EXPERIMENTS ON THE TRANSFER OF TRAINING[1]

WILBUR HARRINGTON NORCROSS

From the Psychological Laboratory of the Johns Hopkins University, Baltimore, Maryland

I. INTRODUCTION

It has long been known that if an individual be given training ("practice") in some operation which involves the musculature of one side of the body only, there will be an apparent improvement in the same or similar operations carried on through the corresponding musculature of the other side of the body, although this musculature has not been involved in the "practice." If, for example, the individual is given practice in operating a typewriter with the right hand only, and the practice is continued until a considerable degree of improvement in speed and accuracy is attained, it will be expected that the individual will show now an improvement in the same respects in operating the machine with the left hand, as compared with his performance with the left hand before "practice," although only the right hand has been employed in the "practice" work. This apparent carrying over the "practice" effect from the one side of the body to the other is technically known as *bilateral transfer of training.*

The phenomenon of bilateral transfer is first recorded as observed by Weber (28) and Fechner (9) in the ease with which an individual's unpracticed hand made letters similar to those made by his practiced hand. Volkmann (26) reported similar results in the transference of sensitivity to tactile impressions in distance discriminations. Scripture (20) noted that improve-

[1] The experimental work reported in this paper was done for the greater part at the Johns Hopkins University during the years 1914–1916, and completed at Dickinson College during the year 1917–1918. An extensive historical summary which had been prepared was lost, during the author's absence in the army, through no fault of his. In its present form, the paper was completed May 1, 1920.

ment in steadiness, strength and muscular control was transferable bilaterally. Davis (6) reported the results of tests and practice in lungeing, and with dumbbells, tapping, dynamometer and ergograph; and from his data concludes that "the effects of exercise may be transferred to a greater or less degree from the parts practiced to other parts of the body. This transfer is greatest to symmetrical and closely related parts." Wissler and Richardson (32) concluded from data gathered by experiments with a hand dynamometer, that large transfer of training accrues to the unpracticed hand. "The accessory muscles of one side gained approximately as much from the exercise of the corresponding muscles of the opposite side as from the exercises of the fundamental muscles of the same side." Wallin (27) trained observers in monocular control of the illusive phases of reversible perspectives. The improvement that resulted from the training of one eye was shared by the untrained eye.

Swift (22) concluded from his experiments in tossing two balls, that in the majority of cases the training of the right hand was effectively transferred to the left hand. In one case, in four days of practice the left hand excelled the attainments of the right hand previously practiced eleven days; the transfer being perhaps due to the "content already learned." Hill (11) found positive evidence of transfer of training from the practiced to the unpracticed hand in his experiments on mirror-drawing of a star.

The phenomena observed have been given various tentative explanations, mostly in terms of physiological theories. The problem cannot, however, be divorced from the more general problem of transfer of training, which is included in the much debated topic of "formal discipline," which is the supposed training of abilities in one subject, study or direction, in such manner that the abilities may be applied effectively to other studies or in other directions. Under this topic belong the hypothetical "training of memory" and of other "faculties," and the "training of the mind" through the study of a subject such as Greek or mathematics in the hope of making thereby the mind more efficient in other work.

On the subject of "formal discipline" or "transfer" in general, the investigations have been numerous and the literature is extensive. It is not necessary nor desirable in this report to give a complete summary of the same. Only a few of the more striking examples will be mentioned here.[2] Bennett (2) reported transference of the effect of training the memory in learning poetry, to learning of rows of digits and lists of names; Ebert and Meumann (8) in a elaborate study of the influence of memory-training in learning nonsense-syllables, tested by memory work in numbers, poetry, optical designs and word pairs in German and Italian, reported in favor of effective influence of this special learning upon the tests; Dearborn (7) in repeating these tests with controls, obtained data from which he inferred that much of the improvement in the test is, in fact, to be considered as due to the special training. Fracker (10) reported that a course of training in memorizing a series of tones of varying intensities results in marked gains in memory tests in memory for poetry, colors (grays), pitch, geometrical figures and muscle movements; Winch (31) reported gain in ability to memorize history as a result of practice in memorizing poetry. Rall (16) found evidence of transfer of training resulting from miscellaneous memory work twenty minutes a day carried over to tests in memorizing "Evangeline" and nonsense syllables. Sleight (21) found transfer from memory training in poetry to memorizing of nonsense syllables; from training in memorizing tables to the memorizing of dates; and from training in memorizing prose to memorizing prose and names; Thorndike and Woodworth (23) reported transfer of improvement resulting from a training course in estimating areas in rectangles, of from ten to one hundred square centimeters in area, over to the estimating of areas of various sizes and shapes. Judd (12) in his investigation of the Müller Lyer illusion under varied conditions, found evidence that the effect of the training in estimating the error of the illusion in

[2] For a very complete résumé of the literature on the subject of Transfer, the reader is referred to Coover, Formal Discipline, Psychol. Rev. Mon., vol. xx, no. 3. Most of the bibliography presented in this report was read, as well as the work of the investigation done, before the monograph by Coöver was read.

one form of presentation is transferred to estimating the error in another form of presentation; Ruediger (17) found possible the transfer of general ideals, e.g., of neatness, from one school situation to another; Lewis (14) found in his study of the Müller-Lyer illusion that after continued practice in one form, the illusion may be made to disappear, and when the illusion plate is subsequently presented in another form, the illusion will reappear, but may be overcome more quickly by a training course in auditory discrimination; Angel and Coover (1) found that the power of discrimination of brightness and color is increased, and that typewriting becomes speedier and more accurate, following a training course in card sorting. They found also that training in sorting cards under one set of conditions produces an improvement in the sorting cards under different conditions. Pyle (15) and Saxby (19) found that training in the quick perception of numbers and in the observations of specified objects produced positive improvement of general observations: and that training in ideals of accuracy and neatness in one kind of work may be effective in temporary transfer of those ideals to other kinds of work. Coover (5), in experiments testing sensory discrimination, attention, muscular coördination, memory, discrimination and choice, claimed full justification for stating that skill gained in specific exercises may be available for general use.

II. EXPERIMENTS ON THE TRANSFER OF TRAINING

The experimental work herein reported was conducted principally on bilateral transfer from one hand to the other, with subsidiary experiments designed to secure material for the interpretation of the bilateral effects. The apparatus consisted essentially of a Burroughs adding machine, subtractor model, ten column, motor driven. Certain devices described below were supplementary to this machine. The work was done in the "middle four" columns, the other columns being cut off. At the top of each column is a release button, pressing which releases any digit buttons depressed in that column, and makes possible the correction of an error, should such be detected before printing. At the right side of the keyboard of the machine is the *error button*, pressing which releases all the digit buttons depressed. The printing operation was accomplished by a single movement of pressing the *print bar* situated at the right hand of the keyboard. Instructions were that no attempt at correction was to be made by the reactor after the number had been printed, but there were no restrictions set upon using the release buttons at the head of the digit columns, or of the error button prior to the printing operation. This feature of the manipulation of the machine was usually learned without difficulty.

The adding machine presents a relatively simple problem to a novice. The keyboard is learned almost at a glance. One need not get lost looking for the proper "button" or "key," as is frequently the case with a beginner at the typewriter. The adding machine also makes it possible to work with either hand with almost identical movements. The only asymmetrical movement required in these experiments was that made by the left hand in pressing the print bar. This was a movement across the entire body, since the print bar was attached on the right side of the machine. The right hand could press the print bar by moving from the center of the machine to the right of the machine; not a cross body movement.

Number-sheets as work units for the adding machine are of more uniform difficulty than word-lists for the typewriter, numbers probably require a more uniform effort for recognition than do words. Accumulative memory products are also not so probable when number sheets are used as they are when word lists are used on a typewriter.

