards with pictures, which are likely to be of different degrees of complexity and difficulty, and of different degrees of familiarity with different subjects, or words, which in themselves might have interfering associations, I used "flinch" cards. These are very smooth and are easily shuffled, and have simple numbers, and the numbers are printed at both ends so that they are always right side up. The cards are 2 by 3½ inches in size. The numbers used were from 1 to 10, and hence are of equal familiarity and difficulty. There were eighty cards used, eight of each kind from 1 to 10.

The cards were not to be sorted at random, as in Bergström's experiment, but had to be thrown into boxes made for them. Fig. 1 shows the boxes and the arrangement for two sortings. These boxes made an ideal arrangement for easy sorting. The boxes have no bottom so that after each sorting the frame is lifted up, put into another position, and is ready for a second sorting. The little boxes are four inches square and hence are plenty large enough to receive the cards. The back of each box is 2 inches higher than the front so that the cards must fall in the right boxes unless wrongly thrown. There is no possibility of a card slipping from one section to another and a card on the wrong pile means that it was thrown wrongly. The subjects were required to pick up cards which they dropped and to pick them out of the box if wrongly thrown. Thus there are no errors to take into consideration.

The time was taken with the stop watch. The watch was started when the signal was given to the subject and stopped when the last card was thrown. The cards were always thoroughly mixed, special care being taken that two of the same kind did not follow each other. There were enough packs of cards and enough helpers to

[1] Bergström, *loc. cit.*, pp. 434, 435.

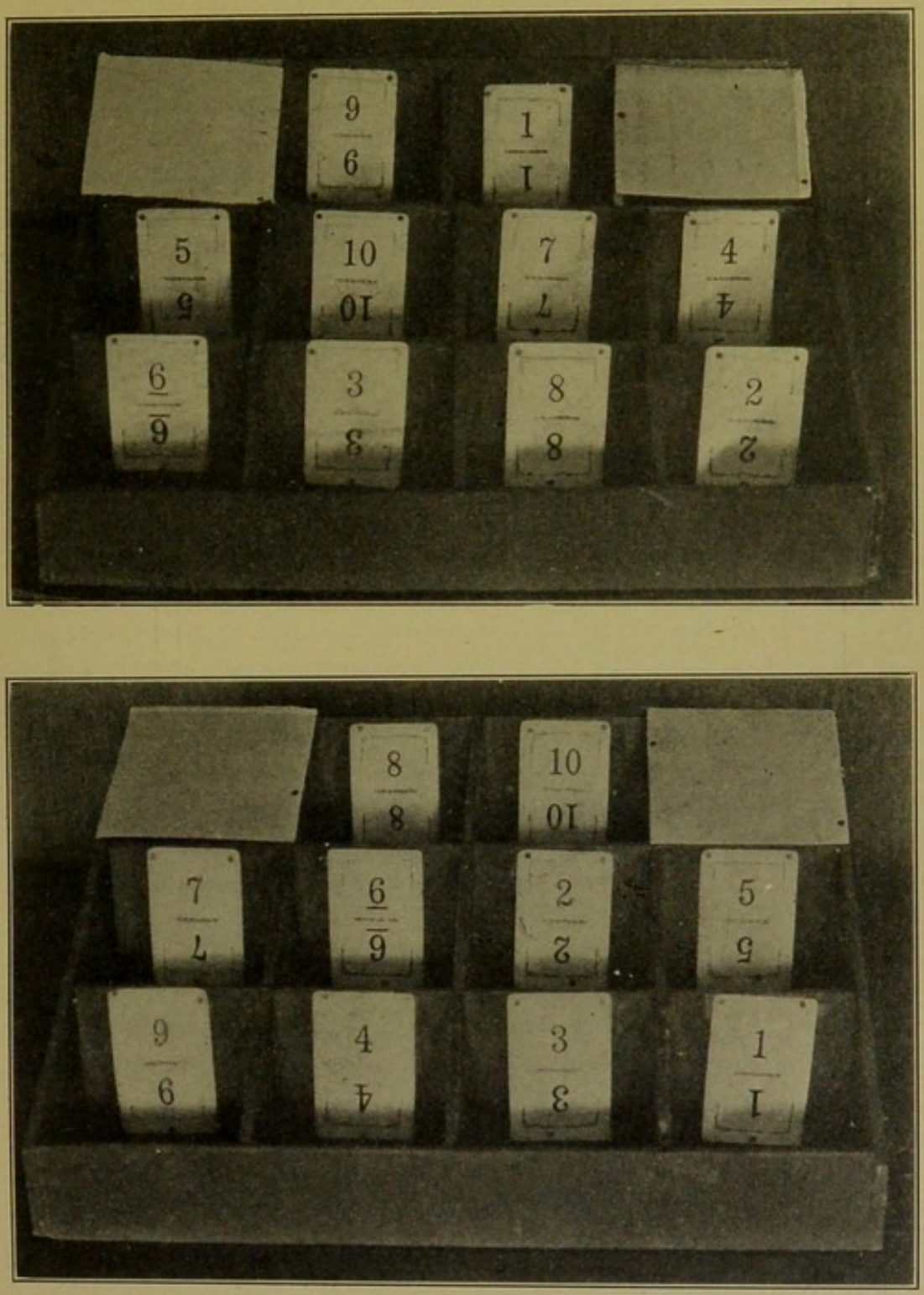



FIG. 1. Description in text.

keep the subject going no matter how rapid he was. A rest of 30 seconds was always given between sortings whether of the same or opposing arrangements. This was kept constant for Bergström had shown that the interference decreases rapidly with the increase of the interval between the sortings. Sixteen sortings were taken at

one sitting which continued for six days giving a total of 96 sortings, 48 of each arrangement. The element of fatigue did not enter in at all, as at no time were more than sixteen sortings held.

The subjects were divided into four groups, an equal number of men and women in each group. The men and women for each group were chosen at random. The first group is composed of four men and four women and is known as the "practise group" or Group I. This group sorted the cards only into the one arrangement and are used to determine the practise curve without interference as a comparison test for the other three groups. They sorted the cards 48 times.

The second group was composed of three men and three women. They sorted alternately according to the following formula:

$$A_1^1, A_2^1, A_1^2, A_2^2, A_1^3, A_2^3, \ldots, A_1^{48}, A_2^{48}.$$

($A_1$ throughout the discussion will indicate the first arrangement, and $A_2$ the second, while the exponential numbers will give the number of times the respective arrangements are sorted.) Each arrangement was thus sorted eight times each day for six days, alternating with the other arrangement. Bergström had the alternating arrangement, but the conditions here are different from those in Bergström's experiments in that the interval between the sortings is thirty seconds, while his were nearly two minutes; in that each arrangement is fixed for all the subjects and kept constant; and in that it is continued six times as long. This group will be referred to as the alternating group or Group II.

The third group was under the same conditions as Group II., except that the first arrangement was sorted four times, thus being fixed more firmly than in Group II., then the other arrangement four times, and then to the first again according to the following formula:

$$A_1^4, A_2^4, A_1^4, A_2^4, \ldots, A_1^{48}, A_2^{48}.$$

On the same day there were only two periods of each arrangement, which made sixteen sortings in all. The first arrangement for the first section was not subject to interference, but the second arrangement always was and the second section of the first was also. This group had seven men and seven women and will be referred to as Group III.

The fourth group was like the third except that the cards were sorted into the first arrangement eight times, and then eight times into the second according to the following formula:

$$A_1^8, A_2^8, A_1^8, A_2^8, \ldots, A_1^{48}, A_2^{48}.$$

In this group the first arrangement was never subject to immediate previous interference, as only one turn at each arrangement could be had at a sitting. The second arrangement had the interference effect of eight previous sortings of the first, but was itself continued for eight, giving it greater time to overcome the interference. This group, which will be referred to as Group IV., had three men and three women.

The experiments were held in the afternoon or early evening on successive days. In several cases a day had to be missed, but no influence was detected. Where however the subject had to remain away for considerable time, he had to be dropped. Several subjects had to be thrown out because of such irregularity.

The subjects ranged in age from 16 to 36. Only two of them had special training in psychology. They will be referred to by the following designations.

Group I. Men: Wa, Co, Ol, and Be, all students at Union Theological Seminary. Women: Sm and Co, clerks; Fo and St, students.

Group II. Men: Em, clerk; Gr, theological student; My, graduate student in psychology. Women: Cu and Mt, married women with high school training; Bk, musician.

Group III. Men: Ca, Si and Dr, theological students; Wi and Rd, high school students; Sv, architectural draughtsman, Sp, salesman. Women: Ku, Wo, Sv, Su, Ar, wives with high school and college training; Br and Th, clerks with high school training.

Group IV. Men: As and Bl, theological students; Cu, graduate student in psychology. Women: Mrs. Th, with high school training, Mor and Ag, music teachers.

All men will be referred to by the initials and women will be referred to by initials prefixed with Mrs. or Miss. The context or definite statement will show in what group the subject under consideration performed.

## II. *Results of the Experiments*

As stated in the description of the experiments Group I. will be used as a practise group for comparison and the other three groups in a study of interference. Group II. sorted the cards alternately, Group III. sorted them four times by one arrangement and then four times by the other, and Group IV. sorted them first eight times the one way, then eight times the other.

The individual records of Group III. are given in Table V. This group had seven men and seven women and is the only one that will be used for a study of individual differences. The other groups had

three men and three women each and have their value principally in the discussion of the relative interference effect of the various methods, and the rapidity with which the associations can become automatic in each.

The curves for this group are given in Plate II. for the women and III. for the men. Plate IV. shows the average curves for the men and women of this group, together with the performance in the practise group for purposes of comparison. The Roman type of the table gives the records of the first arrangement and the Italic type those of the second.

Table VI. gives the averages and their deviations for the four groups. Plate V. gives the graphic record of the averages for Groups II. and IV. The Roman and Italic types give the records of the first and second arrangements respectively. Since the first group had only 48 sortings and those of only one arrangement they are all printed in Roman numerals and are continued through the

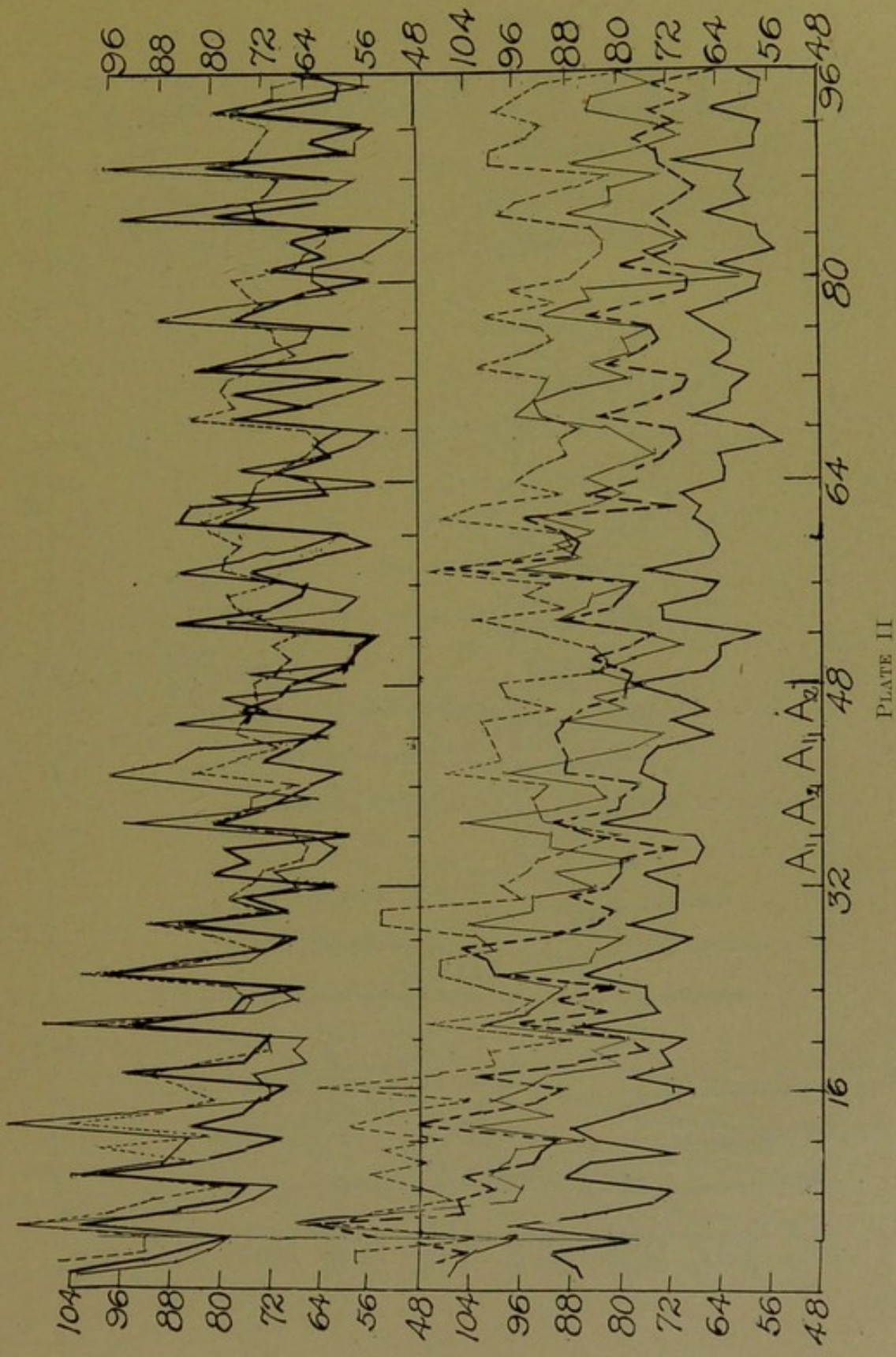
Plates II. and III. give the curves for the women and men, respectively, in the card sorting experiment, Group III., Arrangement $A_1$ four times, $A_2$ four times. Each plate gives seven curves, four in the lower sections and three in the upper. The ordinates give the time in seconds and the abscissas the number of times sorted. The days are marked by the lines with the numerals, each day having sixteen performances, and the change from one arrangement to another is shown by the smaller graduated scale. The procedure each day is made clear by the arrangement being shown on the third day. The rise in time after each change is clearly seen in both, though much more pronounced with the men. The curves in the lower sections are allowed to extend into the upper at the beginning to show them in full.

To avoid overcrowding the plate the following references to curves are given: Plate II. Women: Lower section, heavy line, Mrs. Wo; heavy dotted, Miss Br; light, Ku; light dotted, Sv. Upper section, heavy, Mrs. Ar; light, Mrs. Su; light dotted, Miss Th.

Plate III. Men: Lower section, heavy, Wi; heavy dotted, Sv; light, Sp; light dotted, Rd. Upper section, light, Ca; heavy, Dr; light dotted, Si.

Plate IV. gives the average curves in the card sorting experiment, Group III., for the 7 men and 7 women. The average practise curve for the men and women is also given. Solid line curve gives records of women, dotted of men. The change in arrangement is so clearly seen in the spires of the curves that no marking is necessary. Every day has its three rises after the three changes. It is also noticeable that each day's beginning is about at practise level of previous day. The curves of the men will be seen to rise higher after the change than the women, although their average is lower until the fourth day, when they begin to remain as low or lower.

Plate V. gives the curves for men and women in the second and fourth groups, Group IV. above, Group II. below. Solid line, women; dotted line, men. The scale on the ordinate is just half that of the average curve of Group III.


96
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32
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A1 A2 A1 A2

PLATE II

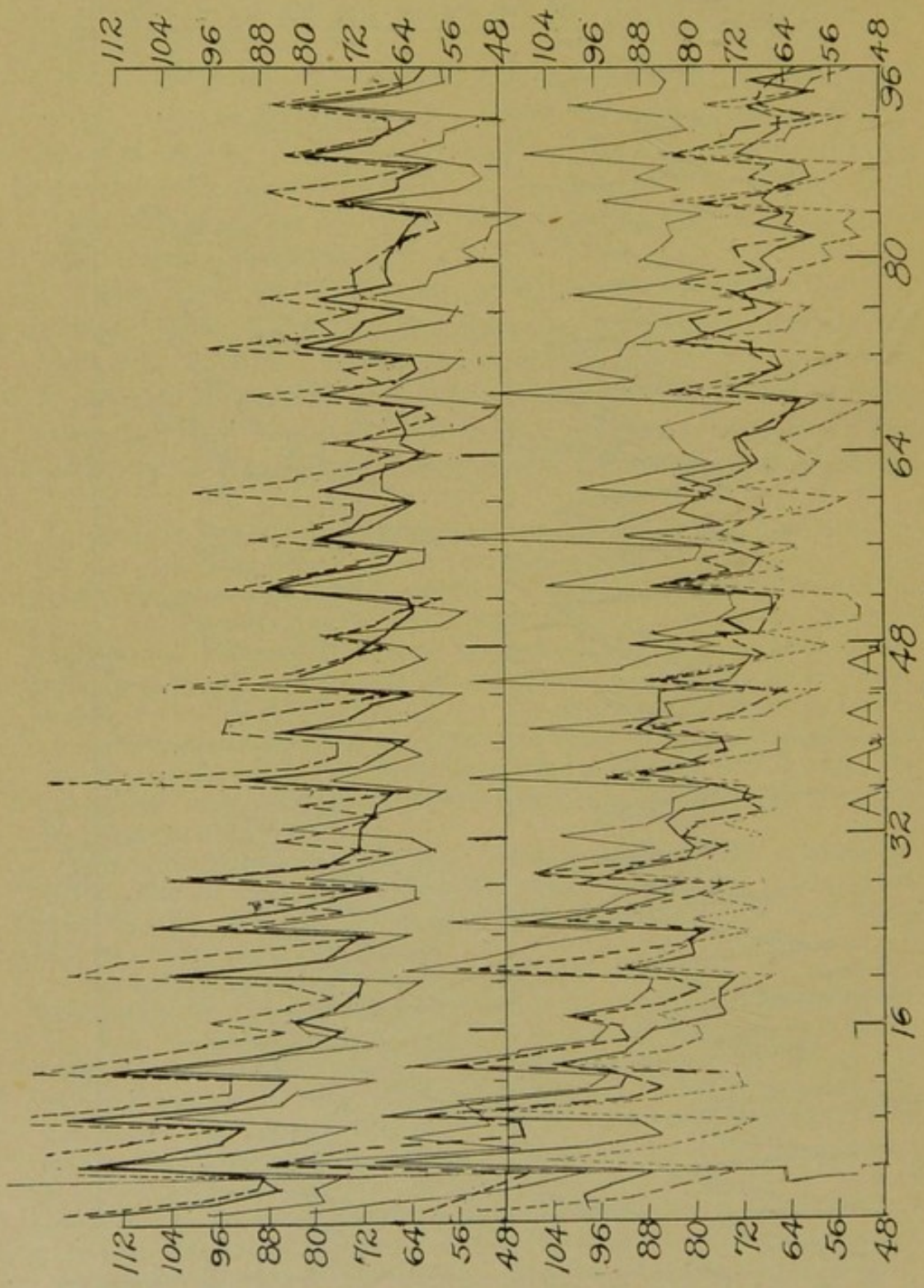
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PLATE III