The numbers on the work sheets comprise the "four-place" number addition system of the Johns Hopkins Psychological Laboratory, and will be printed separately later. These work-sheets consist of ninety four-place numbers, derived by a system such that no number shall have zero as a final digit, and with the distribution of the various digits such that each sheet is exactly as difficult as any other; and yet the numbers are so varied that there is no detectable memory complication in reading the sheets. For convenience in reading, the sheets were cut into work strips of forty-five four-place numbers each, since a list of ninety numbers is not easily handled on the work table. The totals in time and accuracy are, however, in the units of the whole work-sheet with the single exception, section 2, page 358, where the fastest third is considered. In this case, the unit is the *work-strip*, i.e., half the work sheet, having forty-five four-place numbers in it, on which unit the kymographic record was made.

Since the ordinary work-table of the left side of the adding machine was unsuited to this test, a special one was provided. On a pair of upright rods, supported by heavy iron pedestals to keep them firm, a rectangular frame was placed around the machine at the height of, and inclined to the same angle as, the keyboard, and extending 12 inches on each side of the same. Sheets of aluminum were fastened to this frame, fitted tightly on each side of the machine at the height and angle of the keyboard. On these aluminum sheets was fastened heavy cardboard of neutral gray color, to prevent reflection.

Around the machine was placed a screen covered with a dead black cloth so that no reflection from the sides of the room could reach the reactor. The keyboard and work-table were lighted by a 40-watt Mazda bulb, hanging immediately above the machine. Uniform conditions of lighting were thus maintained. The maximal speed of the adding machine was forty-five printing operations in thirty-one seconds. The machine was tested at irregular intervals throughout the course of the experiments and this speed was always maintained.

Each reactor was given specific and uniform instructions, including illustrations of the manner of putting numbers into the machine. Any question asked was fully answered before the work began, but no practice was allowed prior to the test. Each reactor was told that he would be graded for speed and accuracy. No reactor was informed during the progress of the experiment as to his proficiency. A few of the reactors knew they had made errors, because they had seen that they had pressed the wrong digit button, but could not inhibit the movement to press the print bar in time to prevent printing the error. The totals were taken by the experimenter, the reactors doing the listing and printing only. By "listing" is meant setting on the keyboard of the adding machine the numbers of the work sheets. The time was measured by a split-second stop-watch.

The work strips were fastened to the cardboard cover of the work table on the side opposite to the hand which was to be practiced. The "idle" hand was used by the reactor to follow the items of the work strips.

The first day's work for each reactor (the "preliminary tests") consisted of an equal number of sheets to be listed by each hand. The first training series was usually nine or ten one hour periods, distributed over about three weeks, and but one hand was used on the machine in this practice period. A "semi-final" test was then given to each hand and usually this semi-final test was followed by a practice period for the "idle" hand of the previous training period. The series then concluded with a "final" test of each hand. This scheme was varied in some instances which will be noted in the proper places.

After the first day's work (the preliminary test), the work strips were started on a four-minute "head-way;" i.e., the second strip was started four minutes after the starting of the first, the third was started four minutes after the starting of the second, and so on; consequently, as the time required for each strip decreased, the lengths of the rest-periods increased. In some few cases, towards the close of the training the work periods were a little less than half the total time of the day's series.

The work of the several reactors may be grouped as follows: A: *Simple listing*, by which we mean reading the numbers from the work sheets and putting the numbers read into the machine. B: *Observation*, which means watching at close range other reactors working at simple listing under conditions described in section B. C: *Auditory listing*, when the reactors put into the machine numbers from the work sheets read to them by the experimenter. D: *Number reading training*, when, under condition detailed in section D, the reactors practiced reading the numbers of the work sheets but did not operate the machine.

E: *Machine training,* where reactors practiced on the machine but did not have work sheets. Detailed description of conditions of this group is given in section E.

Section A. Simple listing. Six subjects, H., Sg., Lo., E., Cl., Mc., worked at simple listing. Table 1 gives in condensed form the results of this work (Plates I–VI).

TABLE 1

Improvement in simple listing

Semi-final tests

REACTORS	PER CENT OF IMPROVEMENT OF WORKING HAND	PER CENT OF IMPROVEMENT OF IDLE HAND	ORDER OF TESTING HANDS	
			Preliminary	Semi-final
H.	R. 16	L. 14	L. R.	R. L.
Sg.	R. 41	L. 32	L. R.	R. L.
Lo.	R. 25	L. 20	L. R.	R. L.
E.	R. 40	L. 48	L. R.	R. L.
Cl.	R. 50	L. 29	R. L.	R. L.
Mc.	R. 25	L. 26	L. R.	R. L.

Final tests

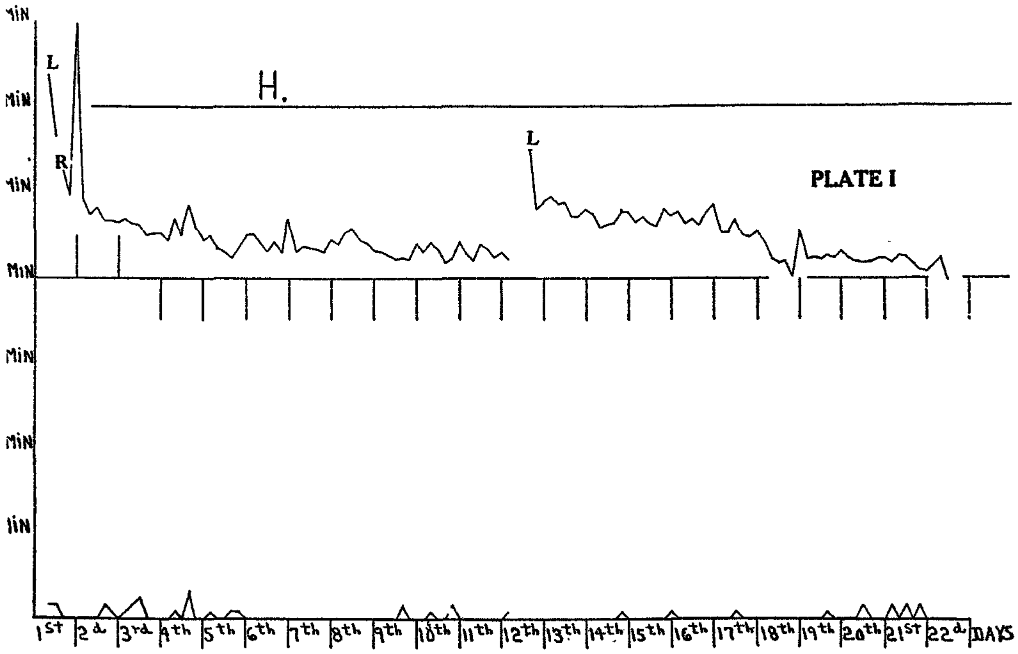
REACTORS	PER CENT OF IMPROVEMENT OF WORKING HAND	PER CENT OF IMPROVEMENT OF IDLE HAND	COMPARISON*
H.	L. 20	R. 3	5*
Sg.	Not completed	Not completed	5*
Lo	L. 5	R. 2	3†
E.	L. 16	R. 10	‡
Cl.	Not completed	Not completed	
Mc.	L. 13	R. 7	5*