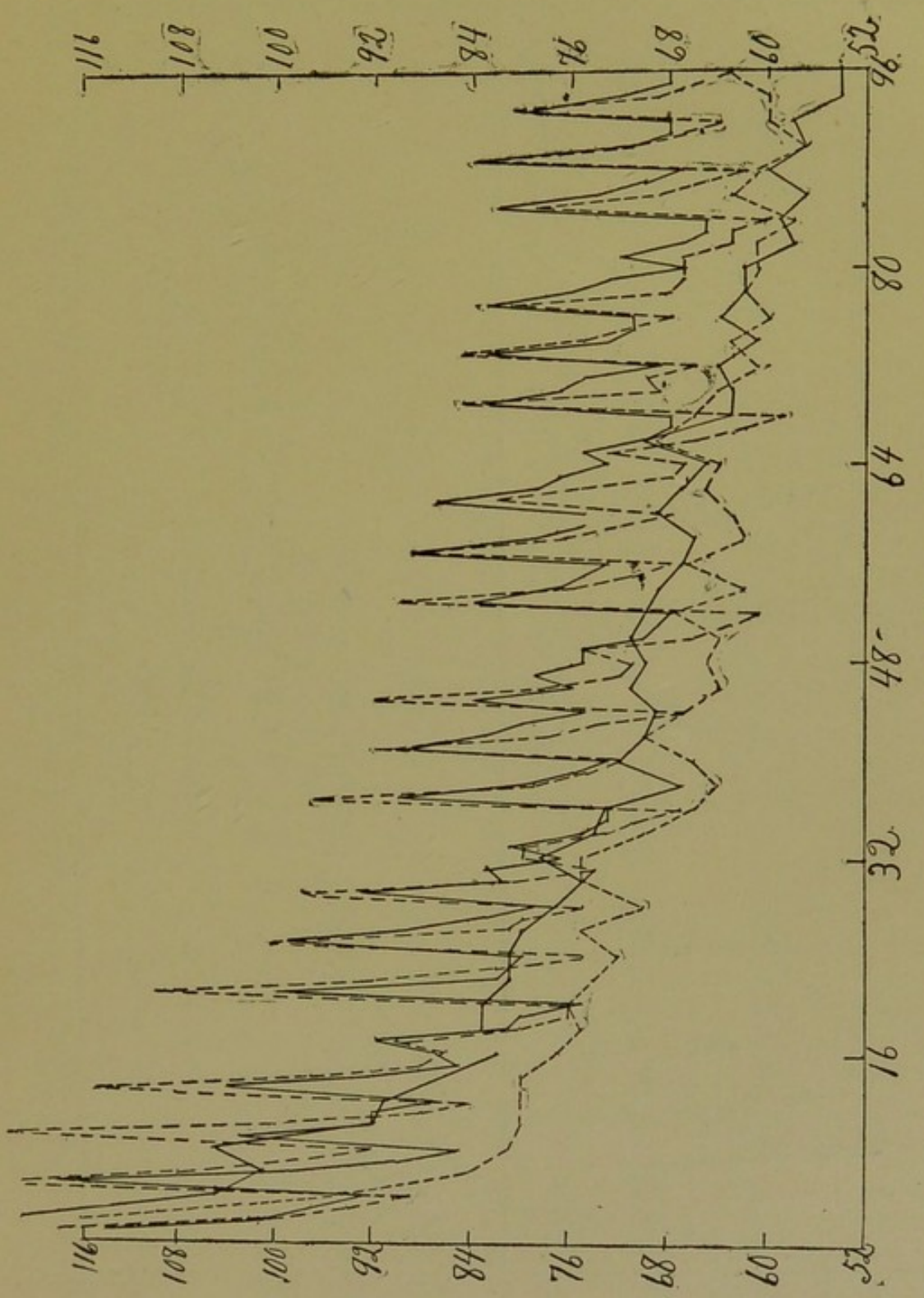


PLATE IV

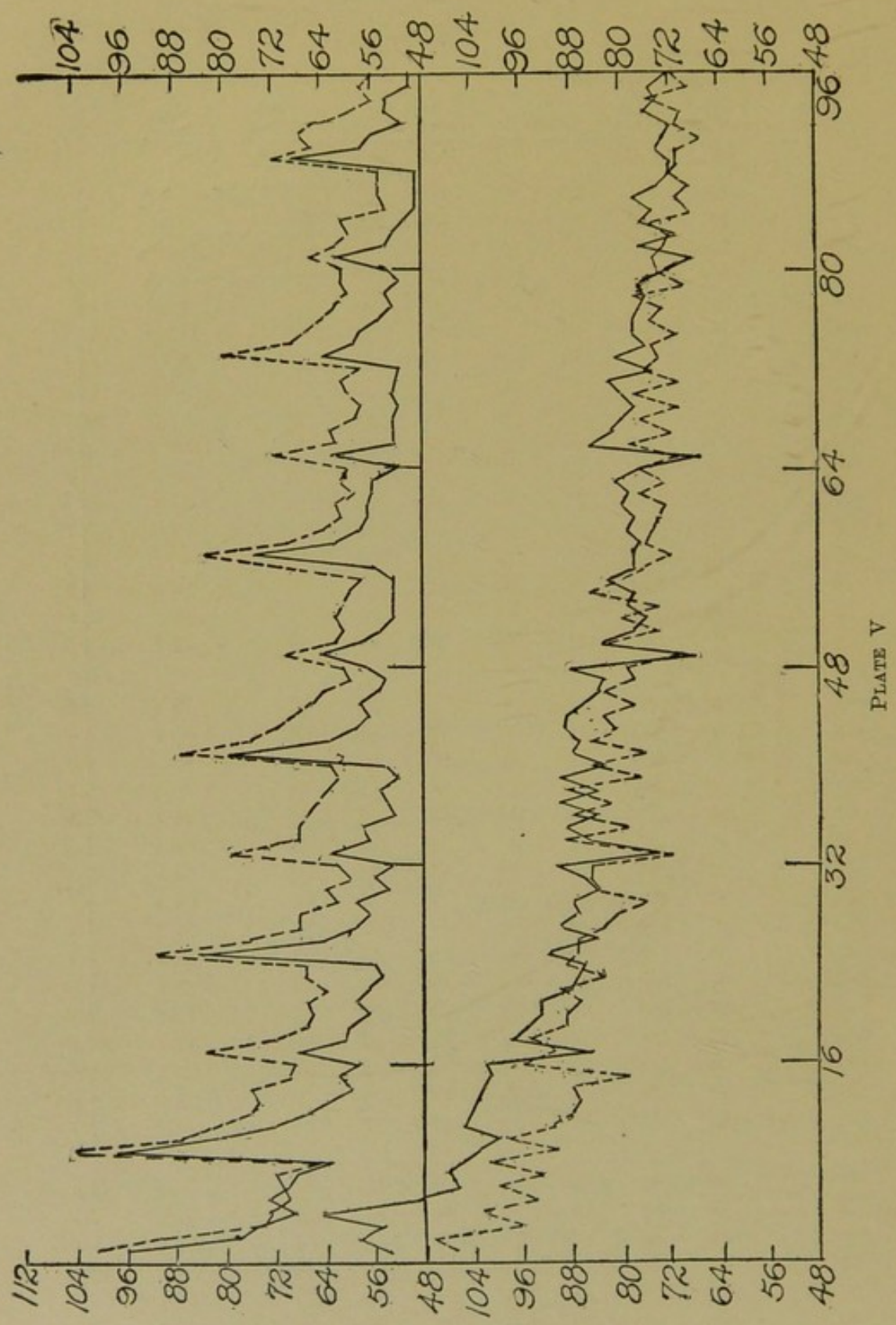


PLATE V

## TABLE V

### Individual Records of Women in Card-sorting, Group III

The Roman type gives records in seconds of Arrangement 1; Italic type, of Arrangement 2. Spaces separate successive days.

| | Ku | Sv | Wo | Br | Su | Th | Ar | Average | A.D. |
|---|---|---|---|---|---|---|---|---|---|
| 1 ..... | 107 | 138 | 86 | 140 | 103 | 118 | 104 | 113.7 | 15.8 |
| 2 ..... | 106 | 122 | 87 | 109 | 87 | 106 | 92 | 101.3 | 10.9 |
| 3 ..... | 103 | 122 | 91 | 104 | 82 | 92 | 85 | 97.0 | 10.9 |
| 4 ..... | 97 | 104 | 79 | 118 | 79 | 92 | 79 | 92.6 | 11.4 |
| 5 ..... | *132* | *126* | *98* | *130* | *113* | *121* | *103* | *117.6* | *11.0* |
| 6 ..... | *119* | *120* | *86* | *105* | *81* | *97* | *87* | *99.4* | *13.1* |
| 7 ..... | *97* | *107* | *75* | *106* | *75* | *91* | *79* | *89.7* | *11.4* |
| 8 ..... | *96* | *112* | *72* | *100* | *71* | *80* | *76* | *85.2* | *13.8* |
| 9 ..... | 101 | 120 | 89 | 105 | 104 | 100 | 100 | 102.6 | 5.9 |
| 10 ..... | 98 | 111 | 85 | 94 | 89 | 84 | 82 | 91.6 | 7.1 |
| 11 ..... | 97 | 118 | 71 | 93 | 87 | 100 | 76 | 91.7 | 11.7 |
| 12 ..... | 86 | 109 | 84 | 90 | 85 | 82 | 70 | 86.6 | 7.1 |
| 13 ..... | *104* | *123* | *88* | *112* | *114* | *104* | *85* | *104.3* | *10.3* |
| 14 ..... | *91* | *116* | *80* | *102* | *93* | *89* | *76* | *92.4* | *9.6* |
| 15 ..... | *101* | *104* | *73* | *93* | *72* | *81* | *73* | *85.2* | *12.2* |
| 16 ..... | *95* | *128* | *68* | *89* | *72* | *86* | *69* | *86.7* | *14.4* |
| 17 ..... | 92 | 109 | 79 | 103 | 75 | 92 | 95 | 92.1 | 8.7 |
| 18 ..... | 80 | 100 | 72 | 87 | 66 | 83 | 76 | 80.6 | 8.0 |
| 19 ..... | 85 | 101 | 74 | 85 | 68 | 72 | 74 | 80.1 | 9.0 |
| 20 ..... | 79 | 88 | 70 | 79 | 66 | 73 | 72 | 75.3 | 5.7 |
| 21 ..... | *102* | *111* | *87* | *96* | *108* | *100* | *94* | *99.7* | *6.3* |
| 22 ..... | *95* | *97* | *74* | *82* | *74* | *76* | *78* | *82.1* | *8.0* |
| 23 ..... | *92* | *94* | *76* | *90* | *67* | *75* | *76* | *81.4* | *9.0* |
| 24 ..... | *89* | *102* | *76* | *81* | *71* | *78* | *66* | *80.4* | *8.7* |
| 25 ..... | 100 | 109 | 86 | 100 | 98 | 102 | 100 | 99.3 | 4.1 |
| 26 ..... | 85 | 109 | 80 | 101 | 75 | 85 | 87 | 88.9 | 9.2 |
| 27 ..... | 84 | 100 | 73 | 105 | 73 | 74 | 73 | 83.1 | 11.3 |
| 28 ..... | 80 | 103 | 69 | 91 | 69 | 81 | 67 | 79.4 | 9.4 |
| 29 ..... | *104* | *118* | *79* | *84* | *91* | *90* | *86* | *93.1* | *10.1* |
| 30 ..... | *94* | *118* | *71* | *81* | *70* | *73* | *69* | *82.1* | *13.6* |
| 31 ..... | *94* | *95* | *71* | *88* | *78* | *78* | *76* | *82.9* | *8.1* |
| 32 ..... | *84* | *99* | *71* | *82* | *67* | *75* | *61* | *77.0* | *9.7* |
| 33 ..... | 90 | 95 | 76 | 80 | 70 | 73 | 81 | 81.0 | 6.6 |
| 34 ..... | 78 | 93 | 68 | 80 | 64 | 67 | 75 | 75.0 | 7.4 |
| 35 ..... | 91 | 86 | 67 | 71 | 61 | 66 | 79 | 74.4 | 7.4 |
| 36 ..... | 91 | 80 | 68 | 85 | 65 | 68 | 59 | 73.7 | 10.3 |
| 37 ..... | *105* | *92* | *83* | *91* | *95* | *81* | *80* | *89.6* | *7.0* |
| 38 ..... | *90* | *93* | *75* | *80* | *76* | *75* | *71* | *80.0* | *6.7* |
| 39 ..... | *82* | *94* | *71* | *80* | *64* | *75* | *65* | *75.9* | *8.1* |
| 40 ..... | *84* | *91* | *71* | *77* | *60* | *67* | *60* | *72.6* | *9.4* |
| 41 ..... | 98 | 108 | 77 | 89 | 97 | 84 | 73 | 89.4 | 10.0 |

TABLE V (*continued*)

| | Ku | Sv | Wo | Br | Su | Th | Ar | Average | A.D. |
|---|---|---|---|---|---|---|---|---|---|
| 42 ..... | 87 | 99 | 76 | 88 | 87 | 77 | 70 | 83.4 | 7.7 |
| 43 ..... | 78 | 100 | 74 | 89 | 83 | 70 | 64 | 80.0 | 7.9 |
| 44 ..... | 73 | 101 | 65 | 90 | 62 | 77 | 61 | 75.3 | 12.0 |
| 45 ..... | *89* | *102* | *72* | *89* | *87* | *76* | *76* | *84.4* | *8.4* |
| 46 ..... | *79* | *90* | *66* | *86* | *72* | *73* | *70* | *76.3* | *7.4* |
| 47 ..... | *84* | *98* | *71* | *79* | *79* | *74* | *66* | *78.7* | *7.6* |
| 48 ..... | *74* | *99* | *78* | *79* | *59* | *74* | *61* | *75.0* | *9.0* |
| 49 ..... | 84 | 83 | 66 | 78 | 75 | 70 | 66 | 74.6 | 5.3 |
| 50 ..... | 78 | 82 | 64 | 84 | 58 | 68 | 58 | 70.3 | 7.6 |
| 51 ..... | 70 | 84 | 64 | 78 | 58 | 71 | 57 | 68.7 | 8.0 |
| 52 ..... | 77 | 92 | 58 | 75 | 55 | 67 | 54 | 68.3 | 11.4 |
| 53 ..... | *90* | *103* | *73* | *89* | *78* | *72* | *86* | *84.4* | *8.6* |
| 54 ..... | *85* | *89* | *73* | *81* | *60* | *77* | *71* | *76.6* | *7.3* |
| 55 ..... | *84* | *95* | *66* | *79* | *57* | *78* | *66* | *75.0* | *10.0* |
| 56 ..... | *77* | *91* | *64* | *77* | *67* | *71* | *65* | *73.1* | *7.3* |
| 57 ..... | 96 | 110 | 76 | 103 | 86 | 79 | 74 | 89.3 | 11.7 |
| 58 ..... | 86 | 95 | 65 | 87 | 76 | 79 | 64 | 78.8 | 9.1 |
| 59 ..... | 90 | 87 | 64 | 86 | 67 | 76 | 55 | 75.0 | 11.1 |
| 60 ..... | 84 | 89 | 65 | 89 | 59 | 81 | 60 | 75.3 | 12.0 |
| 61 ..... | *92* | *108* | *68* | *95* | *79* | *82* | *86* | *87.1* | *9.6* |
| 62 ..... | *84* | *102* | *67* | *71* | *73* | *75* | *84* | *79.3* | *9.1* |
| 63 ..... | *79* | *89* | *70* | *85* | *80* | *74* | *62* | *77.0* | *7.1* |
| 64 ..... | *85* | *96* | *63* | *77* | *55* | *73* | *64* | *73.3* | *10.9* |
| 65 ..... | 80 | 93 | 63 | 77 | 76 | 69 | 70 | 75.4 | 8.6 |
| 66 ..... | 74 | 88 | 64 | 73 | 64 | 65 | 61 | 69.9 | 7.3 |
| 67 ..... | 78 | 89 | 54 | 70 | 57 | 63 | 64 | 67.9 | 9.6 |
| 68 ..... | 82 | 86 | 59 | 71 | 54 | 65 | 60 | 68.1 | 10.0 |
| 69 ..... | *96* | *92* | *69* | *83* | *77* | *84* | *77* | *82.7* | *7.1* |
| 70 ..... | *93* | *93* | *62* | *75* | *66* | *77* | *64* | *76.6* | *9.6* |
| 71 ..... | *87* | *92* | *62* | *70* | *59* | *79* | *77* | *75.4* | *9.4* |
| 72 ..... | *78* | *89* | *59* | *69* | *53* | *78* | *58* | *69.1* | *10.9* |
| 73 ..... | 84 | 102 | 65 | 82 | 83 | 82 | 81 | 82.7 | 6.4 |
| 74 ..... | 78 | 95 | 62 | 77 | 74 | 67 | 58 | 73.0 | 9.1 |
| 75 ..... | 79 | 90 | 62 | 73 | 65 | 70 | 59 | 71.3 | 8.0 |
| 76 ..... | 75 | 92 | 65 | 75 | 64 | 71 | 58 | 71.4 | 8.0 |
| 77 ..... | *92* | *101* | *69* | *85* | *89* | *76* | *77* | *83.4* | *8.1* |
| 78 ..... | *84* | *90* | *63* | *76* | *79* | *72* | *71* | *76.3* | *6.9* |
| 79 ..... | *85* | *97* | *58* | *69* | *60* | *75* | *65* | *73.1* | *11.3* |
| 80 ..... | *60* | *87* | *57* | *69* | *64* | *77* | *55* | *67.0* | *9.1* |
| 81 ..... | 71 | 85 | 64 | 80 | 64 | 67 | 71 | 71.7 | 6.3 |
| 82 ..... | 76 | 82 | 55 | 72 | 56 | 65 | 62 | 66.9 | 8.4 |
| 83 ..... | 70 | 82 | 57 | 69 | 52 | 62 | 68 | 65.1 | 7.3 |
| 84 ..... | 75 | 84 | 58 | 72 | 49 | 61 | 58 | 65.3 | 10.0 |
| 85 ..... | *88* | *99* | *66* | *74* | *94* | *73* | *80* | *82.0* | *9.8* |
| 86 ..... | *81* | *96* | *59* | *68* | *76* | *74* | *63* | *73.7* | *9.1* |
| 87 ..... | *81* | *87* | *61* | *67* | *61* | *71* | *61* | *69.9* | *8.4* |

TABLE V (*continued*)

| | Ku | Sv | Wo | Br | Su | Th | Ar | Average | A.D. |
|---|---|---|---|---|---|---|---|---|---|
| 88 ..... | *73* | *81* | *60* | *70* | *57* | *69* | *61* | *67.4* | *6.8* |
| 89 ..... | 87 | 100 | 71 | 73 | 97 | 77 | 81 | 83.7 | 9.4 |
| 90 ..... | 77 | 100 | 58 | 74 | 57 | 74 | 58 | 70.7 | 11.1 |
| 91 ..... | 70 | 94 | 58 | 77 | 57 | 72 | 64 | 67.7 | 9.3 |
| 92 ..... | 74 | 92 | 57 | 71 | 54 | 71 | 56 | 67.9 | 10.4 |
| 93 ..... | *85* | *99* | *65* | *75* | *80* | *76* | *77* | *79.6* | *7.4* |
| 94 ..... | *84* | *96* | *57* | *68* | *69* | *70* | *60* | *72.0* | *10.3* |
| 95 ..... | *74* | *92* | *57* | *73* | *54* | *70* | *59* | *68.4* | *11.4* |
| 96 ..... | *80* | *78* | *61* | *64* | *64* | *64* | *65* | *68.0* | *6.3* |

## TABLE V

### Individual Records of Men in Card-sorting, Group III

The Roman type gives records in seconds of Arrangement 1; Italic type, of Arrangement 2. Spaces separate successive days.

| | Ca | Si | Dr | Sv | Wi | Sp | Rd | Average | A.D. |
|---|---|---|---|---|---|---|---|---|---|
| 1 ..... | 98 | 122 | 118 | 117 | 98 | 145 | 127 | 117.9 | 11.7 |
| 2 ..... | 79 | 99 | 96 | 99 | 91 | 120 | 120 | 100.6 | 10.9 |
| 3 ..... | 80 | 90 | 86 | 83 | 95 | 110 | 115 | 94.1 | 10.7 |
| 4 ..... | 75 | 89 | 89 | 74 | 88 | 99 | 109 | 89.0 | 8.6 |
| 5 ..... | *120* | *146* | *118* | *105* | *134* | *152* | *152* | *132.0* | *15.4* |
| 6 ..... | *95* | *127* | *105* | *85* | *98* | *110* | *139* | *107.7* | *14.4* |
| 7 ..... | *82* | *111* | *96* | *75* | *86* | *129* | *109* | *98.3* | *15.4* |
| 8 ..... | *74* | *94* | *92* | *70* | *90* | *115* | *110* | *92.1* | *9.6* |
| 9 ..... | 107 | 135 | 121 | 116 | 133 | 117 | 125 | 122.0 | 7.7 |
| 10 ..... | 86 | 112 | 94 | 86 | 116 | 120 | 92 | 100.1 | 13.0 |
| 11 ..... | 83 | 94 | 88 | 72 | 93 | 98 | 86 | 88.0 | 6.0 |
| 12 ..... | 70 | 94 | 85 | 73 | 92 | 95 | 76 | 83.0 | 9.0 |
| 13 ..... | *108* | *127* | *115* | *103* | *104* | *129* | *122* | *115.4* | *9.0* |
| 14 ..... | *86* | *112* | *91* | *84* | *92* | *110* | *105* | *97.1* | *10.1* |
| 15 ..... | *70* | *98* | *80* | *79* | *90* | *97* | *91* | *88.1* | *10.1* |
| 16 ..... | *81* | *85* | *75* | *80* | *85* | *95* | *93* | *85.6* | *4.4* |
| 17 ..... | 84 | 97 | 83 | 86 | 75 | 102 | 100 | 89.6 | 8.5 |
| 18 ..... | 71 | 84 | 78 | 78 | 76 | 91 | 85 | 80.3 | 5.1 |
| 19 ..... | 66 | 77 | 73 | 72 | 76 | 88 | 80 | 76.0 | 4.6 |
| 20 ..... | 62 | 84 | 72 | 67 | 73 | 87 | 84 | 75.7 | 8.1 |
| 21 ..... | *103* | *121* | *104* | *92* | *93* | *129* | *120* | *110.2* | *13.6* |
| 22 ..... | *77* | *113* | *78* | *85* | *80* | *115* | *95* | *91.9* | *13.4* |
| 23 ..... | *71* | *85* | *76* | *80* | *81* | *107* | *82* | *81.7* | *5.3* |
| 24 ..... | *64* | *70* | *72* | *71* | *79* | *92* | *77* | *75.0* | *6.4* |
| 25 ..... | 90 | 96 | 107 | 80 | 110 | 121 | 102 | 100.6 | 11.1 |
| 26 ..... | 70 | 75 | 87 | 70 | 90 | 96 | 90 | 81.4 | 7.6 |
| 27 ..... | 63 | 88 | 76 | 79 | 84 | 92 | 80 | 80.3 | 6.4 |
| 28 ..... | 63 | 69 | 69 | 70 | 100 | 82 | 74 | 75.3 | 7.3 |
| 29 ..... | *81* | *101* | *104* | *94* | *93* | *107* | *106* | *98.0* | *7.3* |
| 30 ..... | *71* | *76* | *78* | *86* | *81* | *100* | *80* | *80.7* | *7.5* |
| 31 ..... | *60* | *67* | *73* | *79* | *80* | *87* | *75* | *74.4* | *6.5* |
| 32 ..... | *63* | *86* | *72* | *69* | *83* | *103* | *82* | *79.7* | *10.0* |

TABLE V (*continued*)

| | Ca | Si | Dr | Sv | Wi | Sp | Rd | Average | A.D. |
|---|---|---|---|---|---|---|---|---|---|
| 33 ..... | 85 | 75 | 72 | 75 | 85 | 88 | 80 | 80.0 | 5.1 |
| 34 ..... | 71 | 69 | 70 | 67 | 82 | 82 | 69 | 73.1 | 5.2 |
| 35 ..... | 62 | 82 | 69 | 61 | 69 | 82 | 72 | 71.0 | 6.4 |
| 36 ..... | 58 | 64 | 66 | 58 | 76 | 78 | 71 | 67.3 | 6.4 |
| 37 ..... | 77 | *124* | *92* | *94* | *89* | *118* | *95* | *96.7* | *15.4* |
| 38 ..... | *69* | *83* | *72* | *79* | *78* | *97* | *81* | *79.4* | *5.5* |
| 39 ..... | *62* | *76* | *69* | *66* | *87* | *89* | *75* | *74.9* | *7.6* |
| 40 ..... | *67* | *76* | *64* | *66* | *83* | *71* | *76* | *71.9* | *5.4* |
| 41 ..... | 86 | 95 | 85 | 92 | 90 | 108 | 87 | 91.9 | 6.0 |
| 42 ..... | 64 | 94 | 74 | 68 | 86 | 84 | 73 | 77.7 | 9.0 |
| 43 ..... | 60 | 82 | 70 | 65 | 86 | 85 | 69 | 73.9 | 9.0 |
| 44 ..... | 55 | 67 | 63 | 59 | 86 | 72 | 65 | 66.7 | 7.0 |
| 45 ..... | *92* | *103* | *84* | *88* | *73* | *117* | *88* | *92.1* | *7.2* |
| 46 ..... | *67* | *83* | *82* | *76* | *72* | *92* | *73* | *77.9* | *6.5* |
| 47 ..... | *61* | *75* | *75* | *65* | *70* | *87* | *68* | *71.9* | *6.1* |
| 48 ..... | *64* | *68* | *68* | *58* | *91* | *76* | *72* | *71.0* | *7.1* |
| 49 ..... | 77 | 78 | 68 | 69 | 71 | 87 | 76 | 75.1 | 5.0 |
| 50 ..... | 58 | 69 | 66 | 52 | 75 | 76 | 68 | 66.3 | 6.4 |
| 51 ..... | 54 | 65 | 63 | 52 | 67 | 73 | 67 | 63.0 | 5.5 |
| 52 ..... | 48 | 58 | 64 | 54 | 67 | 74 | 65 | 61.4 | 6.6 |
| 53 ..... | *87* | *94* | *91* | *81* | *87* | *105* | *85* | *90.0* | *5.7* |
| 54 ..... | *70* | *83* | *80* | *65* | *70* | *93* | *74* | *76.1* | *7.7* |
| 55 ..... | *61* | *72* | *67* | *69* | *69* | *80* | *78* | *71.1* | *5.3* |
| 56 ..... | *61* | *64* | *65* | *63* | *74* | *79* | *67* | *67.6* | *5.3* |
| 57 ..... | 78 | 90 | 79 | 85 | 91 | 123 | 76 | 88.9 | 10.7 |
| 58 ..... | 70 | 79 | 73 | 78 | 75 | 93 | 72 | 77.1 | 5.3 |
| 59 ..... | 66 | 73 | 71 | 59 | 82 | 86 | 68 | 72.1 | 7.3 |
| 60 ..... | 63 | 73 | 63 | 54 | 80 | 78 | 73 | 68.3 | 6.4 |
| 61 ..... | *68* | *99* | *78* | *72* | *76* | *99* | *82* | *82.0* | *9.7* |
| 62 ..... | *68* | *82* | *71* | *61* | *83* | *88* | *73* | *75.1* | *7.9* |
| 63 ..... | *67* | *71* | *65* | *59* | *70* | *77* | *69* | *68.3* | *3.9* |
| 64 ..... | *58* | *66* | *61* | *62* | *72* | *81* | *70* | *67.1* | *6.1* |
| 65 ..... | 77 | 74 | 65 | 65 | 73 | 83 | 72 | 72.7 | 4.6 |
| 66 ..... | 54 | 67 | 64 | 59 | 66 | 85 | 68 | 66.1 | 6.1 |
| 67 ..... | 50 | 59 | 65 | 55 | 64 | 79 | 64 | 62.3 | 6.6 |
| 68 ..... | 48 | 62 | 61 | 50 | 59 | 72 | 62 | 59.1 | 5.9 |
| 69 ..... | *68* | *90* | *78* | *85* | *74* | *114* | *84* | *84.7* | *10.0* |
| 70 ..... | *64* | *68* | *65* | *64* | *69* | *90* | *66* | *69.4* | *6.3* |
| 71 ..... | *57* | *74* | *62* | *60* | *65* | *100* | *70* | *69.7* | *10.0* |
| 72 ..... | *54* | *64* | *63* | *54* | *66* | *92* | *70* | *66.1* | *8.4* |
| 73 ..... | 77 | 97 | 81 | 89 | 83 | 91 | 78 | 85.0 | 6.3 |
| 74 ..... | 70 | 76 | 73 | 64 | 75 | 85 | 80 | 74.7 | 4.9 |
| 75 ..... | 57 | 79 | 71 | 63 | 69 | 86 | 69 | 71.0 | 5.4 |
| 76 ..... | 55 | 72 | 64 | 60 | 65 | 76 | 71 | 67.6 | 7.4 |
| 77 ..... | *71* | *88* | *78* | *75* | *73* | *100* | *82* | *81.3* | *8.0* |
| 78 ..... | *60* | *72* | *66* | *64* | *66* | *85* | *66* | *68.4* | *5.6* |
| 79 ..... | *59* | *73* | *67* | *59* | *66* | *76* | *70* | *67.1* | *5.0* |
| 80 ..... | *51* | *70* | *67* | *56* | *68* | *88* | *72* | *67.4* | *8.0* |

TABLE V (*continued*)

| | Ca | Si | Dr | Sv | Wi | Sp | Rd | Average | A.D. |
|---|---|---|---|---|---|---|---|---|---|
| 81 ..... | 54 | 67 | 66 | 58 | 65 | 85 | 73 | 67.0 | 7.1 |
| 82 ..... | 50 | 64 | 62 | 51 | 59 | 83 | 60 | 61.1 | 7.0 |
| 83 ..... | 49 | 58 | 63 | 54 | 69 | 84 | 64 | 62.9 | 8.1 |
| 84 ..... | 44 | 60 | 61 | 52 | 64 | 78 | 63 | 60.3 | 7.0 |
| 85 ..... | *73* | *79* | *76* | *83* | *68* | *95* | *78* | *79.3* | *5.4* |
| 86 ..... | *55* | *87* | *65* | *66* | *69* | *82* | *62* | *69.4* | *8.9* |
| 87 ..... | *51* | *71* | *65* | *56* | *60* | *89* | *70* | *64.6* | *7.7* |
| 88 ..... | *53* | *61* | *59* | *52* | *61* | *84* | *66* | *62.0* | *6.9* |
| 89 ..... | 65 | 84 | 81 | 85 | 72 | 108 | 83 | 82.6 | 8.6 |
| 90 ..... | 57 | 74 | 69 | 64 | 68 | 91 | 73 | 70.9 | 7.3 |
| 91 ..... | 57 | 66 | 66 | 63 | 65 | 80 | 72 | 67.0 | 5.1 |
| 92 ..... | 51 | 67 | 62 | 54 | 65 | 83 | 60 | 63.6 | 6.6 |
| 93 ..... | *81* | *86* | *83* | *77* | *70* | *100* | *69* | *80.9* | *7.7* |
| 94 ..... | *65* | *78* | *67* | *61* | *61* | *85* | *68* | *69.3* | *6.9* |
| 95 ..... | *57* | *64* | *62* | *59* | *70* | *84* | *66* | *66.3* | *6.0* |
| 96 ..... | *57* | *65* | *60* | *53* | *58* | *86* | *62* | *63.0* | *7.1* |

## TABLE VI

Table VI. gives averages and A.D.'s of all the groups of Card-Sorting Experiment. Group I., being the Practise Group and having only one arrangement, has only 48 records, but are given throughout whole length of experiment for purposes of comparison. Roman type gives Arrangement 1; Italic type, Arrangement 2.

| | *Group I* | | | | *Group II* | | | | *Group III* | | | | *Group IV* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | | Men | | Women | |
| 1 | 116.3 | 17.3 | 121.3 | 15.8 | 107.0 | 7.3 | 118.6 | 16.0 | 117.9 | 11.7 | 113.7 | 15.8 | 100.7 | 11.7 | 96.3 | 15.0 |
| 2 | | | | | *111.3* | *8.3* | *124.3* | *17.0* | 100.6 | 10.9 | 101.3 | 10.9 | 91.0 | 4.7 | 78.0 | 12.7 |
| 3 | 95.0 | 6.0 | 105.0 | 13.5 | 95.7 | 6.0 | 119.3 | 9.3 | 94.1 | 10.7 | 97.0 | 10.9 | 73.7 | 4.7 | 74.7 | 9.0 |
| 4 | | | | | *101.7* | *11.7* | *129.0* | *13.3* | 89.0 | 8.6 | 92.6 | 11.4 | 73.3 | 6.7 | 69.3 | 6.7 |
| 5 | 84.3 | 7.8 | 101.0 | 10.5 | 94.3 | 11.0 | 111.7 | 9.7 | *132.0* | *15.4* | *117.6* | *11.0* | 70.3 | 3.3 | 73.0 | 10.7 |
| 6 | | | | | *100.3* | *6.3* | *107.0* | *3.3* | *107.7* | *14.4* | *99.4* | *13.1* | 71.0 | 8.0 | 70.0 | 6.7 |
| 7 | 81.3 | 5.8 | 104.5 | 14.5 | 92.7 | 7.0 | 108.0 | 5.0 | *98.3* | *15.4* | *89.7* | *11.4* | 72.3 | 10.7 | 69.0 | 4.7 |
| 8 | | | | | *101.3* | *1.7* | *105.7* | *2.3* | *92.1* | *9.6* | *85.2* | *13.8* | 64.7 | 3.0 | 62.7 | 5.0 |
| 9 | 80.3 | 7.3 | 91.7 | 12.3 | 96.0 | 7.7 | 102.7 | 3.0 | 122.0 | 7.7 | 102.6 | 5.9 | *104.0* | *2.0* | *97.0* | *4.0* |
| 10 | | | | | *99.0* | *6.7* | *99.7* | *1.0* | 101.1 | 13.0 | 91.6 | 7.1 | *87.3* | *11.0* | *80.7* | *4.0* |
| 11 | 79.7 | 6.3 | 90.3 | 8.3 | 91.3 | 7.7 | 104.7 | 4.3 | 88.0 | 6.0 | 91.7 | 11.7 | *82.3* | *11.0* | *71.7* | *6.3* |
| 12 | | | | | *88.0* | *8.0* | *104.3* | *5.0* | 83.6 | 9.0 | 86.6 | 7.1 | *76.0* | *10.0* | *66.7* | *3.7* |
| 13 | 80.0 | 7.0 | 85.7 | 9.3 | 87.3 | 9.0 | 103.0 | 6.0 | *115.4* | *9.0* | *104.3* | *10.3* | *75.3* | *13.7* | *64.0* | *4.0* |
| 14 | | | | | *88.3* | *9.0* | *102.0* | *4.7* | *97.1* | *10.1* | *92.4* | *9.6* | *76.0* | *12.0* | *60.3* | *5.0* |
| 15 | 77.3 | 5.8 | 81.5 | 10.3 | 79.0 | 8.0 | 100.7 | 5.7 | *88.1* | *10.1* | *85.2* | *12.2* | *70.0* | *11.3* | *62.0* | *4.7* |
| 16 | | | | | *96.0* | *10.0* | *103.3* | *3.7* | *85.6* | *4.4* | *86.7* | *14.4* | *68.7* | *8.0* | *59.3* | *3.7* |
| 17 | 75.3 | 7.3 | 83.3 | 9.3 | 90.7 | 12.3 | 84.7 | 7.0 | 89.6 | 8.5 | 92.1 | 8.7 | 83.0 | 14.7 | 69.3 | 3.7 |
| 18 | | | | | *95.3* | *1.7* | *98.0* | *5.3* | 80.3 | 5.1 | 80.6 | 8.0 | 71.4 | 14.0 | 60.7 | 4.3 |
| 19 | 76.3 | 4.3 | 83.0 | 10.0 | 89.0 | 8.7 | 95.3 | 1.7 | 76.0 | 4.6 | 81.1 | 9.0 | 66.7 | 10.7 | 59.7 | 3.0 |
| 20 | | | | | *88.7* | *7.0* | *92.7* | *5.0* | 75.7 | 8.1 | 75.3 | 5.7 | 66.0 | 10.0 | 56.7 | 2.3 |
| 21 | 74.3 | 4.8 | 81.3 | 11.8 | 87.0 | 10.0 | 92.7 | 5.7 | *110.2* | *13.6* | *99.7* | *6.3* | 66.4 | 11.3 | 58.7 | 3.7 |
| 22 | | | | | *90.0* | *10.7* | *87.7* | *3.7* | *91.9* | *13.4* | *82.1* | *8.0* | 64.0 | 10.3 | 56.7 | 3.0 |
| 23 | 72.0 | 2.5 | 80.5 | 7.0 | 83.0 | 6.7 | 87.0 | 4.0 | *81.7* | *5.3* | *81.4* | *9.0* | 67.3 | 5.3 | 55.3 | 4.3 |
| 24 | | | | | *88.7* | *1.7* | *86.0* | *2.7* | *75.0* | *6.4* | *80.4* | *8.7* | 66.7 | 8.3 | 56.0 | 1.7 |