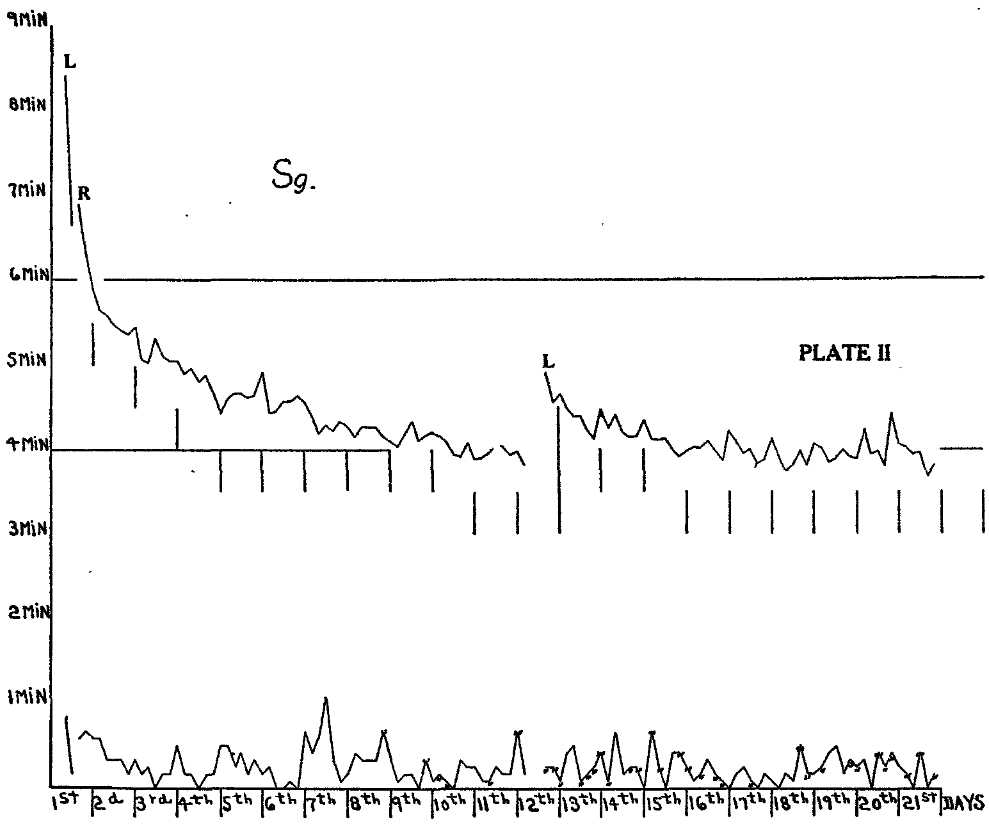
* Number of days required by working hand following the semi-final test to equal record on semi-final test of hand previously working.

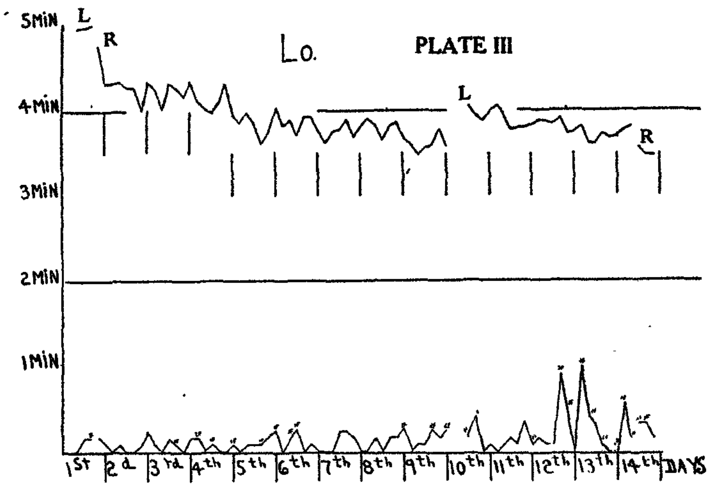
† Unpracticed hand (L.) in semi-final test reached level requiring four days of practiced hand, and in three days reached level requiring eight days work of right hand to equal or surpass.

‡ In two days the unpracticed hand (L.) reached level requiring practicing hand six days to reach.

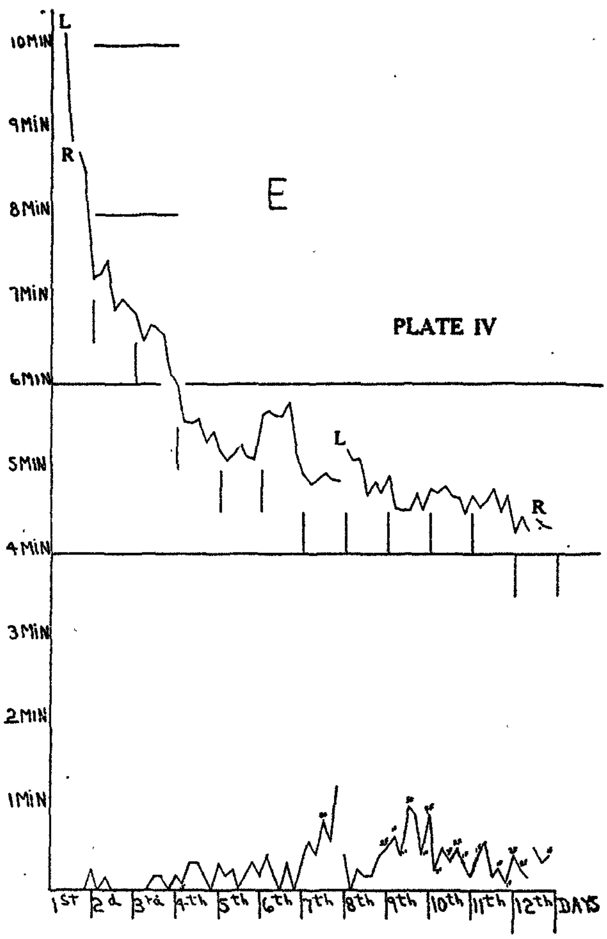
In every case the unpracticed hand improved over its former test from 14 per cent (H.) to 48 per cent (E.). In two instances the percentage of improvement in the unpracticed hand exceeds that of the practiced hand (E.), (Mc.). After this semi-final


H.
L
R
L
PLATE I
DAYS


9MIN
8MIN
7MIN
6MIN
5MIN
4MIN
3MIN
2MIN
1MIN
Sg.
L
R
L
PLATE II
DAYS



5 MIN
4 MIN
3 MIN
2 MIN
1 MIN
L
R
Lo.
PLATE III
1st 2d 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th DAYS



10 MIN
9 MIN
8 MIN
7 MIN
6 MIN
5 MIN
4 MIN
3 MIN
2 MIN
1 MIN
L
R
E
PLATE IV
1st 2d 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th DAYS

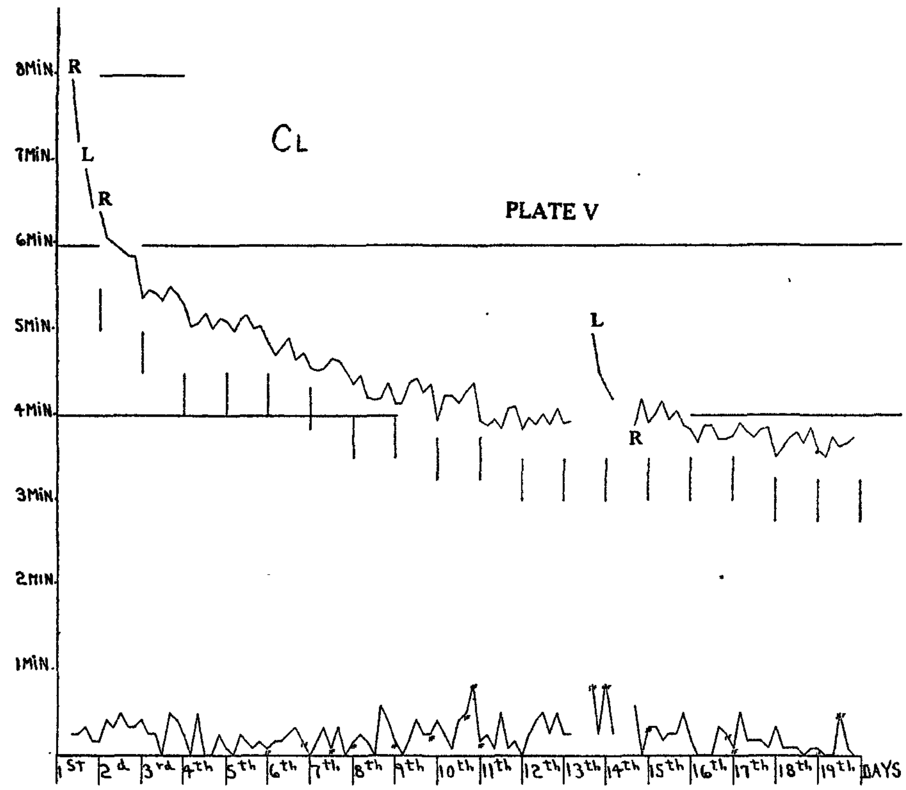


PLATE V

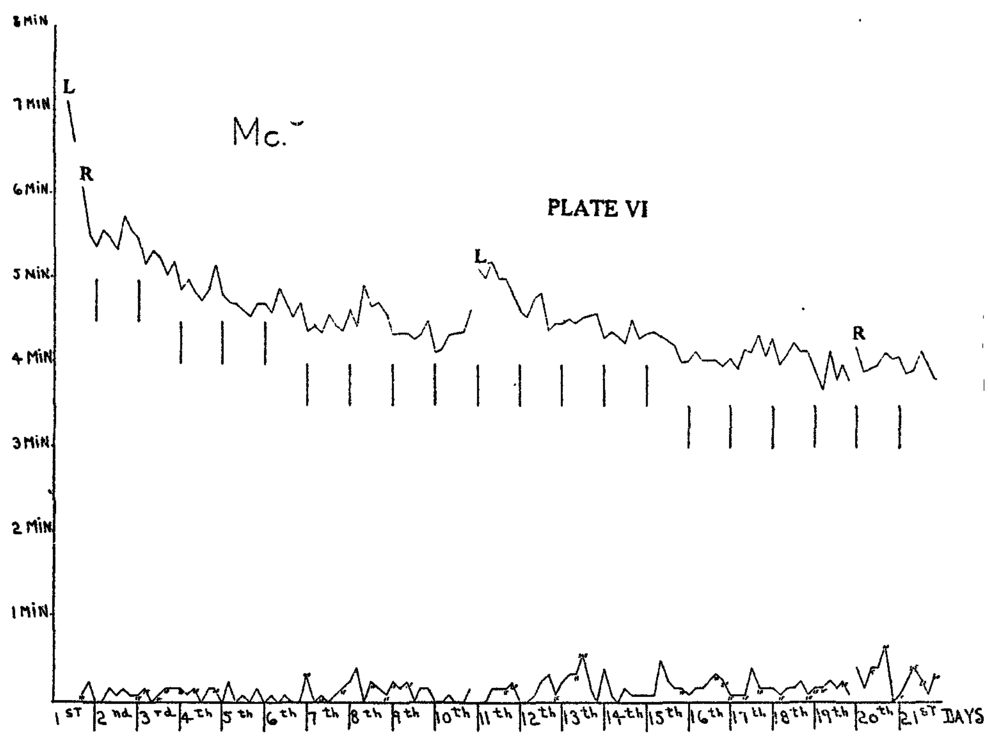


PLATE VI

test, four reactors continued the experiment, working the hand which was "idle" during previous training test. The results of this training appear with positive evidence for improvement in both hands. The percentages of improvement for the "idle"

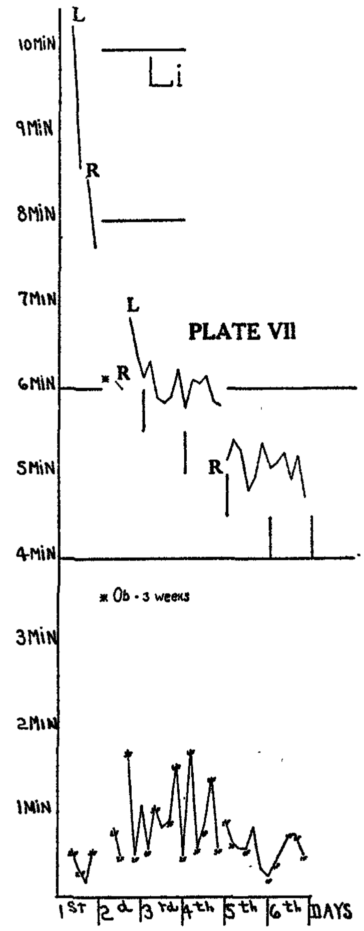


PLATE VII

hand range from (Lo.) 2 per cent while the working hand gained 5 per cent, to (E.) 10 per cent for the "idle" hand while the working hand gained 16 per cent. The percentages indicate the decrease in the amount of time required to do a fixed amount of listing.