TABLE VI (*continued*)

| | *Group I* | | | | *Group II* | | | | *Group III* | | | | *Gronp IV* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | | Men | | Women | |
| 25 | 74.5 | 5.5 | 80.3 | 12.8 | 86.7 | 5.7 | 92.0 | 2.3 | 100.6 | 11.1 | 99.3 | 4.1 | *91.0* | *10.7* | *84.3* | *8.3* |
| 26 | | | | | *87.3* | *6.3* | *84.0* | *3.0* | 81.4 | 7.6 | 88.9 | 9.2 | *76.3* | *12.3* | *64.0* | *3.0* |
| 27 | 70.3 | 5.8 | 77.3 | 8.8 | 82.7 | 8.3 | 89.7 | 3.7 | 80.3 | 6.4 | 83.1 | 11.3 | *68.3* | *13.0* | *59.3* | *6.3* |
| 28 | | | | | *81.3* | *4.3* | *87.3* | *2.3* | 75.3 | 7.3 | 79.4 | 9.4 | *68.0* | *11.3* | *56.7* | *7.7* |
| 29 | 74.5 | 5.0 | 75.0 | 8.0 | 75.7 | 10.3 | 87.7 | 7.0 | *98.0* | *7.3* | *93.1* | *10.1* | *62.3* | *9.0* | *59.3* | *4.3* |
| 30 | | | | | *84.3* | *5.7* | *84.3* | *2.3* | *80.7* | *7.5* | *82.1* | *13.6* | *64.0* | *11.3* | *54.3* | *7.0* |
| 31 | 74.7 | 14.3 | 78.7 | 7.0 | 85.0 | 14.0 | 86.3 | 4.3 | *74.4* | *6.5* | *82.9* | *8.1* | *59.7* | *13.7* | *56.3* | *5.7* |
| 32 | | | | | *85.3* | *9.0* | *90.3* | *5.7* | *79.7* | *10.0* | *77.0* | *9.7* | *61.7* | *13.7* | *52.7* | *5.7* |
| 33 | 69.8 | 4.3 | 73.5 | 8.0 | 71.7 | 3.7 | 74.3 | 3.7 | 80.0 | 5.1 | 81.0 | 6.6 | 78.7 | 9.7 | 63.0 | 8.7 |
| 34 | | | | | *89.0* | *8.7* | *85.3* | *2.3* | 73.1 | 5.2 | 75.0 | 7.4 | 68.3 | 7.7 | 57.3 | 2.3 |
| 35 | 66.3 | 4.8 | 72.7 | 5.3 | 79.0 | 13.3 | 88.7 | 0.4 | 71.0 | 6.4 | 74.4 | 7.4 | 68.3 | 8.7 | 58.3 | 5.0 |
| 36 | | | | | *87.7* | *12.3* | *83.7* | *5.0* | 67.3 | 6.4 | 73.7 | 10.3 | 66.7 | 10.3 | 53.0 | 4.7 |
| 37 | 64.0 | 3.0 | 66.7 | 7.3 | 82.0 | 12.0 | 90.0 | 4.0 | *96.7* | *15.4* | *89.6* | *7.0* | 64.7 | 11.0 | 53.7 | 6.3 |
| 38 | | | | | *88.7* | *10.3* | *83.7* | *3.7* | *79.4* | *5.5* | *80.0* | *6.7* | 63.0 | 9.3 | 55.3 | 3.0 |
| 39 | 66.3 | 4.3 | 72.0 | 6.5 | 77.3 | 9.7 | 89.7 | 3.0 | *74.9* | *7.6* | *75.9* | *8.1* | 62.0 | 2.7 | 52.0 | 6.7 |
| 40 | | | | | *84.7* | *13.0* | *83.3* | *5.7* | *71.9* | *5.4* | *72.6* | *9.4* | 62.7 | 8.3 | 53.7 | 3.3 |
| 41 | 69.7 | 2.3 | 70.2 | 7.3 | 75.7 | 18.3 | 90.3 | 4.7 | 91.9 | 6.0 | 89.4 | 10.0 | *86.7* | *7.7* | *78.7* | *5.7* |
| 42 | | | | | *85.0* | *8.0* | *87.3* | *5.0* | 77.7 | 9.0 | 83.4 | 7.7 | *75.7* | *11.7* | *63.3* | *4.0* |
| 43 | 67.3 | 5.3 | 68.5 | 4.0 | 81.0 | 9.7 | 88.4 | 6.0 | 73.9 | 9.0 | 80.0 | 7.9 | *72.0* | *14.0* | *59.0* | *8.0* |
| 44 | | | | | *83.3* | *7.3* | *89.0* | *3.3* | 66.7 | 7.0 | 75.3 | 12.0 | *69.0* | *13.3* | *56.7* | *4.3* |
| 45 | 63.7 | 4.3 | 71.0 | 7.5 | 77.7 | 9.0 | 86.3 | 3.0 | *92.1* | *7.2* | *84.4* | *8.4* | *66.3* | *14.3* | *57.7* | *3.0* |
| 46 | | | | | *83.0* | *11.0* | *83.3* | *3.0* | *77.9* | *6.5* | *76.3* | *7.4* | *63.7* | *11.0* | *54.7* | *3.7* |
| 47 | 64.7 | 1.8 | 69.5 | 7.0 | 77.7 | 9.0 | 82.7 | 4.3 | *71.9* | *6.1* | 78.7 | 7.6 | *60.0* | *11.3* | *54.0* | *4.0* |
| 48 | | | | | *79.3* | *7.0* | *86.7* | *12.3* | *71.0* | *7.1* | *75.0* | *9.0* | *61.3* | *10.0* | *57.0* | *2.0* |

TABLE VI (*continued*)

| | *Group I* | | | | *Group II* | | | | *Group III* | | | | *Group IV* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | | Men | | Women | |
| 49 | 64.3 | 1.8 | 70.7 | 11.3 | 71.0 | 5.3 | 68.3 | 3.0 | 75.1 | 5.0 | 74.6 | 5.3 | 70.3 | 5.0 | 64.0 | 9.0 |
| 50 | | | | | *82.0* | *9.3* | *83.3* | *3.0* | 66.3 | 6.4 | 70.3 | 7.6 | 61.7 | 6.3 | 58.0 | 4.7 |
| 51 | 67.7 | 4.8 | 69.7 | 5.8 | 73.7 | 8.3 | 78.0 | 2.7 | 63.0 | 5.5 | 68.7 | 8.0 | 61.3 | 8.3 | 55.3 | 2.3 |
| 52 | | | | | *80.0* | *8.0* | *76.0* | *0.0* | 61.4 | 6.6 | 68.3 | 11.4 | 61.7 | 7.0 | 53.0 | 4.7 |
| 53 | 62.0 | 2.5 | 68.5 | 5.0 | 74.3 | 9.0 | 79.0 | 4.7 | *90.0* | *5.7* | *84.4* | *8.6* | 60.7 | 4.7 | 53.0 | 5.0 |
| 54 | | | | | *85.0* | *13.3* | *78.7* | *5.3* | *76.1* | *7.7* | *76.6* | *7.3* | 60.3 | 10.3 | 53.0 | 3.7 |
| 55 | 67.3 | 3.3 | 66.7 | 6.8 | 81.7 | 14.0 | 81.7 | 2.3 | *71.1* | *5.3* | *75.0* | *10.0* | 58.0 | 6.3 | 52.7 | 4.3 |
| 56 | | | | | *77.0* | *7.7* | *78.3* | *5.0* | *67.6* | *5.3* | *73.1* | *7.3* | 56.3 | 9.7 | 55.7 | 3.7 |
| 57 | 62.0 | 3.0 | 66.0 | 8.0 | 72.0 | 11.0 | 77.7 | 1.7 | 88.9 | 10.7 | 89.3 | 11.7 | *83.0* | *6.3* | *75.3* | *9.0* |
| 58 | | | | | *76.3* | *5.0* | *76.7* | *3.3* | 77.1 | 5.3 | 78.8 | 9.1 | *69.7* | *8.3* | *61.7* | *7.7* |
| 59 | 62.7 | 1.8 | 68.7 | 7.3 | 74.7 | 12.3 | 79.3 | 0.4 | 72.1 | 7.3 | 75.0 | 11.1 | *64.3* | *8.3* | *58.3* | *4.3* |
| 60 | | | | | *74.0* | *5.3* | *78.3* | *5.0* | 68.3 | 6.4 | 75.3 | 12.0 | *60.7* | *8.0* | *57.3* | *3.7* |
| 61 | 65.3 | 5.8 | 67.0 | 9.0 | 73.0 | 12.0 | 80.0 | 4.0 | *82.0* | *9.7* | *87.1* | *9.6* | *62.3* | *8.7* | *56.7* | *5.0* |
| 62 | | | | | *77.0* | *12.0* | *79.3* | *1.7* | *75.1* | *7.9* | *79.3* | *9.1* | *59.3* | *7.7* | *56.0* | *4.7* |
| 63 | 64.3 | 3.3 | 65.0 | 7.0 | 73.3 | 11.7 | 80.7 | 5.0 | *68.3* | *3.9* | *77.0* | *7.1* | *61.3* | *7.0* | *55.7* | *5.0* |
| 64 | | | | | *77.3* | *9.7* | *77.3* | *0.4* | *67.1* | *6.1* | *73.3* | *10.9* | *59.7* | *11.0* | *51.7* | *5.7* |
| 65 | 69.3 | 4.8 | 70.2 | 8.8 | 70.0 | 6.0 | 67.0 | 3.3 | 72.7 | 4.6 | 75.4 | 8.6 | 72.3 | 9.0 | 61.7 | 6.3 |
| 66 | | | | | 78.7 | *8.3* | *85.3* | *2.3* | 66.1 | 6.1 | 69.9 | 7.3 | 61.7 | 7.0 | 53.3 | 6.3 |
| 67 | 66.5 | 4.5 | 63.3 | 6.8 | 72.3 | 11.0 | 82.6 | 6.7 | 62.3 | 6.6 | 67.9 | 9.6 | 63.3 | 10.3 | 53.0 | 5.7 |
| 68 | | | | | *77.0* | *12.0* | *80.3* | *1.7* | 59.1 | 5.9 | 68.1 | 10.0 | 59.0 | 9.3 | 52.7 | 3.7 |
| 69 | 63.5 | 6.5 | 63.0 | 4.5 | 71.3 | 14.7 | 79.6 | 2.3 | *84.7* | *10.0* | *82.7* | *7.1* | 57.7 | 9.7 | 52.0 | 4.7 |
| 70 | | | | | *77.7* | *7.7* | *79.7* | *5.0* | *69.4* | *6.3* | *76.6* | *9.6* | 60.0 | 7.3 | 53.7 | 2.7 |
| 71 | 61.3 | 4.8 | 64.0 | 4.5 | 70.7 | 11.7 | 80.0 | 0.0 | *69.7* | *10.0* | *75.4* | *9.4* | 60.7 | 11.0 | 52.0 | 3.3 |
| 72 | | | | | *76.3* | *10.3* | *75.3* | *1.7* | *66.1* | *8.4* | *69.1* | *10.9* | 58.0 | 12.0 | 51.3 | 3.0 |

TABLE VI (*continued*)

| | *Group I* | | | | *Group II* | | | | *Group III* | | | | *Group IV* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | | Men | | Women | |
| 73 | 62.5 | 4.0 | 61.0 | 3.5 | 73.7 | 12.3 | 80.7 | 4.7 | 85.0 | 6.3 | 82.7 | 6.4 | *80.0* | *3.3* | *64.3* | *11.0* |
| 74 | | | | | *75.0* | *11.3* | *76.3* | *3.7* | 74.7 | 4.9 | 73.0 | 9.1 | *69.3* | *7.7* | *59.0* | *4.7* |
| 75 | 59.8 | 4.3 | 64.3 | 4.3 | 71.3 | 10.3 | 77.7 | 5.0 | 71.0 | 5.4 | 71.3 | 8.0 | *67.3* | *9.0* | *57.7* | *4.3* |
| 76 | | | | | *75.0* | *6.0* | *78.3* | *2.3* | 67.6 | 7.4 | 71.4 | 8.0 | *63.7* | *10.3* | *55.0* | *4.7* |
| 77 | 62.0 | 4.5 | 62.0 | 7.0 | 72.7 | 13.7 | 77.0 | 3.3 | *81.3* | *8.0* | *83.4* | *8.1* | *62.0* | *12.0* | *53.3* | *5.7* |
| 78 | | | | | *78.0* | *15.3* | *75.7* | *5.0* | *68.4* | *5.6* | *76.3* | *6.9* | *60.3* | *10.3* | *54.0* | *2.7* |
| 79 | 60.7 | 5.8 | 61.5 | 5.5 | 75.3 | 12.3 | 77.0 | 4.0 | *67.1* | *5.0* | *73.1* | *11.3* | *61.3* | *9.0* | *52.0* | *5.3* |
| 80 | | | | | *74.3* | *9.0* | *73.0* | *1.3* | *67.4* | *8.0* | *67.0* | *9.1* | *61.3* | *9.0* | *54.0* | *3.0* |
| 81 | 60.7 | 7.3 | 57.7 | 4.8 | 74.7 | 4.3 | 68.0 | 3.7 | 67.0 | 7.1 | 71.7 | 6.3 | 66.0 | 8.0 | 62.3 | 8.7 |
| 82 | | | | | *73.3* | *7.0* | *77.3* | *5.0* | 61.1 | 7.0 | 66.9 | 8.4 | 61.7 | 12.3 | 54.0 | 9.3 |
| 83 | 58.3 | 4.3 | 58.7 | 6.8 | 72.0 | 10.7 | 71.3 | 2.3 | 62.9 | 8.1 | 65.1 | 7.3 | 59.7 | 10.3 | 52.7 | 5.0 |
| 84 | | | | | *75.3* | *5.0* | *77.3* | *1.0* | 60.3 | 7.0 | 65.3 | 10.0 | 60.7 | 12.3 | 51.3 | 6.3 |
| 85 | 62.7 | 6.8 | 57.0 | 4.5 | 69.0 | 8.7 | 75.0 | 4.0 | *79.3* | *5.4* | *82.0* | *9.8* | 54.0 | 6.0 | 48.7 | 4.3 |
| 86 | | | | | *71.0* | *8.0* | *78.3* | *3.7* | *69.4* | *8.9* | *73.7* | *9.1* | 55.0 | 7.3 | 49.7 | 5.3 |
| 87 | 60.5 | 7.0 | 60.3 | 8.3 | 69.3 | 9.7 | 74.3 | 3.0 | *64.6* | *7.7* | *69.9* | *8.4* | 55.0 | 8.7 | 49.3 | 3.7 |
| 88 | | | | | *72.3* | *10.3* | *72.0* | *1.0* | *62.0* | *6.9* | *67.4* | *6.8* | 55.0 | 7.3 | 48.7 | 5.0 |
| 89 | 57.3 | 8.3 | 56.7 | 6.8 | 71.0 | 10.0 | 72.3 | 3.0 | 82.6 | 8.6 | 83.7 | 9.4 | *71.7* | *3.7* | *69.0* | *7.3* |
| 90 | | | | | *71.3* | *9.7* | *73.7* | *4.3* | 70.9 | 7.3 | 70.7 | 11.1 | *66.0* | *7.3* | *58.3* | *9.7* |
| 91 | 59.5 | 4.5 | 58.0 | 9.0 | 67.3 | 8.3 | 73.3 | 1.7 | 67.0 | 5.1 | 67.7 | 9.3 | *67.7* | *8.3* | *51.3* | *5.0* |
| 92 | | | | | *71.3* | *6.3* | *72.3* | *1.0* | 63.6 | 6.6 | 67.9 | 10.4 | *63.0* | *8.7* | *51.3* | *5.0* |
| 93 | 60.3 | 4.8 | 54.0 | 4.0 | 69.7 | 8.3 | 76.0 | 6.0 | *80.9* | *7.7* | *79.6* | *7.4* | *60.0* | *9.3* | *54.0* | *5.3* |
| 94 | | | | | *75.0* | *13.7* | *73.7* | *3.7* | *69.3* | *6.9* | *72.0* | *10.3* | *56.3* | *7.7* | *54.3* | *3.0* |
| 95 | 60.3 | 7.8 | 53.7 | 3.8 | 69.3 | 9.7 | 74.7 | 5.0 | *66.3* | *6.0* | *68.4* | *11.4* | *58.0* | *5.3* | *50.3* | *3.7* |
| 96 | | | | | *71.0* | *8.7* | *71.7* | *2.3* | *63.0* | *7.1* | *68.0* | *6.3* | *54.0* | *6.3* | *50.3* | *3.7* |

table for purposes of comparison. There are no errors to deal with as all misthrows had to be corrected by the subject. All figures used represent time in seconds.