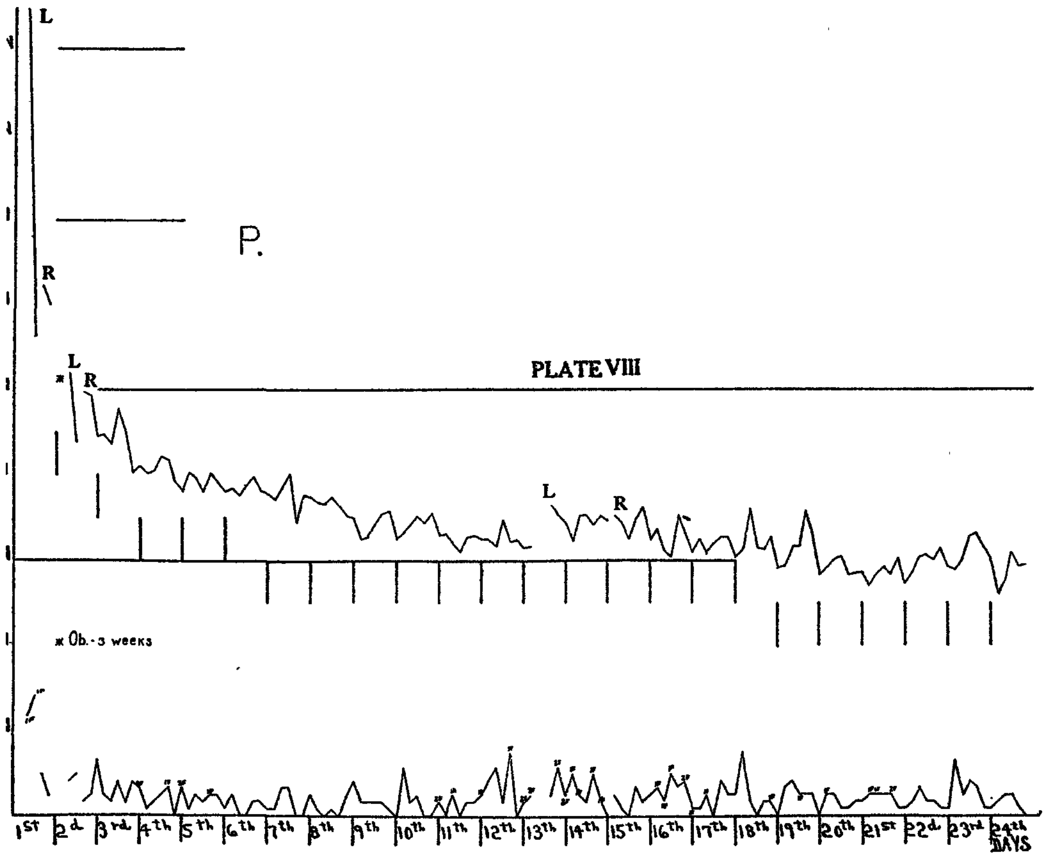


PLATE VIII

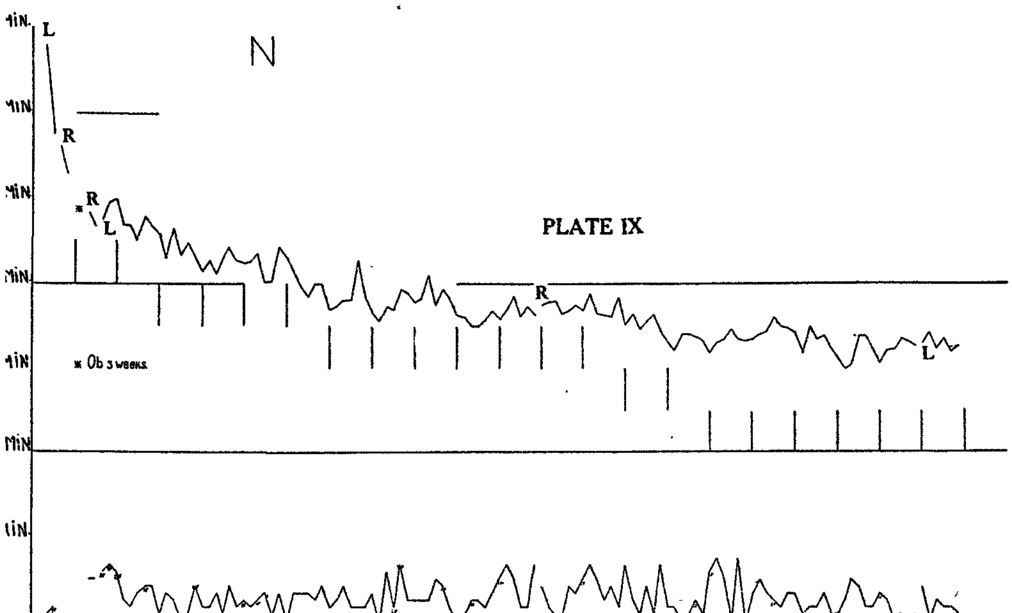
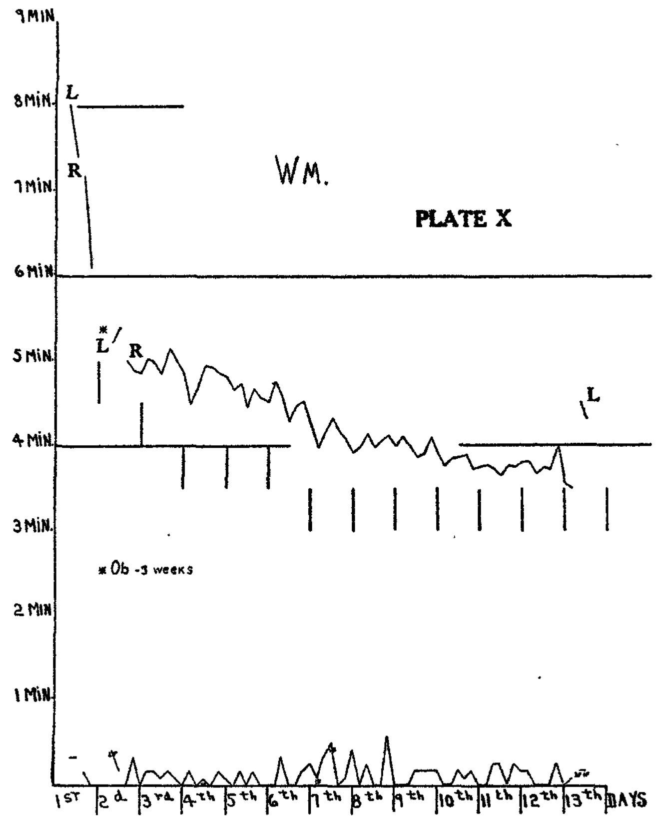
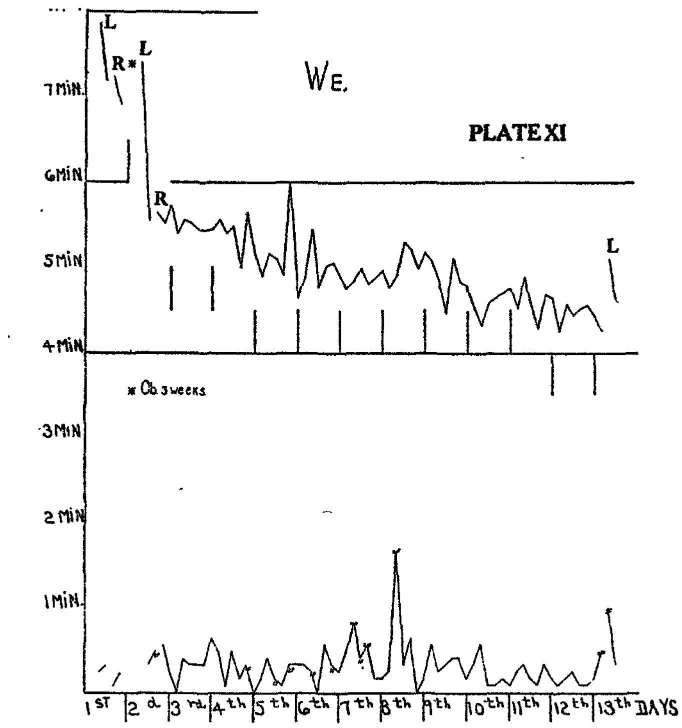


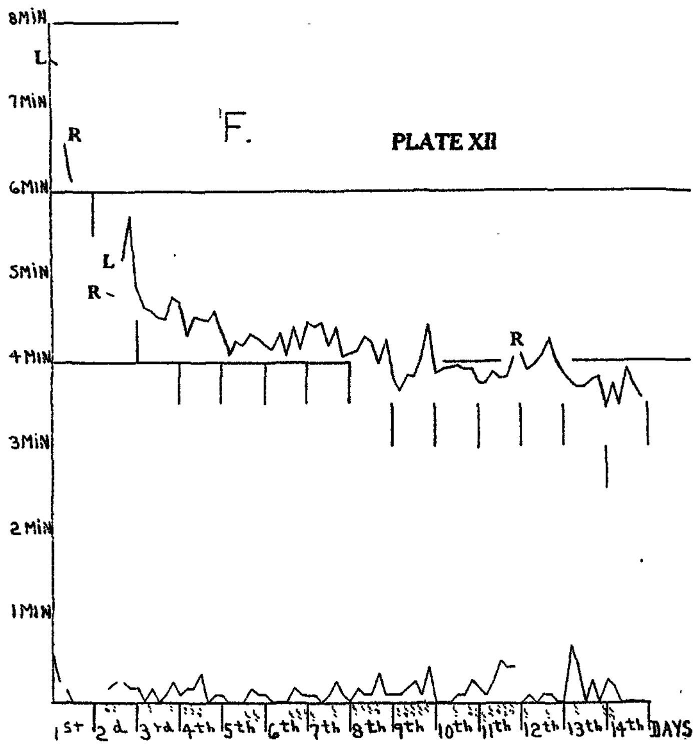
PLATE IX

Section B. Observation with training in number reading. There are two major processes in simple listing on an adding machine; (a) reading the numbers and (b) putting the numbers into the machine. The first of these processes is a common factor in working either hand, and improvement in the ease and accuracy of reading the numbers may be the medium of apparent



transfer of training evidenced in the increase of speed shown by the semi-final trials of the unpracticed hands. To test the practice value of the number-reading process, reactors Li., P., N., Wm., We. and F. (Plates VII–XII), were each given the regular preliminary test and then served as observers for periods as described below.