The curves as well as the tables show the interference effect and its relation to the practise effect, and indicate that the two associations are becoming automatic. All the interference curves of all the groups show that the interference is present but that it is overcome, and that the associations are becoming automatic. This is true for every individual in all the groups, although the individual curves of Groups II. and IV. are not shown.

In the alternate group the first sorting is about the same as that of the practise group. Among the women $A_1$ is 118 sec., $A_2$ is 123 sec., while in the practise series it is 120 sec. Among the men $A_1$ is 107 sec., and $A_2$ is 111 sec., while the practise group record is 117 sec. But the practise curve drops very rapidly, especially among the men, while the alternate curve does not show rapid improvement. The practise curve is concave while the alternate curve is a straight line descending from about 96 sec. to 72 sec. for the men. The women's curve is concave due to the very rapid improvement of the first day, after which it follows the men's curve closely. The rate of gain on the percentage basis is higher in the practise group than it is in the alternate group, being .36 for the men and .48 for the women in the practise group as compared to .29 and .37 respectively in the alternate group.

There are no distinct plateaus except that of My during the fourth and fifth day. On the sixth day he makes rapid improvement though he is uniformly poorer than the average of the group. But this plateau does not mean no improvement, nor that interference annuls practise, for on the first day he ranges between 100 and 115 seconds, while on the last day he remains between 80 and 90 seconds.

The first sorting of each day is decidedly quicker than any other and shows a decided drop in the curve. This decrease in time is because of the fact that the first practise has no interference, while for the rest of the sortings the interference of the opposing arrangement is present. The good initial records of each day indicate where the curve would be were it not for the interference. This shows that the two associations are well established and that the interference of the previous day has faded away. The women have a better initial record than the men, yet their general curve is slightly poorer. There seems to be a greater discrepancy between what they could do without interference and with it than there is among the men. These initial drops however both among men and women become relatively less and less and are hardly noticeable on the last day.

This is because of the fact that the records of the whole day are down to the standard set by the initial records, and that the interference has less and less influence. That they do not quite attain to the practise limit is obvious from the conditions of the experiment. When the change is made there is a temporary disadvantage to be overcome. This is often overcome in a few seconds, but it will always require a little time. There were individuals even in this group who sorted the eighty cards in 55 seconds, and for the entire sixth day did not go above 65 seconds. This is very near and in some cases below the practise limit. Em and Gr, although the poorest of the groups, kept under 70 seconds for the entire sixth day.

In Plates II. and III. and in Table V. we have the individual curves and records for Group III. The average curve is given in Plate IV. The average curves show three spires each day showing clearly the changes in arrangement. At the beginning of each day there is no rise of any account in the curve, which begins on the practise level of the previous day, no interference effect being retained. The first arrangement without interference attains as low a point in the curve as is attained on that day and with the women a little lower. Towards the last the best absolute time is made in the first four without interference, but this is very small and with some subjects nothing at all. It may be because of being perfectly fresh at the experiment. The curves show that the improvement is very rapid after the changes and that the same efficiency is reached as before.

Although the women's practise curve is a little better than that of the men, their curve in Group III. is not quite so good, which is most plainly shown in the last few days by the drop in the men's curve. The men's curve surpasses their practise curve quite frequently but the women's does not, except at first.

For the first three days the men rise higher after the change than the women, for the last three days they are about the same. In spite of this higher rise of the first three days and the equivalent rise of the last three, the men attain a greater efficiency than the women, shown by the fact that their curve comes lower than the women for the last sortings of each section. The four women in the lower section of Plate II. do not show the changes in arrangement so clearly. There were many cases where the last sorting of a section took longer than the first. Among the men there were very few cases where the second sorting of an arrangement took as long as the first; among the women there were many where it took longer. During many of the sections there is negative improvement among the women; never among the men. Of course the women do not rise so high for the first sorting after the change but on the other hand they do not im-

prove so rapidly. The previous association seems to be made automatic by the men more quickly than by the women.

The average curves show that by the second sorting the same plane of efficiency is reached as had been attained before the change. This allows the two remaining sortings to accumulate practise effect and reach a better level. The men's curve passes that of the women, being a little higher on the first day, but on and after the second day it is lower than that of the women. Both among the men and the women the rise after the change becomes less and less, and is not nearly so great on the last day.

The interference becomes less and less, the two associations become automatic, and need only the first sorting to reduce them to the practise level and overcome the temporary disadvantage. The improvement on the percentage basis for the first arrangement is .29 for the men and .27 for the women; for the second arrangement .34 for the men and .25 for the women. The curves are slightly concave, nearly as much so as the practise curve, and in this are differentiated from those of the alternative group which are straight lines. The best record in Group III. was that of Ca, 44 seconds, which was one second less than the best in the practise group. Thus the best record is in the group having interference.

Mrs. Sv and Mr. Sp are the only subjects showing plateaus in Group III. Sp makes no progress after the third day and is decidedly poorer on the sixth day. His performance on the first day averages about 110 sec. with a wide range, while on the last day he varies between 85 and 95 seconds. It is noticeable that at his best he rises high immediately after the change, while on the sixth day he does not rise so high, but neither does he reach such a low level.

Mrs. Sv varies from 110 to 125 seconds at the beginning, but on the last day she ranges between 85 and 95 seconds. Though she makes the least improvement she by no means stands still. Often after the break she does nearly as well as and sometimes better than before, but her improvement is low within the sections and many times negative.

The average records of men and women in Group IV. are shown in Plate V. The change to the second arrangement is very clearly shown every day while there is just a little rise at the beginning of the day. Here the record of the women is a little better than that of the men, due to the poor records of As among the men and to there being only three subjects. Moreover the work of Misses Mor and Ag was exceptional among the women. Miss Ag made the best record of the entire experiment, sorting the eighty cards in 42 seconds, and having many records below 50 seconds. After two or three days the time was as good for the second arrangement with interference as

for the first without it. As and Mrs. Th were much poorer on the second arrangement than on the first for the first three days, after which the two were about the same. In this group the men again seem to rise a little higher after the change but it is not nearly so pronounced as in Group III.

Group IV. shows a higher rate of improvement than Group III. (.35 for both men and women in the first arrangement and .34 for both in the second arrangement). The curve is concave and is as good as the practise curve except immediately after the changes. Here we find a much more rapid automatization of both associations, and interference playing less and less a part. The interference effect of eight previous sortings seems no more than that of four. What relation the number of repetitions have to the interference effect will come up for discussion under the head of "Relation of Interference to Practise Effect."

Bair asked the question whether the interference becomes greater with the number of practises of the previous association,[2] that is, whether a habit made more permanent with many practises offers more resistance than one formed by only one or a few practises. He found that the difference between the last sorting of the first series and the first sorting of the second is slightly greater with many repetitions of the first. He concluded, however, that this was due not to interference but to the decrease in the first order. His results showed that it took less time to make the associations in the second order after practising the first order many times than with only a few practises of the first order.

Table VII. summarizes the results under this heading for all the groups. This gives us a change to the new order after one order had been fixed by one, four, eight, and forty-eight repetitions. The data of Group I. were obtained by having the subjects sort the cards into the second arrangement after their forty-eight sortings of the first arrangement. The data of the other three groups are the records of each group for the first sortings of each arrangement on the first day of the experiment.

We find that in Groups II., III., and IV., where one, four and eight sortings of the first order were given before changing to the second, the first performance of the second order takes longer than the first performance of the first order. But we find in Groups III. and IV. a more rapid improvement in the second arrangement than in the first. This is due to the transfer effect of the sortings of the first order. The higher rise then is due entirely to interference but the interference is very rapidly overcome. Bair found that with ten

[2] J. H. Bair, *loc. cit.*, p. 37.

practises of the first order the second took 1 second less. Group IV. takes just four seconds more. Bair had just half as many cards, so that the difference between his results and the present are very

TABLE VII

The upper column gives the first four sortings of the one arrangement, except in the alternating group, where only one could be obtained; the lower column gives the first four sortings of the new arrangement, except in Group II., where only one sorting could be obtained.

| *Group I* | | *Group II* | | *Group III* | | *Group IV* | |
|---|---|---|---|---|---|---|---|
| Men | Women | Men | Women | Men | Women | Men | Women |
| 117 | 120 | 107 | 118 | 118 | 114 | 101 | 93 |
| 95 | 105 | | | 100 | 101 | 91 | 78 |
| 84 | 101 | | | 94 | 97 | 74 | 75 |
| 81 | 104 | | | 89 | 93 | 73 | 69 |
| | | | *Change to New Order* | | | | |
| 120 | 107 | 111 | 123 | 132 | 118 | 104 | 97 |
| 102 | 98 | | | 108 | 99 | 87 | 81 |
| 93 | 90 | | | 98 | 90 | 82 | 72 |
| 86 | 85 | | | 92 | 86 | 76 | 67 |

small. In the practise group which had forty-eight sortings of the first order before changing to the second, the results tally with Bair's. The men's time increases just 3 seconds while that of the women decreases 13 seconds, which on the average (as Bair takes it) brings the time a little less for the changed order than for the first. In Group I. the women improve much more rapidly after the change than in the first four of the first order, but the men have about the same rate of improvement.

TABLE VIII

| *Group I* | | *Group II* | | *Group III* | | *Group IV* | |
|---|---|---|---|---|---|---|---|
| Men | Women | Men | Women | Men | Women | Men | Women |
| 60 | 53 | 4 | 5 | 43 | 25 | 39 | 34 |

Table VIII. shows, as Bair found, that the difference in time between one sorting and another requiring antagonistic reactions is greater, the greater the number of sortings of the first arrangement. We find that the greatest difference is in the first group, the next greatest in the fourth group, the next in the third group, and only a small difference in the first group. The difference is greater with the increasing practises of the first order. But as shown above this increasing difference is due to the better records attained in the first order and not due to interference.

These results fully agree with those of Bair, with the additional fact that the second arrangement shows greater rapidity of improvement.

## CHAPTER IV

### Individual Differences

### 1. *Rate of Improvement*

An important question in both experiments is that of the amount and rate of gain. What is the rate of gain in the card sorting experiment when interfering associations are present as compared with that of simple practise? What is the rate of gain in the typewriting experiment after the break as compared with that before? Are the differences among the group greater or less when interfering associations are present?

Table I. gives the initial performance, final performance, absolute gain, and rate of gain in the typewriting experiment. Table X. gives the initial performance, final performance, absolute gain, and percentage of gain, for each of the arrangements in all the groups of the card sorting experiment. The accompanying table gives the averages, medians and variability of the several groups in both experiments. The variability is expressed by the Pearson coefficient of variability. The group marked "Sectional gains of Group III." is obtained by finding the average improvement of the sections of four sortings of each arrangement. The difference between the first and fourth sorting is divided by the first sorting. By taking the average of the twelve sections for each arrangement (there being two sections each day) we have a fair measure for purposes of comparison as to how much gain is made in the individual sections. This has no significance for the total gain, but it has value as a measure of the immediate rate of improvement when four repetitions of the previous association are present. The median is used for the purpose of comparing the groups and the average for the determination of the variability. Only in a few cases are the averages and medians different.

We find that 28 per cent. of the men of the typewriting experiment reach or surpass the median of the women both before and after the break. In the practise group of the card sorting experiment 25 per cent. of the men reach or surpass the median of the women. In the alternating series no men reach the median of the women. In Group IV. one third of the men reach the median of the women. These groups are however too small to warrant any conclusions as to sex differences.

TABLE X

*Group I*

| | Initial Performance | | Final Performance | | Absolute Gain | | Percentage of Gain | |
|---|---|---|---|---|---|---|---|---|
| | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ | $A_1$ | $A_2$ |
| Wa ..... | 103 | | 53 | | 50 | | .48 | |
| Co ..... | 82 | | 54 | | 28 | | .34 | |
| Ol ..... | 100 | | 70 | | 30 | | .30 | |
| Br ..... | 91 | | 60 | | 31 | | .34 | |
| Miss Sm ..... | 115 | | 56 | | 59 | | .52 | |
| Miss Co ..... | 85 | | 47 | | 38 | | .45 | |
| Miss Fo ..... | 127 | | 67 | | 60 | | .47 | |
| Miss St ..... | 104 | | 53 | | 51 | | .49 | |
| *Group II* | | | | | | | | |
| Em ..... | 85 | 95 | 60 | 65 | 25 | 30 | .29 | .31 |
| Gr ..... | 97 | 102 | 65 | 65 | 32 | 37 | .33 | .35 |
| My ..... | 108 | 113 | 83 | 86 | 25 | 27 | .23 | .24 |
| Mrs. Cu ..... | 100 | 108 | 67 | 74 | 33 | 34 | .33 | .32 |
| Miss Br ..... | 123 | 111 | 76 | 75 | 47 | 36 | .39 | .32 |
| Mrs. Mt ..... | 120 | 130 | 70 | 69 | 50 | 61 | .41 | .47 |
| *Group III* | | | | | | | | |
| Ca ..... | 83 | 92 | 57 | 65 | 26 | 27 | .31 | .29 |
| Si ..... | 100 | 120 | 73 | 73 | 27 | 47 | .27 | .38 |
| Dr ..... | 97 | 103 | 69 | 68 | 28 | 35 | .29 | .34 |
| Wi ..... | 93 | 102 | 67 | 65 | 26 | 37 | .28 | .36 |
| Sv ..... | 93 | 84 | 66 | 63 | 27 | 21 | .29 | .25 |
| Sp ..... | 119 | 126 | 90 | 89 | 29 | 37 | .24 | .29 |
| Rd ..... | 117 | 126 | 72 | 67 | 45 | 59 | .38 | .47 |
| Miss Br ..... | 118 | 110 | 74 | 70 | 44 | 40 | .37 | .36 |
| Mrs. Kv ..... | 103 | 111 | 77 | 81 | 26 | 30 | .25 | .27 |
| Mrs. Wo ..... | 86 | 83 | 61 | 60 | 25 | 23 | .29 | .28 |
| Mrs. Sv ..... | 122 | 116 | 97 | 91 | 25 | 25 | .20 | .22 |
| Mrs. Su ..... | 88 | 85 | 66 | 66 | 22 | 19 | .25 | .22 |
| Miss Th ..... | 102 | 98 | 73 | 70 | 29 | 18 | .28 | .18 |
| Mrs. Ao ..... | 90 | 86 | 65 | 65 | 25 | 21 | .28 | .24 |
| *Group IV* | | | | | | | | |
| As ..... | 91 | 100 | 64 | 68 | 27 | 32 | .30 | .32 |
| Cu ..... | 75 | 76 | 44 | 47 | 31 | 29 | .41 | .38 |
| Bl ..... | 86 | 86 | 56 | 56 | 30 | 30 | .35 | .35 |
| Miss Mor ..... | 76 | 76 | 51 | 51 | 25 | 25 | .33 | .33 |
| Miss Ag ..... | 68 | 75 | 42 | 47 | 26 | 28 | .38 | .37 |
| Mrs. Th ..... | 95 | 86 | 45 | 58 | 30 | 28 | .32 | .33 |

| | *Men* | | | | *Women* | | | |
|---|---|---|---|---|---|---|---|---|
| | Av. | A.D. | Med. | Var. | Av. | A.D. | Med. | Var. |
| Typewriting, before break ... | .72 | *.04* | .73 | *.47* | .745 | *.05* | .76 | *.58* |
| Typewriting, after break .... | .50 | *.07* | .50 | *.99* | .57 | *.07* | .58 | *.93* |
| Prelim. Group before break .. | .67 | *.03* | .67 | *.37* | | | | |
| Prelim. Group after break ... | .53 | *.12* | .53 | *1.59* | | | | |
| Card-sorting Group III.—$A_1$ . | .29 | *.03* | .29 | *.55* | .27 | *.03* | .28 | *.57* |
| Card-sorting Group III.—$A_2$ . | .34 | *.07* | .34 | *1.20* | .35 | *.04* | .24 | *.80* |

Sectional gains of Group III.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $A_1$ without interference ... | .16 | *.05* | .14 | *1.25* | .12 | *.04* | .10 | *1.14* |
| $A_1$ with interference ..... | .25 | *.04* | .26 | *.80* | .16 | *.07* | .13 | *1.75* |
| $A_2$ ..... | .23 | *.05* | .25 | *1.04* | .17 | *.06* | .15 | *1.46* |
| Practise Group ..... | .36 | *.05* | .34 | *.83* | .48 | *.02* | .48 | *.29* |
| Alternate Group ..... | .29 | *.04* | .29 | *.75* | .36 | *.05* | .35 | *.83* |
| Group IV.—$A_1$ ..... | .35 | *.04* | .35 | *.67* | .34 | *.02* | .34 | *.34* |
| Group IV.—$A_2$ ..... | .35 | *.02* | .35 | *.33* | .34 | *.02* | .34 | *.34* |

In Group III., however, there are seven men and seven women, and the interference effect is most clearly shown. Both in the absolute gain and in the percentage of gain Miss Br alone surpasses the median of the men in both arrangements. In $A_1$ Miss Th surpasses the median of the men. When it comes to sectional gains, Mrs. Su alone reaches or surpasses the median of the men in both arrangements, and Mrs. Ar surpasses their median in $A_1$ only.