We.
PLATE XI
7 MIN.
6 MIN
5 MIN
4 MIN
3 MIN
2 MIN
1 MIN.
* Ob. 3 weeks
DAYS


F.
PLATE XII
8 MIN
7 MIN
6 MIN
5 MIN
4 MIN
3 MIN
2 MIN
1 MIN
DAYS

The "observers" were seated beside the operator near enough the work sheet to read the numbers accurately and as rapidly as the operators. They were able also to observe the digit buttons as they were pressed by the operator. They were instructed to make note of any errors seen, and to report the same privately to the experimenter at the close of the period. A few errors were correctly reported by Wm., and P. N. and F. held in their hands a sensitive rubber bulb, connected by rubber tubing to a Marey tambour which controlled a stylus on a kymograph: and they were instructed to press the bulb gently when an error was noticed. The records show careful attention on the part of the observers and a high degree of accuracy as measured by the errors detected and recorded. It is possible that those observing did not attend to the reading of the numbers with the same degree of care as they would have exercised had they been operating the machine, but they did undoubtedly have considerable practice effect from the reading of the numbers. The sensitive bulb held in the hand to mark errors did not give any record on the kymograph which could be fairly interpreted as evidence of implicit practice of the fingers.

Table 2 contains the number of hours of observation and the percentage gained in listing as shown by the semi-final test. In these cases there is a gain in speed ranging from 13 per cent (N., right) to 31 per cent (Wm., left). There must be taken into account, in appraising the value of these percentages of gain in speed, the order in which the hands were worked in the preliminary and semi-final tests. If the left hand is the first one worked in the preliminary test, then the right hand has the practice value of that period of working, and *vice versa*. If the hand working first in the preliminary test works last in the semi-final test (i.e., the order L. R., R. L.,) then that hand shares the advantage of the two practice periods of the other hand. Three of the six reactors worked in the order L. R., L. R., viz., reactor P., whose percentage of gain of each hand was practically the same, reactor Wm., whose left hand gained five per cent more than the right hand, and reactor We., whose right hand gained 8 per cent more than the left hand. The cases working the order L. R., R. L., show the largest gain to have been made by the hand which worked first and last, suggesting the practice effect of the two working periods of the other hand as well as the preliminary period of its own.

TABLE 2

REACTORS	HOURS	PER CENT GAINED		ORDER OF HANDS	
		Right hand	Left hand	Preliminary	Semi-final
P.	9	30	30	L. R.	L. R.
N.	9	13	23	L. R.	R. L.
F.	9	24	25	L. R.	R. L.
Wm.	10	26	31	L. R.	L. R.
We.	9	22	14	L. R.	L. R.
Li.	6*	25	29	L. R.	R. L.

* In seven weeks.

TABLE 3

	F.		Wm.		We.	
	Working hand	Idle hand	Working hand	Idle hand	Working hand	Idle hand
Total gain	47	45	47	43	38	36
Gain by observation	25	24	26	31	22	14
Gain by work	22		21		16	
Gain by transfer		21		12		22

	N.*	
	Left hand	Right hand
Total gain	47	40
Gain by observation	23	13
Semi-final	18 (working)	19 (resting)
Intermediate	6 (resting)	9 (working)

* Both hands were worked at simple listing after observation with semi-final, intermediate and final tests.

Following the period of observation, four of those who had acted as observers continued the work in simple listing. The evidence of improvement to the "idle" hand in the results of their continued listing are seen in table 3. Reactors F., Wm., and We., worked only one hand after the period of observation and took the final test. Reactor N. worked each hand after the observation period with intermediate and final tests. Table 3 shows the comparative results of work and observation.

The relative value of observation as compared with practice is shown in table 4, presenting total percentage of improvement, and percentage of improvement during observation. These percentages of improvement and total improvement are based on the preliminary tests and are therefore absolutely comparable. Wm., and We., did not practice the left hand at all, the percentages of total improvements of the left hands of these two reactors being due to observation and practice of the right hands. The left hand received only the preliminary, semi-final and final tests. In every case, except N. (right hand), the amount of improvement during observation exceeded the amount of improvement following subsequent practice, indicating the value of the training in reading the numbers.

TABLE 4

	Li.		Po.		N.		F.		Wm.		We.	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
Percentage of total improvement	37	37	45	49	40	47	45	47	47	43	38	36
Percentage of improvement by observation	25	29	30	30	13	23	24	25	26	31	22	14

The mean gain in percentages in simple listing shown by the semi-final tests is: For the working hand (R) 32⅔ per cent; for the "idle" hand (L) 28⅙ per cent.

The mean gain in percentage by observation shown by semi-final tests is: For right hand 23 + per cent; for left hand 26⅔ per cent.

The mean percentages of gains of the right hand of six reactors working nine to ten days is only 9⅓ per cent more than the mean percentage of gains of the right hands of the six reactors who observed them those nine to ten days; and the mean percentages of the "idle" hands of these same six reactors working at simple listing is 1½ per cent more than the mean percentage of the gains of the left hands of the six reactors who acted as observers for those nine or ten periods of work.

Section C. Auditory listing. To give the hand practice in putting into the machine the numbers, and at the same time not train the number-reading process, reactors S., T., W., K. and C. (Plates XIII–XVII), after the regular preliminary tests, put the numbers into the machine as they were read to them by the experimenter. Care was taken not to read the numbers too rap-

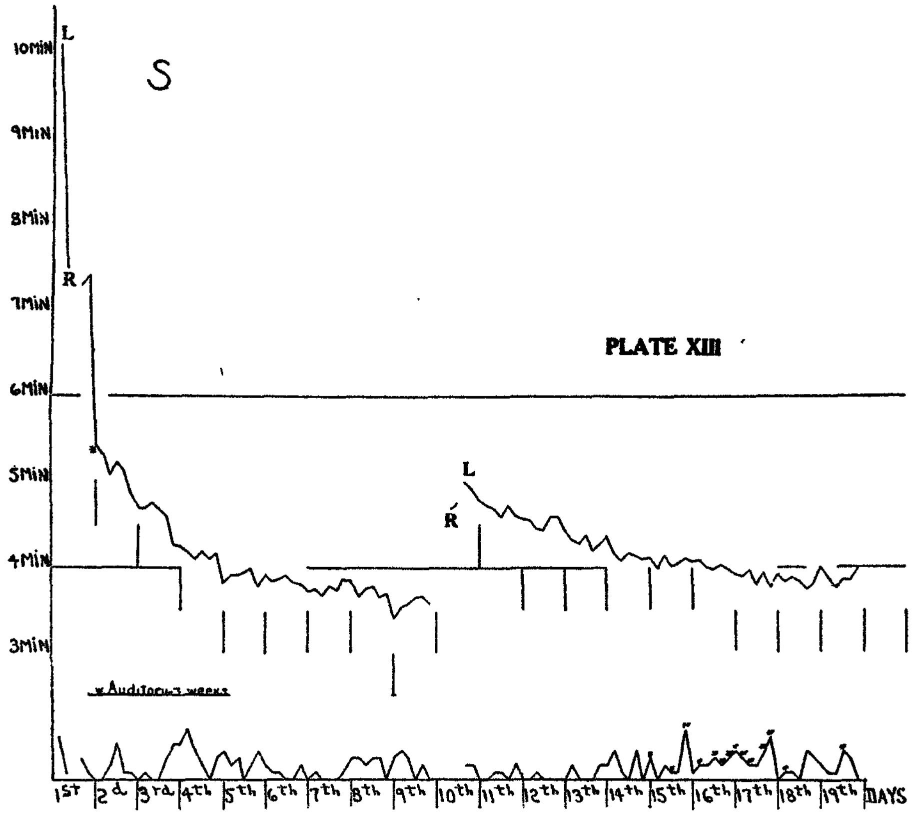


PLATE XIII

idly, and also not to allow any rest between the numbers. The rule followed by the reader was to begin to read as soon as the print bar had been touched. The reactors were instructed to ask for a re-reading if the number was not clearly understood, and this was done in relatively few cases. Generally speaking, there was no difficulty experienced in reading the numbers clearly and with sufficient speed to keep the reactors working regularly. The results of this auditory training and of the regular semi-final and final tests appear in table 5.