We find the women just a little ahead in the typewriting experiment but not sufficiently to cover the probable error. The variability of the two groups is about the same. Both the men and the women in the regular and preliminary groups have greater variability after the break than before. In the regular group of the typewriting experiment the variability after the break is 1.60 greater than before, and for the men 2.11 times as great as before. In the men of the preliminary group the variability is 4.3 times as great after the break as before. This index of variability shows greater differences in improvement when an old association is persisting than without interfering associations. The trend of the entire series of experiments emphasizes this greater variability under conditions of interference.

Another significant fact of the rate of improvement in the typewriting experiment is the lack of correlation between the rate of improvement after the break and before. Were there such a correlation it would indicate that the differences found after the break are simply due to the ability of the subject to improve by practise as the simple practise curve shows. Among the men of the preliminary group there is a negative correlation of —.86 (P.E., .05); among the men of the regular group a correlation of .13 (P.E., .19); and among the women a positive correlation of .45 (P.E., .17). This indicates that the ease and rapidity of improvement after the break is not exclusively due to the same ability as the improvement before. The astonishing fact is that some of the writers before the break, who expected to make great progress after, did not nearly measure up to their expectations, while others did a great deal better after the break than before. Cl was the most rapid writer before the

break, but did very poorly after it. On the other hand Ru who had very poor records before the break became considerably more efficient after it and did not seem to be much disturbed because of the change. Of course a negative correlation of —.86 is exceptional, but the tendency seems to be practically no correlation.

Under the study of relapses is brought out the fact of correlation between efficiency in improvement and avoiding mistakes, which is also important as an index of individual differences.

In the card-sorting experiment we find but little difference as to variability in the rate of improvement. The men are more variable in the simple practise, and less variable in the alternate and sectional measures of Group III. These are the only well-defined sex differences. In both these groups the improvement is greater among the women than among the men. As would be expected the improvement in the practise group is greater than in the alternating group, the difference being .07 for the men and .12 for the women.

In Group III. the rate of improvement is higher than it is in the alternate group. This is especially true of the second arrangement which is continually subject to interference. The differences are greater in the sectional measures of the four sortings of each arrangement. These measures are the average rate of improvement for the sections of four sortings. Here the median percentages under interference are for the men .26 in $A_1$ and .25 in $A_2$; and for the women .13 in $A_1$ and .15 in $A_2$. Since this sex difference is greater than the sex difference in the total rate of improvement, the men must rise higher in the curve after the change and thus be able to improve more rapidly. This is the actual fact and explains the more rapid gain. The curves of Plate IV. show that the men drop lower with practise and rise higher immediately after the change. But this fact is still more clearly shown by the actual difference in time between the last sorting of the one arrangement and the first sorting of the next. This difference is 15 to 20 seconds greater for the men than for the women. This explains the fact that in the sections the men's rate of gain on the percentage basis is about twice as large. After the third day the men do not rise much higher immediately after the change, but they improve more than the women.

This greater immediate interference among the men does not seem to the writer to indicate that four sortings have a greater interference effect on the men than on the women. The men and women who had the least rise after the change had the poorest records, while those who rose high also dropped very low. With the poorer ones neither association seems so well fixed. Mrs. Su and Ar, who made the best records of the women of Group III., rose very high

immediately after the change, but improved rapidly. Miss Ag, who had the best time of any subject, rose very high after the change, but showed rapid improvement. Mrs. Sv and Ku who had the poorest records among the women of Group III., did not rise high, in fact, often did better right after the change than on the fourth sorting, thus giving a negative rate of improvement. It does not seem true that interference has the most lasting effect on those on whom it shows up strongest immediately.

The indication of the experiment is rather that those who rise highest after the change can most easily overcome the interference. It seems to the writer that interference effect must be measured by its *persistency,* and that those in whom it persists the longest are the most subject to interference. If this is true, the women of Group III. are less able to overcome the interference than the men. The men show a greater immediate effect but it is rapidly overcome. The reason the men can overcome the retarding effects of the previous associations more fully is because the two associations are more firmly fixed and more nearly automatic, so that a few sortings will raise the association to its previous efficiency. But why should the men show this greater immediate and momentary interference? Because of the fact that both associations are more firmly fixed and will when in full play require more energy to be displaced and give the momentary advantage to the other association. These higher rises indicate better fixed and more automatic associations, and the smaller effects of the change indicate less well fixed associations. When an individual on the fifth or sixth day of the experiment fails to improve with four sortings, the indications are that both associations are weak. When an individual however shows a great immediate effect but a rapid gain, it indicates that both associations are well fixed. The interference has the greatest effect where no associations are well fixed, for it is the cause that neither is well fixed. With the other individual, interference is an *incident,* but not fundamental. The fundamental thing is the fixing of the two associations.

Through the entire group the individuals that improved most and reached the best absolute time were those that rose high after the change but improved rapidly; those who improved least for the whole experiment and who did not reach the level attained among the others, were those who did not rise high nor improve rapidly. If the above explanation be the correct one, the men's associations are better fixed and interference has less influence over them. Their improvement in the sections is twice as great, the first performance after the change is 15 to 20 sec. poorer than that of the

women, and they reach absolutely lower levels. These differences are also true within the groups.

I do not however think that we are justified in drawing any sweeping conclusions as to sex differences on this point. Aikins[1] says that men have a greater tendency than women to form habits and use them, to build them together and to build one on another, to reconstruct the personality on the basis of habit. This he calls a truly secondary sexual characteristic and it is one of the arguments why woman is more primitive than man. Building up a personality on the basis of highly elaborated and varied habits is certainly a criterion of development. Well-fixed associations would indicate a higher stage of organization, and a greater freedom from overpowering interference than weak associations on which the interference would have great effect. The men in the experiment seem to have better fixed associations, a set of habits better developed, than the women have. The experimental results agree with the contention of Aikins. If these conclusions are correct we should expect men to have stronger habits and associations, and better able to build up the personality on the basis of habit. With them interference would have less effect. Interference would have a greater effect on the women. The men should therefore be better able to adapt themselves readily to the variations which the environment presents.

It must be borne in mind, however, that the sex differences here are not large, not nearly so significant as the individual differences among both men and women.

### 2. *Initial Efficiency and Plasticity*

One of the interesting questions of individual differences in mental traits is that of the relation between initial efficiency and susceptibility to improvement by practise. Does a high initial efficiency indicate a greater ability to profit by practise or does it indicate that the individual is farther along on his practise curve, and therefore, not so susceptible to improvement by further practise? Conversely, does low initial efficiency indicate less ability to improve by practise, or is the slow individual simply not so far along on the curve and therefore susceptible to greater improvement? F. L. Wells[1a] asks the question thus: "Is high initial efficiency a product of greater amount of practise, or of greater ability to profit from practise, and conversely, a low initial efficiency the product of lack of practise or of little ability to profit from practise? As the

[1] H. A. Aikins, "Man, Woman and Habit," *Psy. Bull.*, **5**, 50, 1908.

[1a] F. L. Wells, "Relation of Practise to Individual Differences," *Am. Jour. Psych.*, **23**, 75, 1912.

first or second of these alternatives hold true we may expect less or more improvement by the more efficient."

Wells conducted practise experiments on men and women in a simple addition test and in a number checking test. With few exceptions the curves do not cross. Those having the highest initial efficiency have the highest final efficiency, and those with the lowest initial efficiency have the lowest final efficiency. There is a fair correlation between the relative positions in initial and final efficiency. He concluded thus: "We are confronted then with cases indicating a high initial efficiency as a manifestation of superior ability to profit by practise, or plasticity; and on the other hand with cases exhibiting a low initial efficiency with minor possibilities of practise improvement."[2]

A high correlation exists between the initial efficiency and final efficiency in the card sorting and typewriting experiments, and in the card-sorting experiments there is a correlation between the initial efficiency and the rate of improvement. This shows that not only are those with highest initial efficiency able to improve as much, but even to improve more. With this it must also be borne in mind that those with poor initial records tend naturally to get a high percentage of gain.

In Group IV. of the card-sorting experiment there is a perfect correlation in relative initial and final position in $A_1$ and $A_2$ among both men and women. There is also perfect correlation between initial position and rate of improvement in both $A_1$ and $A_2$ among both men and women. These figures are all given in Table X., which show initial and final efficiency and rates of improvement for all the subjects.

In Group II. there is a perfect correlation between the relative initial and final positions of the first arrangement among both the men and the women. In the second arrangement the Pearson coefficient for the men is 1.00, and for the women .50 P.E. .29. The men have a correlation of .50 P.E. .29 between the initial efficiency and the rate of improvement in both arrangements. There is no correlation between the initial efficiency and rate of improvement among the women.

In Group III., with seven men and seven women, the correlation between the relative initial and final position of $A_1$ is .96 P.E. .02 for the men, and .93 P.E. .03 for the women. In $A_2$ it is .89 P.E. .05 for the men, and .96 P.E. .02 for the women. Between the initial efficiency and rate of improvement of $A_1$ the correlation for the men is .43 P.E. .20. Only one man and 2 women out of the fourteen

[2] Wells, *loc. cit.*, p. 81.

subjects are out of their relative position, though there is not much correlation between initial position and rate of improvement. The outstanding exception among the men of Group III. is Rd, who has the poorest initial record but whose rate of improvement is highest. His low initial record seemed to be due to a peculiar nervousness and hesitancy. He soon seemed at ease in the experiment. He was the only subject showing a very poor initial record and high improvement.

Among the women of the practise group there is perfect correlation between the initial and final efficiency, but none between the initial efficiency and rate of improvement. Among the men of the practise group there is no correlation between relative initial and final position. Wa is the poorest at the beginning and the best at the close.

If we take the results of the two arrangements of Groups II., III., and IV., and the one arrangement of Group I., we find a total of 60 cases of initial performance with a practise of 48 repetitions. Out of these sixty only eight curves cross any others. Six of these eight cross only one curve, one crosses two, and one crosses three. Of the six who end just a little better than the one starting next below them three of them are only one second lower. This makes it almost universal with the cases in hand that a higher initial efficiency goes with a higher final efficiency and a lower initial efficiency with lower final efficiency.

We find the most significant exception to this in the practise groups. Among the men of the practise group there is no correlation. In none of the practise groups is there correlation between initial efficiency and rate of improvement. In all the groups having interference we find high correlation between relative initial and final position, and some correlation between initial efficiency and rate of improvement. In Group IV. it is perfect both among the men and women. In Group III. the correlation is high for relative position and .68 between initial position and rate of improvement of the first arrangement for both men and women. In Group I. there is high correlation in relative position and .50 between initial position and rate of improvement for the men in both arrangements, 0 for the women. We find a higher correlation between initial and final efficiency in the interference groups than in the practise group. We also find no correlation in the practise group between initial position and rate of improvement, while we do get several appreciable correlations in the interference groups. It seems then in a test such as the card-sorting experiment, which demands a high degree of attention and quick discrimination, the most efficient are suscept-

ible to not only as great but even to greater improvement than the less efficient at the beginning. And when interference is continually present there is still a higher correlation between plasticity and initial efficiency. Not only are the more efficient able to improve more in pure practice but when the opposing factor of interference comes in their ability comes still more clearly to light. This correlation of the plasticity of the individual, his ability to adapt himself to the new situations and overcome the ever-present interference, with his initial ability is significant, and gives a clearer and more pronounced index of individual efficiency than the simple practise curve can ever give.

Table I. gives the initial and final performance of the typewriting experiment both before and after the break. We find some correlation between the initial and final efficiency, both before and after the break. In the preliminary group the eight men have a correlation of .95 P.E. .02 before the break, and .76 P.E. .09 after it. Among the men of the regular group it is .96 P.E. .02 before the break and .43 P.E. .20 after the break. Among the women the correlation is .60 P.E. .14 before the break and .50 P.E. .17 after the break. There is no correlation worth mentioning between the initial position and rate of improvement. Here we find a distinctly higher correlation before the break than after it. The correlation among the men is higher than that of the women. The smaller correlation after the break is due to the greater variability of improvement which we found after the break. This shows that the break has a very great initial effect on some, but is soon overcome, while others do not show such a great immediate effect but a more persistent one. This same thing is shown by the relapses, rate of improvement and variability, and is clearly seen in the curves.

### 3. *Errors as a Cause of Interference*

Most investigators of the practise curve have pointed out the grouping and individual differences in errors. Yoakum says: "Perhaps the most noticeable individual difference is in the errors and their grouping. They were nearly always found in well limited groups with periods free from errors.[3] Swift and Schuyler also pointed out that the errors come in bunches and that there are long periods without any errors.[4] Book says that there is a direct correlation between the errors and the fluctuations of attention.[5] Again

[3] C. L. Yoakum, "Experimental Study of Fatigue," *Psy. Rev. Mon. Supp.*, **46**, 77, 1909.

[4] Swift and Schuyler, "The Learning Process," *Psy. Bull.*, 1, 310, 1907.

[5] Book, "Psychology of Skill," University of Montana Publications, 1, 118.

he says, "blunders, false associations, and bad habits are liable to repetition."[6]

Outside of these remarks there is no analysis of these groupings of errors. What is the nature of the groupings? Are there various kinds of errors or repetitions of the same error? Are there individual differences and if so what is their relation to the general performance? What is the cause of the grouping, and why is this cause not operating during periods that are free from errors? Book continually hints at something which may give a clue but which he does not develop. He uses such expressions as "interfering habits, associations, and tendencies," "bad associations," etc., very frequently throughout his discussion of errors. These interfering associations and tendencies may have a very important bearing upon the grouping of errors with reference to their nature and effects.

TABLE XI

For explanation of table, see text.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Women: | | | | | | | | | | | | | | | |
| Ha ..... | 51 | 25 | 10 | 2 | | | | | | | | | | | |
| | | | 4 | 3 | | | | 1 | | | 1 | | 1 | 1 | |
| Mo ..... | 27 | 8 | 1 | 1 | 1 | | | | | | | | | | |
| | | | 1 | 1 | | 2 | | | | | | | | | |
| Ta ..... | 22 | 9 | 2 | | | | | | | | | | | | |
| | | | 2 | 1 | | | 1 | | | | | | | | |
| Hf ..... | 11 | 3 | | | | | | | | | | | | | |
| | | | 1 | | | | | | | | | | | | |
| McC ..... | 34 | 28 | 29 | 4 | 1 | 1 | | | 1 | | | | | | |
| | | | 3 | 2 | | 1 | | 2 | 2 | 1 | 2 | | | | |
| Wa ..... | 36 | 23 | 4 | 1 | 1 | | | 1 | 1 | | 1 | | | | |
| | | | 4 | 2 | | 1 | | 1 | | | | | | | |
| Wh ..... | 10 | | 1 | | | | | | | | | | | | |
| Og ..... | 23 | 8 | 1 | 1 | | | | | | | | | | | |
| | | | 3 | 1 | | | | | | | | | | | |
| Gr ..... | 31 | 3 | 4 | 2 | | 1 | | | | | | | | | |
| | | | 1 | | 1 | 1 | | | | | | | | | |
| Men: | | | | | | | | | | | | | | | |
| Cl ..... | 22 | 11 | 1 | | | | | | | | | | | | |
| | | | 3 | | | | | | | | | | | | |
| Ru ..... | 22 | 13 | 5 | | 2 | | | | | | | | | | |
| | | | 5 | 1 | | | | | | | | | | | |
| Ha ..... | 43 | 21 | 10 | 5 | 1 | 2 | | | | | | | | | |
| | | | 7 | 2 | | | | 1 | | | | | 1 | | |
| Br ..... | 27 | 1 | | | | | | | | | | | | | |
| | | | 1 | | | | | | | | | | | | |
| De ..... | 25 | 7 | 1 | | 1 | | | | | | | | | | |
| | | | 1 | 1 | | | | | | | | | | | |
| La ..... | 31 | 7 | 1 | | | | | | | | | | | | |
| | | | 2 | 1 | | | | | | | | | | | |
| McC ..... | 20 | 22 | 5 | | | | | | | | | | | | |
| | | | | 1 | | | 1 | | | | | | | | 1 |

[6] Book, *loc. cit.*, p. 82.

TABLE XII

For explanation of table, see text.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 14 | 15 | 26 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Women: | | | | | | | | | | | | | | | |
| Ha ..... | 1 | | | | 1 | | | | | | | | | | |
| Mo ..... | 4 | 1 | 1 | | | 1 | | | | | | | | | |
| Ta ..... | 4 | 1 | | | 1 | | | | | | | | | | |
| Hf ..... | 6 | | 2 | | | | | | | | | | | | |
| | | | 1 | | | | | | | | | | | | |
| Wa ..... | 25 | 11 | | 3 | | | | | | | | | | | |
| | | | | | | 1 | | | | | | | | | 1 |
| McC ..... | 19 | 5 | 4 | 5 | 1 | | | | | | | | | | |
| | | | 1 | 1 | | | | | | 1 | | 1 | | | |
| Wh ..... | 2 | | | | | | | | | | | | | | |
| Og ..... | 11 | 1 | 2 | 5 | | | 1 | 1 | | | | | | | |
| | | | | | | | | | 1 | | | | | | |
| Gr ..... | 15 | 3 | 4 | 3 | 1 | 1 | | | | | | | | | |
| | | | 1 | | | 1 | | | | | | | 1 | | |
| Men: | | | | | | | | | | | | | | | |
| Cl ..... | 5 | 1 | 3 | | | | | | | | | | | | |
| | | | | | 1 | | | | | | | | | | |
| Ru ..... | 8 | 2 | | 1 | | | | | | | | | | | |
| | | | | | 1 | | | | | | | | | | |
| Ha ..... | 13 | 6 | | 1 | 2 | | | | | | | | | | |
| | | | 2 | 1 | | | | | | | | | | | |
| Br ..... | 15 | 2 | 3 | | 1 | | | | | | | | | | |
| | | | | 2 | 1 | | | | | | | | | | |
| De ..... | 11 | 2 | | | | | | | | | | | | | |
| | | | 3 | | | | | | | | | | | | |
| La ..... | 12 | 3 | | | | | | | | | | | | | |
| McC ..... | 25 | 7 | 1 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | 1 | |

Table XI. gives the actual grouping of errors among the seven men and nine women of the regular typewriting experiment. I omit the eight men of the preliminary experiment because of the slightly different conditions. The errors given are those committed in the learning process during the 130 repetitions before the break. They do not include errors of omission for the key may have been struck but not hard enough to register. Nor do they include repetitions of the correct letter for that may often be due to a superabundance of movement especially in the early stages. Only where a wrong letter is struck is the error counted.

The figures in the upper horizontal column record one thing and those of the lower horizontal column another thing. The upper horizontal column gives the number of trials or repetitions which

contain a given number of errors. The figures at the top of the table give the number of errors in a trial, and the figures in the horizontal column give the frequency of the trials containing that number of errors. To make it perfectly clear the table shows that the first woman, Ha, has 51 trials each containing one error, 25 trials each containing two errors, 10 trials each containing three errors, etc. It will be remembered that there are 21 letters to be struck in each trial, and that there were 130 trials. If the horizontal column be added we have the total number of trials containing errors. If the figures of the column be multiplied by the number of errors they contain and their products added we have the total number of errors. The tables are not intended to show the totals so much as the distribution.

Turning now to the second horizontal column of the table we have another fact expressed. In reading this part of the table the figures at the top of the table give the number of successive trials each containing one or more errors. The figures of the horizontal column give the frequency of such groups of successive trials containing errors. Turning again to Miss Ha we find that she has four groups in which three successive trials contain errors, three groups where four successive trials contain errors, and one group each of eight, eleven, thirteen, and fifteen successive trials, all containing errors. This shows the tendency of the subjects to have a run of errors in successive trials. In this column no figures are given under 1 and 2 because one or two trials does not give a succession of trials. Table XII. gives the grouping of the relapses after the break in the same way.

Turning now to the upper horizontal column we find great differences in the number of errors per trial. Miss Wa has trials containing eight, nine, and eleven errors each. Br and Miss Wh have only one trial with more than one error. All the subjects except Mrs. McC have a majority of their trials with only 1 error each, Mrs. McC has 34 trials with 1 error and 64 with more than one error. The total number of errors varies from 13 for Miss Wh to 207 for Mrs. McC; the men vary from 29 for Br to 152 for Ha. The number of trials in which the errors occur varies from 11 for Miss Wh to 98 for Mrs. McC; while the men vary from 29 for Br to 82 for Ha. We find that some have an average of over two errors per trial while with others it is just a little over one. The variation is about 2 to 1.

Turning now to the lower horizontal column which gives the frequency with which a succession of trials with errors occur, we find more marked individual differences. Miss Wh has no groups. Br,

De and Mrs. Hf show each one group of three successive trials containing errors, and De shows one of four. On the other hand Miss Ha has separate groups of thirteen and fifteen lines containing errors, while Mrs. McC has a number of eight, nine, ten, and eleven successive trials. McC has one group of twenty successive lines with errors while Ha has one of thirteen. This shows the tendency of errors to repeat. When some individuals make a mistake in one repetition the succeeding repetitions are liable to have errors, with others this is not so true. The table shows the extent to which it is true among the subjects.

Table XII. gives the same information for the relapses. The same facts here are evident though in not so pronounced a form. Here there are of course only fifty trials, and the totals are not nearly so large. Miss Wa and Miss Og show about the same number of relapses, but Miss Og in about half as many trials. Miss Ha with only six relapses has five of them in one trial. Some average three relapses per trial others only one. Turning to the second horizontal column we find that Miss Wa has an extraordinary repetition of relapses, having thirty consecutive trials with relapses. McC has 33 trials containing relapses, but 23 of these come in succession. Mrs. McC has 31 trials containing relapses and 31 of these come in groups. Miss Gr has 24 of her 27 trials containing relapses in groups. Others have no groups. This shows the tendency of one relapse to bring others in the succeeding trials.

It seems to the writer that there is a fundamental difference between the two kinds of grouping shown in the tables. The one kind of grouping is that of several errors in the same trial, the other that of a number of successive trials containing for the most part only one or two errors each, but repeated for many trials. The records as well as the introspections show that one error tends to cause another. This is what Book means when he speaks of "bad associations," "bad tendencies" and "interfering habits." Errors are not grouped merely by chance, but an error makes an interfering association which is hard to overcome. The cause of the grouping of errors is due to these bad and interfering associations. Book finds that in some cases it takes a very long period of time for them to drop out, and that not until they do drop out can there be unimpeded progress. He cites the case of a music teacher who recommends that in learning to play a piano, it is better to practise in periods of 15 minutes with recesses, than to continue for an extended practise, because of the fact that interfering tendencies do come in and cause error. When these drop out gain can be made without the strain and useless labor that would be expended in a

long practise at the time. This accounts also for the little improvement on some days and the smooth progress made on other days.

Where many errors occur in the same trial we have what I shall term "general" interference due to the bad association. A wrong reaction may bring on four or five incorrect reactions, none of them a repetition of the first but all different and due to a sort of confusion brought on by the first error. Many observations show that a single error destroyed the freedom of movement, broke up the general association connection, misplaced the confidence of the subject, and had a general inhibiting effect, causing various errors in the same trial. Often the subject would completely recover and on the following trials make no errors or only incidental ones.

But where a wrong reaction occurs in a given trial and is repeated in the succeeding trials, giving us a large group of lines containing the same errors, we have "specific" interference of the bad association. Miss Ha made one wrong reaction 18 and another 22 successive times on the same day, while generally she made comparatively few errors, and at no time did she make many errors in one line. She was told that she was making an error, but never suspected what it was and was surprised at the result at the end of the experiment. This is a very pointed case of "specific" interference, and yet never does the repeated error show any bad effect in the general sense upon the other reactions of the same trial. The same subject made only six relapses. Immediately after the break she arose to the situation, but other errors crept in and persisted without correction to the end. The table shows that she had many repetitions of the same error.

On the other hand, Miss Wa has many trials containing 2, 3, 5, 8, 9, and even 11 errors, but no repetitions in successive trials until after the "break" one relapse repeats itself a number of times. One error may upset her for the whole trial, causing great confusion, lack of confidence, slowing up of speed, deranging the association and generally inhibiting the work. There may be errors in the next line but not necessarily a repetition. She has a very marked general interference of the error but no specific interference.

Hf of the preliminary group (no table is here given for them) made more errors than any other subject, but the effect of an error was not specific but general, nearly always bringing others. He had hardly any trials with only one error. Ja of the same group did not show general interference but specific, once having a run of 17 repetitions of the same error.

McC presents a marked case of specific interference with a gen-

eral inhibitory effect which lowered his speed. After the "break" he had a run of 26 relapses and before the "break" a run of 13 repetitions of an error. This error and relapse did not cause other errors for he rarely made more than 2 errors or 1 relapse in a trial. The former habit had apparent control of this particular reaction, for after each relapse he would say he had made a mistake but did not know what and did not think it was the same one as before, being quite surprised later to find out that it was. The error seemed to make him very deliberate. The observer could in practically every trial see him about to strike the relapse number, then shake his head and strike the correct one. Sometimes he was about to strike the wrong one several times. Many times he would hesitate, even moving his fingers several times before striking, although he had the right reaction in mind. He said that his inhibitions were very strong and that he could not attain great speed on account of the mistakes. We see here that the specific interference had great control over him while the general effect was to increase his time but not to cause errors.

These bad associations take many forms. In writing the three-place numerals inversions often occur. There are repetitions. 639 was repeated instead of 628, the "6" giving the cue to the previous association. Sometimes the "3" of 853 was changed to "1" following the association of the "1" with the "5" in the previous 751. Sometimes also a number farther on was placed back and then correctly repeated in its proper position. Most of the errors however are the association of an absolutely wrong number with the reaction and then its repetition.

The individual differences in grouping may seem to be minimized by the fact that those making the greatest number of errors are those having more errors per trial and more groups of successive trials containing errors. This is of course what will happen from the law of averages. But why do some make more errors than others? And why do the errors tend to form such groups? We can not separate all the factors which go to causing errors in the learning process. But one of them seems clearly to be this general and specific interference. An error is likely to happen for some cause or other, but whether that error will cause others or not may be a matter of individual difference. The evidence at hand seems to point to that conclusion. With some individuals an error does not seem to have bad interfering effect, with others it has a general interference effect, with still others a specific effect. That they both operate to some extent is evident, but that one operates more strongly in one individual and the other in another, is also evident.

The fact that there is no correlation between the errors and relapses shows individual differences in meeting one kind of interfering associations which are not the same as those meeting another kind of interfering associations.

The overcoming of such interference is important in all forms of the learning process. Much of the delay and lack of progress, and to a large extent the plateaus themselves, are due to such a combination of bad associations and tendencies, which must be overcome. Whether their effect be to cause general confusion and lack of control or repetition of the specific error, they must be reckoned with. Suffice it to say here that a closer analysis of errors is needed for the purpose of offsetting their bad effects.

### 4. *Variability*

The variability is greater when interference is present than under performance without interference. Table XIII. gives the medians of the average deviations in the card-sorting experiment for the men and women.

TABLE XIII

| | Practice Groups | | Group II | | Group III | | Group IV | |
|---|---|---|---|---|---|---|---|---|
| | Med. | P.E. | Med. | P.E. | Med. | P.E. | Med. | P.E. |
| Men ..... | 4 | 1 | 8 | 2 | 7 | 1 | 9 | 1.5 |
| Women ... | 7 | 1.5 | 4 | 1 | 9 | 1 | 5 | 1 |

In Groups II. and IV. there are only three subjects of each sex. In each group one of the men was very much slower, while the women happened to be quite uniform. So the figures for those two groups can not be considered of great value. In Group III. however there were seven subjects and consequently the results are much more reliable. With the exception of the women in Groups II. and IV., each of the interference groups show higher variability than the practise group.

When we turn to the percentage rates of improvement the variability becomes more significant. In the typewriting experiment the variability as expresed by the Pearson formula[7] before and after the break is as follows:

| | | |
|---|---|---|
| Regular men ..... | .47 before break | .99 after break |
| Preliminary men ..... | .37 before break | 1.59 after break |
| Women ..... | .58 before break | .93 after break |

[7] Pearson formula, $\frac{\text{Gross variability}}{\sqrt{\text{Average}}}$. This is the form as modified by Professor E. L. Thorndike. See "Theory of Mental and Social Measurements," 1904, p. 102.

Nor do these rates of improvement correlate, showing that those improving fastest before the break do not improve most after it. The correlation figures are: Men, preliminary group —.86 P.E. .06, men regular group .13 P.E. .19; women .45 P.E. .17.

This variability is further emphasized by the fact that those making the most relapses have the slowest rate of improvement, as shown by the following correlations.

BETWEEN RELAPSES AND RATE OF IMPROVEMENT

| | | |
|---|---|---|
| Men, regular group | $r = -.76$ | P.E. 10 |
| Men, preliminary group | $r = -.69$ | P.E. 12 |
| Women | $r = -.09$ | P.E. 28 |

In the card-sorting the same thing is true. Table XIV. gives the variability as expressed by the Pearson formula for each of the groups, for both men and women.

TABLE XIV

| | Practice Group | Group II | Group III | Group IV |
|---|---|---|---|---|
| Men, $A_1$ | .83 | .75 | .55 | .67 |
| Men, $A_2$ | | | 1.20 | .33 |
| Women, $A_1$ | .29 | .83 | .57 | .34 |
| Women, $A_2$ | | | .80 | .34 |

One subject among the men of the practise group brings the rate to higher than normal—Wa, who is the only subject of the entire series to begin as poorest and end up as best of the group. His first records were so phenomenally high as to make it purely accidental in that group. The rest of the table uniformly shows greater variability under interference.

In the discussion under plasticity the figures are given to show greater differences in plasticity under interference than in the simple practise curve, and consequently higher correlation between initial efficiency and final efficiency and between initial efficiency and rate of improvement.

## CHAPTER V

### Discussion and Summary

### 1. *Method*

Münsterberg[1] pointed out three experimental conditions for the investigation of his problem. They were: (*a*) The movements must be entirely mechanical so as not to call in the attention. (*b*) They must be easily varied. (*c*) They must call in the attention whenever a false movement is made or whenever the old habit returns. Because of the first requirement he held that the experiments could not be performed in the laboratory. The card-sorting experiment, it seems to the writer, meets all the conditions for the investigation of the problem of interference and meets them more decisively than his experiments do. It meets the needs of an experiment better because it can be more strictly measured, because it brings out greater possibilities of interference, and because it requires the maximum of attention.

In this experiment we have exactly similar conditions for each individual with reference to the number of repetitions, which would not be possible in an experiment of the kind described by Münsterberg. It means more exact measurement and makes possible a study of individual differences. In the second place the changes, coming quickly as they do, and requiring the exclusion of the ten former associations, give greater opportunity for interference to show its full force. Not until we know the full force of the interference are we ready to get any results of the overcoming of that interference. When a watch is changed to another pocket and the number of wrong reactions counted, there are a number of things which might affect the number of wrong reactions. The pressure of the watch in the other pocket, the accidental moves to that pocket, a lack of record of the number of times the watch was actually sought during the day, the varying conditions from day to day, leave a possibility that interference does not get its full play or at least gets a varying opportunity. By the immediate change of arrangements and by an equal number of repetitions in a given length of time this factor is better controlled.

This experiment requires the maximum of attention. The cards

[1] Hugo Münsterberg, *loc. cit.*, p. 71.

do not come in a given order and consequently there is no chance to grow lazy on the habit. There must be eighty individual discriminations and as many reactions. Attention did not waver in the card-sorting experiment as it sometimes did in the typewriting experiment. It continually calls the discriminative powers into play, but in the most simple form, a simple stimulus and its consequent reaction. The stimulus is not given until the card just above the one in question is thrown, and consequently the conditions for each are exactly the same. The point for which Münsterberg contended was that attention could not be centered on the performance before it was to take place. That condition is met here because the stimulus is not perceived until it must be acted upon.

The card-sorting experiment, it seems to the writer, is somewhat better than the typewriting experiment for the problems here investigated. The typewriting experiment, while perfectly valid, has two hindrances. In the first place there is such a difference between individuals in skill in manipulating a machine as to minimize the individual differences of the experiment. In the present experiment this factor has not been of such great importance because the results show that there is no correlation between the native skill on the typewriter and the ability to break the habit.

In the second place the gain on the typewriter is so great because of the poor initial performance, which in turn is caused by the fact that the subjects are awkward on the machine. This high initial record makes the retardation after the break seem small. After the break the subjects are familiar with the machine and can make fairly good records as compared with their initial records. The interference is clearly shown but not in the proportion which it really holds. Only in a few cases was the first performance after the break absolutely poorer than the first performance in the practise curve before the break. On the other hand in the card-sorting experiments the interference of the first four or eight sortings always made the time of the first sorting of the new arrangement longer. But there was no such great general transfer effect as in the typewriting experiment. If all the subjects were used to handling a machine the same thing would undoubtedly be true in the typewriting experiment.

The criticism has been made that the cards did not come in a given order. It has been held that the cards should be arranged in a given order for each ten, for example, 9, 1, 7, 2, 10, 6, 4, 8, 3, 5 for the first ten and then the same order repeated for every ten through the eighty cards. The subject could then learn this order and the arrangement and of course reach a better absolute time record than

in the present experiment. This would miss the purpose of the experiment. A chance order with no card repeating itself successively is the ideal for the purpose. Under the proposed scheme one would substitute units of ten for the single units. We have in the eighty cards just eighty repetitions of what would happen if a single stimulus appeared in a tachistoscope and a definite reaction was made, because each single card is seen only after the one above it is removed, and the entire process occupies in the later stages about three fourths of a second and with some was reduced to nearly one half second per card. The total time gives the measurement of eighty such simple reactions, each one under exactly the same conditions. Sorting the cards in sixty seconds means that it is practically automatic, or three fourths of a second is the automatic limit. If a change is then made to the other arrangement and the total time goes up to 80 seconds and one second is the measure of a single reaction. If in the second sorting the time is again sixty seconds we have a measure of the interference and the rapidity with which it is overcome both for the total and for a single reaction. The eighty cards thus arranged leave little room for error, which would not be the case with a single reaction.

Bergström, Bair, and Beazley used pictures on their cards, and Beazley used pictures on the keys of his instrument. The pictures which they used seemed not to be of equal difficulty nor can they be of equal familiarity. Bergström even used cards with a different picture on the other end. This it seems to the writer can not help being a disturbing element. Cards with numerals or letters or some other such simple stimuli should be used.

Bergström[2] allowed an interval of two minutes between the alternate sortings, or nearly two minutes depending on the length of time the sorting took. He had previously found that about two thirds of the decrease in the amount of interference took place in the first minute. How long an interval should be given between the sortings is therefore a very important factor. That he should find the interference effect so great after an interval, when according to his own experiments more than two thirds of the interference had already faded, is surprising and is discussed at another place. In the present experiment the intervals were kept uniform at thirty seconds. This, it was felt, would bring out the interference more strongly. The results here obtained, so different from Bergström's, were consequently not due to less rigorous conditions but to more rigorous.

The results of the card-sorting experiment show that for purposes of further investigation the alternate method and the four-by-

[2] Bergström, *loc. cit.*, p. 436.

four trial method of Group III. are the best. Nothing new is yielded by the eight arrangement method except that the interference is not much more, if any, with eight than with four repetitions, and that it is sooner overcome. The four-trial method seems to be the best employed by the writer.

### 2. *Relation of Interference to Practise Effect*

The specific problem with which Bergström was concerned in his second report on interference effect was its relation to the practise effect, as to whether it was greater, equal to, or less than the practise effect. His conclusion was that the interference effect was equal to the practise effect.[3] He also says that if the experiment had been taken at the same stage of practise as the one he previously performed the interference effect might have been greater than the practise effect. He thinks that the previous and opposing associations are not effaced because they have the same effect on a third arrangement as they have on each other. Bair finds no such large amount of interference and thinks a large part of Bergström's is due to indisposition on the part of the subject.[4]

Bergström had only one arrangement, that of alternating, and conducted it for just eight repetitions, which is included in one day of my experiment. He might use the same cards after several weeks for another similar series but was sure that at that time no practise effect remained over. Then in the second place he used only one subject. With only one subject for such a short time he could hardly draw his strong conclusion, for several of my subjects did not show improvement until the second day, and had they been all used for just one day there would have been little improvement.