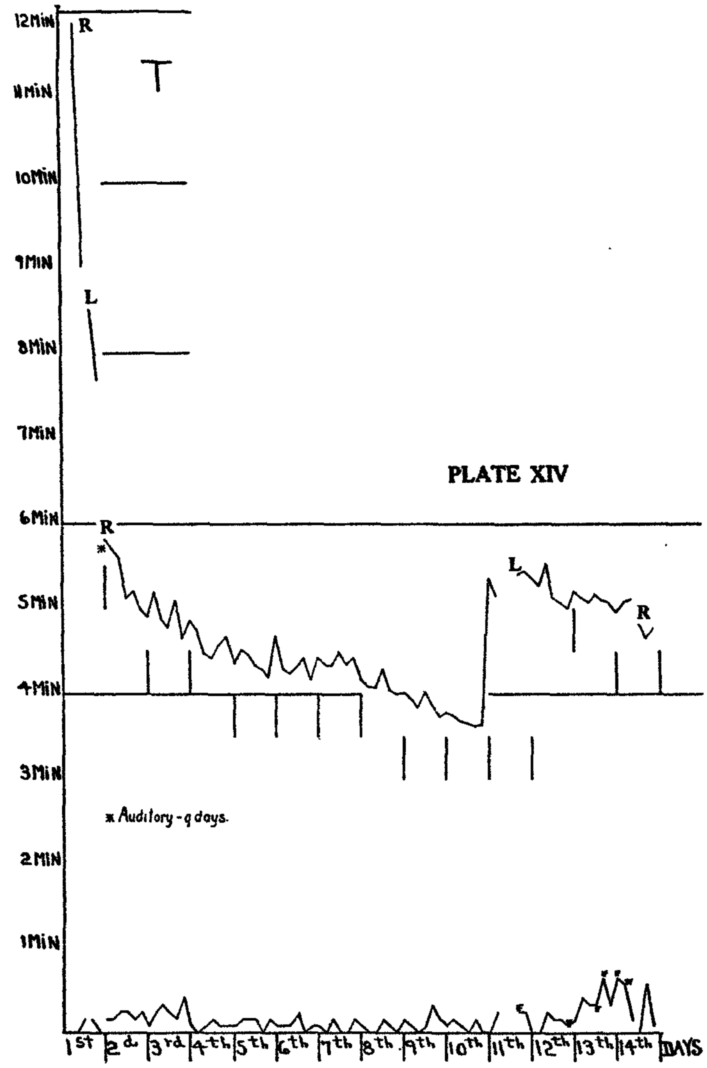


PLATE XIV

In four out of the five auditory listing cases, the idle made greater gains in the semi-final tests than did the working hand, regardless of hand and order of working of hand in preliminary or semi-final test. In no case did the practice in the regular method of working the machine following the auditory listing result in as rapid work as that done in the auditory listing. In simple listing, there are present several minor processes which are absent in the process of auditory listing: i.e., (a) keeping one's place on the work sheet; (b) turning one's head to read the numbers; (c) turning back again to see the keyboard; (d) carrying the numbers read, back to the machine, and (e) identifying the digits read and the proper buttons to be pressed. After practice of considerable length, one may learn to read the entire number, i.e., the four digits, as a single group without separating the group into its individual parts: and the process of putting

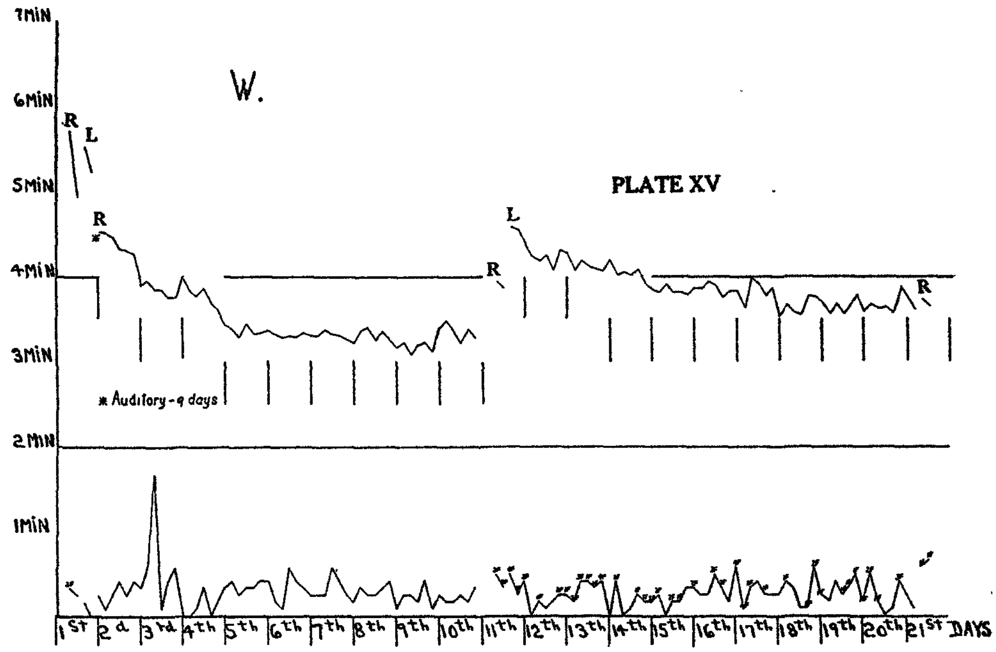
TABLE 5

Showing percentage gains of auditory listing

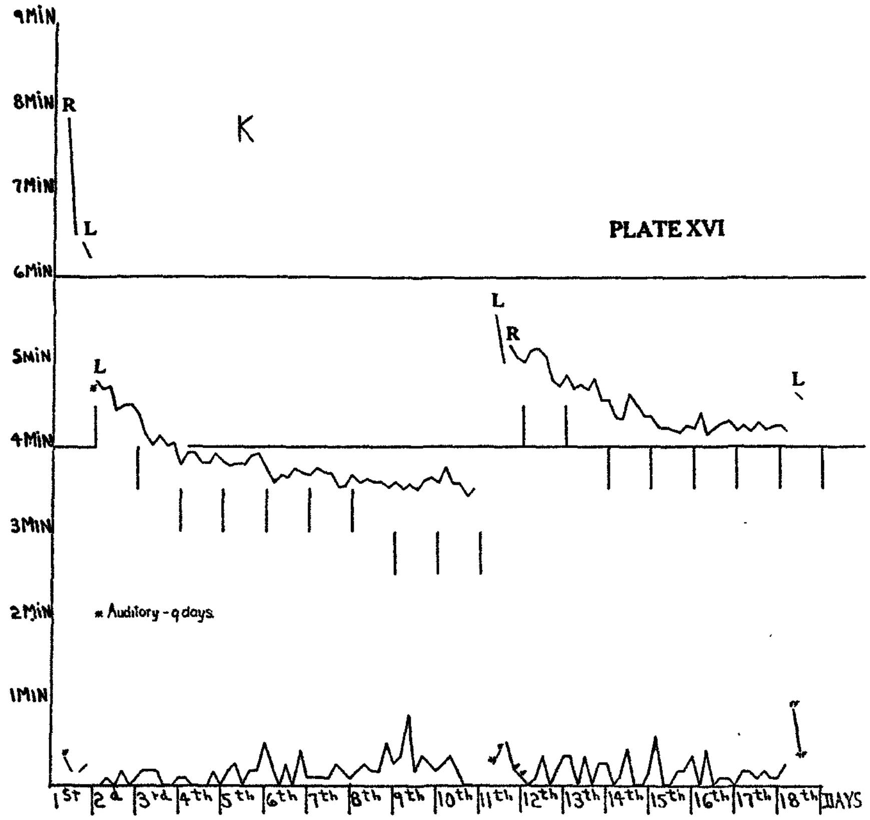
REACTORS	NUMBER OF HOURS AUDITORY	PER CENT GAINED		ORDER OF WORKING HAND	
		Right hand	Left hand	Preliminary	Semi-final
S..............	8	36*	47	L. R.	R. L.
T..............	9	49*	37	R. L.	R. L.
W..............	9	8*	12	R. L.	R. L.
K..............	9	29	17*	R. L.	R. L.
C..............	9	20*	34	L. R.	R. L.