All of the twenty-six subjects in the present experiment show interference effect. Immediately they show more than Bergström's for the sortings were only 30 seconds apart. This is not a matter of indisposition or laziness but interference. The hardest work of the subjects was done right after the change and just when the interference showed most. Except when a record was to be broken the subjects worked hard to keep their time from increasing. Only one subject did not do this and he showed laxness of interest at several points. In spite of hardest work at such times every individual shows immediate interference, and those showing most improvement often show greatest immediate interference.

But the interference is overcome and the two associations become

[3] Bergström, *loc. cit.*, pp. 440, 441.

[4] Bair, *loc. cit.*, p. 47.

automatic. The interference bears a decreasing ratio to the practise effect. Bergström assumes that, if the interference and practise effects are directly proportional to the number of repetitions, the one will be equal to the other times a certain constant. If this constant is equal to 1, interference is equal to the practise, if greater or less than 1, the interference is greater or less than the practise. If they are not directly proportional to the repetitions and yet hold the same relation to each other, then both would have the form of the true practise curve, or nearly so at least, as the mechanical conditions of the experiment admit. However, since the curves of the two opposing associations follow the parallel of the abscissas he holds that the interference and practise effects do vary directly with the number of repetitions and hold the constant relation of one to one to each other and are therefore equal.

The curves of the present experiment show that in simple practise the practise effect varies with the number of repetitions though not directly proportional for the curve is concave. The question then arises whether the interference varies in the same way. If it does its relation to the practise effect would be constant. The constant quantity would be less than 1 if the curve having interference shows any practise effect.

But in the present experiment the interference effect does not vary with the number of repetitions in the same way as does the practise effect. Bergström showed that after twenty-four hours there is no trace of interference left, and the present experiments indicate no interference from the previous day. The practise of one day however begins with the strength of the association of the previous day. Thus on the first day alone would the interference effect and practise effect be based upon the same number of repetitions. On the succeeding days the interference effect would be based only upon the immediately preceding opposing repetitions while the practise effect would be based on all the repetitions of the entire experiment. There can then be no constant relation of the interference effect to the practise, but a variable and continually decreasing relation.

That there is a variable and decreasing relation the curves of the alternate group most clearly show. The practise curve is concave, the alternate group almost a straight line but continually improving to the end. The interference is therefore continually becoming less as related to the practise and if the experiment were carried on for a very long time the two would undoubtedly come together. There is temporary disadvantage to be overcome, which would make just a little difference but would become infinitely small. The interfer-

ence then seems to hold a variable relation to the practise, being just less than 1 at the beginning and approaching 0.

The curve of Group IV. is just as concave as that of the practise group. The interference is readily overcome within the periods themselves and new practise effect is continually gained as if the interference were not present. It is simply temporary within each change of arrangements.

In Group III. the curve shows slightly less improvement than that of the practise group, but it is nevertheless concave and continually reaches the practise group. An indefinite amount of practise would bring the curves closer together and the immediate interference of the change would show less and less.

That the interference is an incident of the course of two associations becoming automatic is clear, but it is overcome, and the two opposing associations become automatic in each of the three groups, with the advantage to those groups having the greater number of consecutive repetitions before changing to an equal number of the opposing reaction.

### 3. *Physiological Considerations*

The question has been raised as to the condition of the neural paths of the previous association when the new association becomes automatic. Münsterberg held that physiologically there remains a molecular disposition of the paths used so that they are more easily reopened when returned to than in the first practise.[5] Bergström asks whether the old association is effaced after the practise of the new one.[6] He concludes that it is not because if a third arrangement $A_3$ is sorted it shows the interference of $A_1$ the same as $A_2$ does. He further holds that the interference effect of the $A_1A_2$ series is no less than that of the $A_1B_1$ series, which we should expect to be the case if the opposing associations had partially effaced each other.

What physiological explanation would then fit his conclusion that the interference effect is equal to the practise effect? If an association fixed by a certain number of repetitions has a well-worn pathway of discharge, that particular association ought to function more readily and automatically at the $n$th repetition than it did at the first, unless it is effaced. His conclusion seems to me contrary to all that we know of the neural process of habit formation. That it is not effaced seems true but then it should function automatically.

The results of the present experiment show just what the physiological facts would lead one to expect. The associations are not

[5] Münsterberg, *loc. cit.*, p. 71.

[6] Bergström, *loc. cit.*, p. 440.

effaced but continually become better worn and function more readily. The high rise in the curve of Group III. comes back to the practise level almost immediately, showing that the association is as strong as before the interference. The same thing is true to a greater degree in Group IV. In the alternate group the first sorting of each day is distinctly better than the others, showing that the association has become well fixed.

Fig. 2 is a schematic representation of the neural connections in

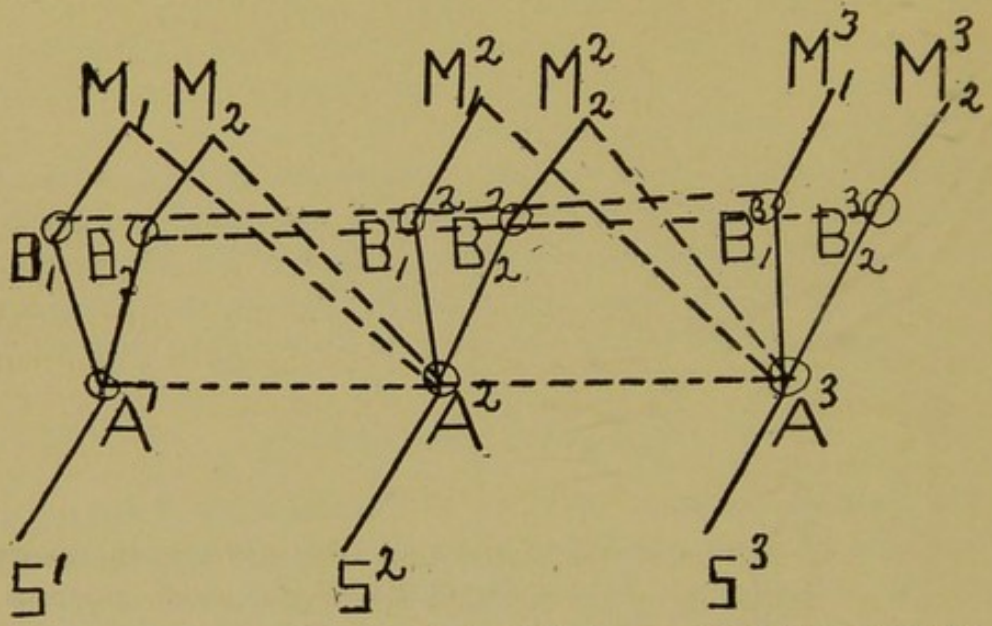


FIG. 2. $S$, $S^2$, ... represent the individual sense impressions received from the various cards coming in to the sense centers $A$, $A^2$, .... In the first arrangement these are discharged into the motor cells $B_1$, $B_1^2$, ..., so as to bring on the movements $M_1$, $M_1^2$, ... throughout the first series. The sense impressions from the stimulus in the second arrangement are the same, so that from the same sense centers $A$, $A^2$, ... there are again discharged impulses, but these pass into motor cells $B_2$, $B_2^2$, ..., which bring about the movements required in the second arrangement, represented by $M_2$, $M_2^2$, ... throughout the entire series. According to the law of contiguity connections are worn between $A^1$, $A^2$, ..., as shown by the dotted line. Likewise connections are worn between $B_1$, $B_1^2$, ... and between $B_2$, $B_2^2$, .... There are also connections formed between the sensations of the movements and the original sense center as shown by the dotted lines. We have established connections between the sense center and two opposing motor cells and consequent movements. Both, however, become automatic and when $S$ is started each will follow according to the law of habit. The movements will follow one arrangement or the other, according which is started and receives the temporary advantage.

the case of the card sorting. $S$ represents the card stimuli pouring into the sense centers $A$. In the first arrangement there is a certain pathway worn $S$, $A$, $B_1$, $M_1$, and so on for the whole ten cards. In the second arrangement we have the same stimulus, and the same

sense center effected but the discharge is through a different motor cell and a subsequent different movement, the whole path being $S$, $A$, $B_2$, $M_2$ and so on through the entire ten cards. There is another set of stimuli coming from the arrangements which are different in the two cases and the neural connections of these determine whether $A$ will discharge into $B_1$ or $B_2$ and consequently give movement $M_1$ or $M_2$. But out of $A$ there are these two pathways of discharge for the same stimulus and neither is effaced, but both are well worn. Now $A$, by the law of contiguity connects with $A^2$, $A^3$, . . ., $B_1$ connects with $B_1^2$, $B_1^3$, . . ., while $B_2$ connects likewise with $B_2^2$, $B_2^3$ and each of the movements $M_1$ and $M_2$ connect with $A$. So all the connections are formed as in forming a single habit, except that here we have two opposing habits and yet both of them becoming automatic. As to which direction the discharge will go depends on the larger complex in which this situation lies, but the fact is that both of them are open and ready to discharge. Münsterberg said that the discharge will follow either path and that it will not divide. This is the case in the experiments, and this the figure in a schematic manner attempts to show in the neural connections.

### 4. *Adaptability*

In the introduction it was stated that adaptation is the general character of mental development, that adaptative reconstruction is the general form of change which is incessantly renewed so long as the individual continues to live, and that this embodies an elaborated form of response and a modification of the response to meet a change in the system of stimuli. The question of adaptability was found to have wide practical interests, racial, political, religious, social and industrial. To investigate these in their broad relations is impossible under experimental conditions. Observation shows that in all these fields adjustments are made with greater or less ease among individuals and groups. The friction which opposes these adjustments or in a more general sense adaptation, is interference. Interference seems to be present to a greater or less extent among all such adjustments.

For the making of these adjustments the nervous system has groups of inherited tendencies, the simple elements of which are associative connections. With these associative connections the experiment has had to do. If these larger complexes have adjustment properties we should expect the associative elements to have them also, though not to such a great extent. If an individual can adapt himself in these wider fields of interest and activity he should be

able to do the same to a lesser degree in the simple associations. What is true of life should be found true in the laboratory.

The experiments show that on simple association interference is an *incident,* but only an incident and not fundamental. Adaptation is the fundamental thing, because the two associations do become automatic. In the wider interests interference is an incident but adaptation is fundamental. This is true in religious conversion, in industrial changes, in social readjustments, in racial migrations and in every form of life where variations occur in the environment. That it is true in associaton *per se* preserves a unity in the nervous organism.

Bergström says in speaking of these wider applications of the problem:[7] "The nervous system has, as is well known, inherited tendencies of growth and adjustment to external circumstances. Perhaps the simplest of these for the organization of nervous activity is the tendency of nerve currents to run from one pattern to the next succeeding. This is modified in many ways by special tendencies of a higher order, which may be classed as fundamental practical adjustments or practical interests. If these are given opportunity to influence the results, we are not dealing with associations *per se,* but with these as modified by other more powerful forces. . . . There are besides great numbers of secondary tendencies by which simple successive association is transformed. Moreover where the conditions are more complex than in this experiment certain conditions may enter and change the results. A person who speaks several languages finds that the words of the same language tend to be recalled together. Some persons also know and can use two different systems of shorthand. In these cases the elements associated are used as members of a group, for the exclusive employment of which there seems to be a strong tendency. The inconvenience of interference is thus to some extent avoided in these cases, but probably only by a proportionate expenditure of energy."

In other words the elements of the complexes show an eternal interference to the tendencies of the complexes themselves. It is rather peculiar that an individual can use automatically two systems of shorthand, each simple association of which excludes the opposing one, and yet can never learn to shuffle a few cards when their associations exclude each other as Bergström's discussion indicates. That there are these higher complexes and that they show wider adaptive tendencies is freely admitted, on the principle that the higher the process the wider the differences and the greater the

[7] Bergström, *loc. cit.,* p. 442.

plasticity. But that there is an irreconcilable conflict is denied. That the larger adjustments are made only because the superior energy overcomes the inferior associative element does not give us a unity but gives us an unexplained difference. If this were the case then no investigations of association would have the slightest value in practical interest and the results of experimental psychology would be in endless contradiction with the truths obtained by observation and general experience. Though we are not yet able to show the correlation between results on simple association and these higher adjustments the search is not futile, but it would be hopeless if the results on association *per se* conflicted irreconcilably with these tendencies which are only groups of association elements, and their adjustment had to be explained on the ground that the lower elements are overcome by their greater energy.

The individual differences in adaptability are great and this is what general experience confirms. The discussion of plasticity as a section in "Individual Differences" shows a correlation between the initial efficiency and the improvement under conditions of interference. This correlation is higher in the groups having interference than in the practise group. The more complex the situation is and the more it calls for adaptability and adjustment in the face of interference, the more does the individual ability appear. Greater ability of performance at the start indicates greater power of adaptability. The fittest will adapt best and survive, the ones most accustomed to the one situation will most readily adapt themselves to the new. The more fully one set of habits is built up the better fitted is the organism for having many habits with mutually exclusive associations.

According to Bryan and Harter the higher the organism the more complex the hierarchy of habits.[8] The higher the organism the greater the power of adaptability. The experiments show that there is progress in spite of interference because fully developed habits are formed, and the more completely each of these habits are formed the less influence interference has and the greater the adaptability of the individual. Adaptability is not manifest because there is little interference from a weakly opposing association, but because all the associations are strong, and the interference has no power of effacing the opposing associations. While Bryan and Harter discuss a different problem in their hierarchy of habits, yet the same general conditions of adaptability seem to underlie the ready formation of a hierarchy of habits, and the formation of a complex of

[8] Bryan and Harter, "On Learning the Telegraphic Language," *Psych. Rev.*, **6**, 1899.

habits as in the present experiment. Their contention also that the hierarchy of habits is an index of higher type of organism agrees with the building in of habits of the present experiment.

The discussion of "variability" also brings out the fact that individual differences are greater under conditions of interference than in the simple practise groups. The average deviation is greater in Group III. than in the practise group. The variation in the rates of improvement as expressed by the Pearson formula are greater after the "break" than before in all the groups of the typewriter experiment, and also among the groups of the card-sorting experiment the variability of the groups under interference is greater than that of the practise groups. The sex differences are not so pronounced.

## Ethical Implications

Professor James has pointed out the enormous consequences of habit as being the precious conservative agent of society.[9] The plaster of life is early set and forever thereafter we are content to remain in the mold. Men grown old in prison ask to be readmitted. While this is true there is another side to the truth. Some in whom the mold has long been set move from the foreign land to this and enjoy the remainder of their days. There are limits to which the plaster will reset to the new conditions. There are adjustments made long after the old associations had been firmly fixed. After the change the new forms for itself another mold of habit and if the former is not returned to will be just as well set as if it were the only one. If the former is returned to the individual will be as perfectly adapted to either as he once was to the first.

One of Professor James's oft-quoted maxims is "Never suffer an exception to occur until the new habit is securely rooted in your life." How true this is many of the subjects in the typewriting experiment can fully testify. Often when the new order seemed to be well established and the old troubled them little, one relapse would set them wrong for the rest of the experiment and it would be harder for them to overcome it than after the immediate "break."

There is another truth which seems to the writer to have great importance and value. Do not passively resist the temptation of the old stimulus, but respond to it by another action which will exclude the previous action. Let the reformed drunkard resist the temptation to drink by every time taking some little refreshment which will give a definite response to the stimulation, but which will exclude the former. Religious societies have long recognized in a general way that the new convert must have other work to do to satisfy his

[9] William James, "Principles of Psychology," Vol. 1, p. 121.

impulses. Only by action which will exclude the former association will there be real success in excluding the former and a true method, psychologically speaking, of ingraining the latter.

## Summary

The results of the experiments may be summed up as follows:

1. When two opposing associations, each of which excludes the other, are alternately practised with one, four, or eight repetitions of each association before the other is resumed, the opposing associations have an interference effect upon each other in all the subjects. The interference effect grows less and less while the practise effect becomes greater. The interference effect is gradually overcome and both opposing associations become automatic so that either of them can be called up independently without the appearance of the other. The curves of the alternating group follow a straight but descending line and gradually approach the true practise curve. The curves in which four or eight repetitions of the one association are given before the other is resumed are concave and closely approach the practise curve. The individual differences in the rate of improvement are as great as in the absolute time records, but in no case is the interference effect equal to the practise effect. Adaptability is fundamental with individual differences; interference is an incident in the course of automatization of the two opposing associations.

2. When a change in reaction to several of a series of long practised stimuli is introduced, as in the typewriting experiment, there is great immediate interference effect. This is shown by the increase in time and the recurrences of the former associations. The improvement is rapid, the interference effect is overcome, and the previous level of efficiency attained. Individual differences are greater than before the change was introduced. The number of recurrences of the former association varies from 2 to 66. There are no sex differences, except that the women are more variable than the men.

3. There is a positive correlation between the adaptability of the eight subjects of the preliminary group of the typewriting experiment and the traits of *individuality, independence* and *originality.*

4. There is a positive correlation between adaptability as shown by the discrimination to red after long practised association with blue, and the color naming test of 100 colors.

5. An error committed in practise tends to introduce interfering associations which will cause other errors. In some cases this interference has a general effect which causes various errors; in other cases it has a specific effect which causes a repetition of the error in

succeeding trials. Some individuals are affected mostly in the first way, while others are affected chiefly in the second way. There are great individual differences in the interference caused by errors.

6. There is a high correlation between initial and final efficiency which shows that the more efficient improve as much as or more than the less efficient. This correlation is higher when interference is present than it is in simple practise, thus bringing out the individual ability more clearly. There is also a slight correlation between initial efficiency and rate of improvement in the groups having interfering associations, while there is none in either the simple practise group or the typewriting experiment.

7. There are no significant sex differences in rate of improvement. The men show greater immediate effect after the change from one sorting to another, but they very rapidly get back to their former level.

8. The variability is greater when interference is present than when it is not. This is shown in a comparison of the practise group with the others in the card-sorting experiment and also by comparing the rate of gain after the break with that before the break in the typewriting experiment. The women show greater variability in relapses but not in actual time records nor in rates of gain.