* Indicates hand working during auditory listing.

those digits in the group into the machine may become a "group movement:" that is to say, while it will always require the pressing of the various buttons, the attention is given to the whole set of necessary movements as one movement. It is as if the numbers at first were read and listed 1–4–7–3, but after considerable practice, the reactor learns to read the numbers 1473, and his impulse to list them is one impulse for the four digits as of one number, 1473. This is a more marked characteristic of some reactors than of others. The reading of the numbers at first requires at least two or more glances. Reactor Pe. read the numbers as groups of digits and listed them as groups. The number 1473 was read and listed 14–73, requiring two glances and two distinct operations. It is true that Pe. was more inclined



W.
PLATE XV
7MIN
6MIN
5MIN
4MIN
3MIN
2MIN
1MIN
* Auditory - 9 days
R
L
1st 2d 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th 15th 16th 17th 18th 19th 20th 21st DAYS



K
PLATE XVI
9MIN
8MIN
7MIN
6MIN
5MIN
4MIN
3MIN
2MIN
1MIN
* Auditory - 9 days
R
L
1st 2d 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th 15th 16th 17th 18th DAYS

PLATE XVII

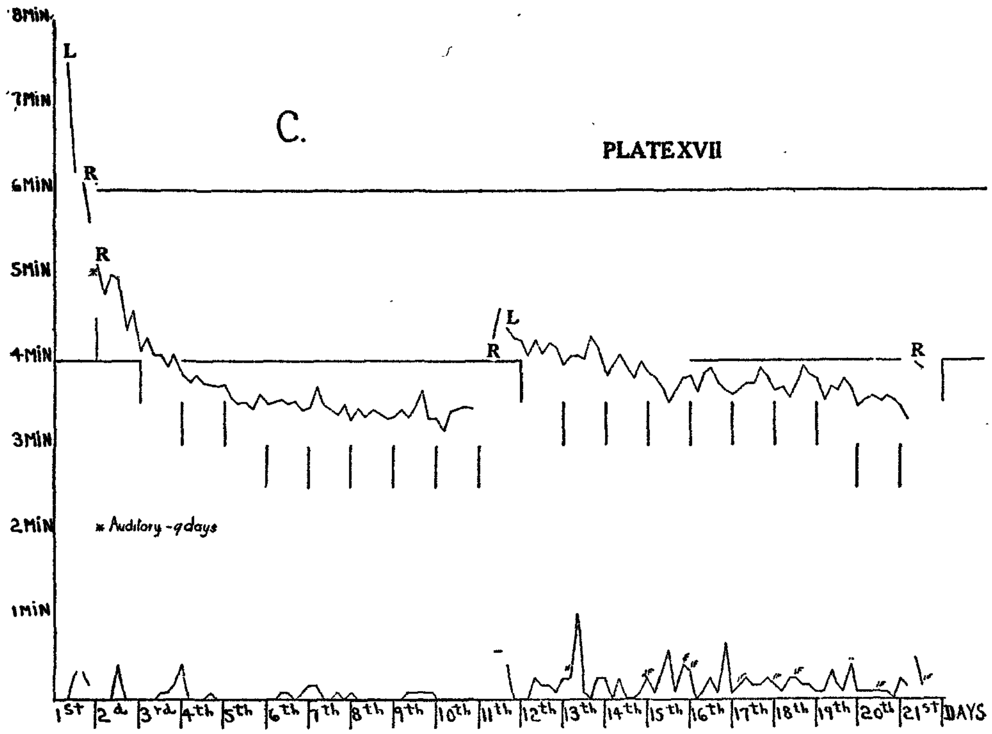
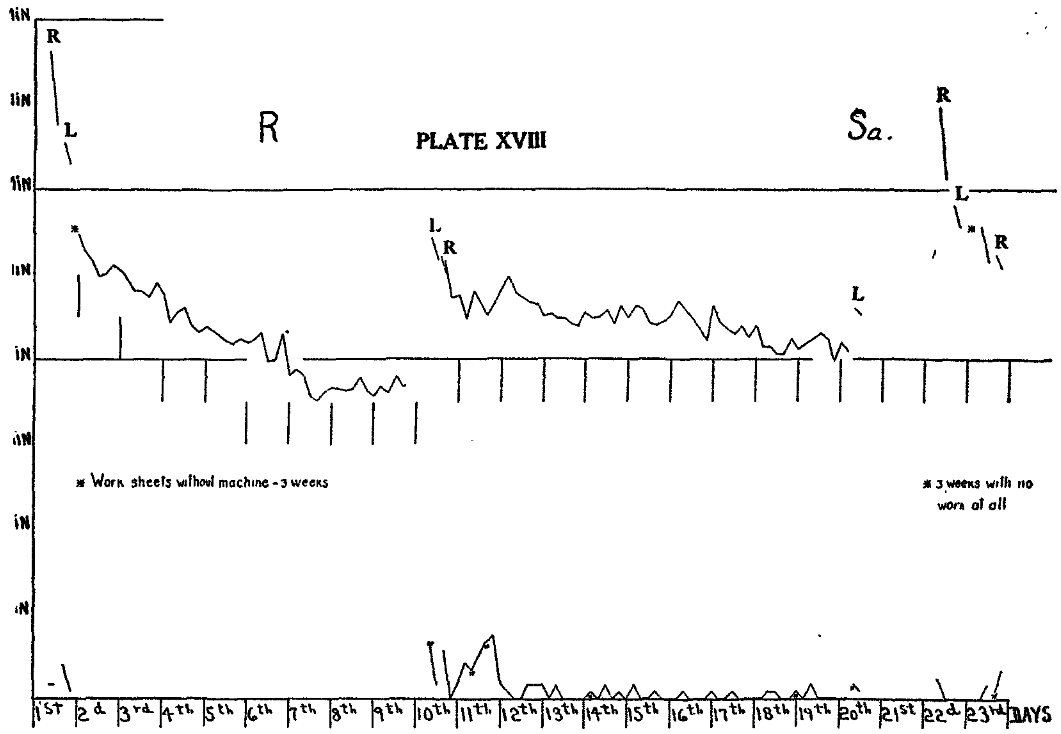


PLATE XVIII



to this method than any other reactor, and yet it was characteristic of all the reactors in the beginning, with the exception of Lo., who had used the machine for a few hours some months prior to taking the preliminary test. Toward the end of the series, every reactor learned to read the number at one glance, only occasionally taking the second glance. The process of reading separate and individual digits became a process of reading a unified group of digits. It is probable that the process of listing is not so perfectly unified, because the practice periods did not extend over a sufficient time. Statements of the reactors would indicate that the listing was not a perfect "group movement," and the experimenter, who gave close observation to the work throughout, is of the opinion that even the best reactors did not attain more than partial unification of four-place listing. This was made evident by the arhythmic listing and by the frequent pauses and periods of confusion. In auditory listing, the process is simpler, for the elements noted above (a), (b), (c) and (d) are not present. Attention is not diverted from the keyboard. As soon as individual digits are heard, they are put into the machine, and after some practice, it is not uncommon for a reactor to have listed the third digit in a four-place number by the time the last digit of the number is read, i.e., the reactor is listing only one digit behind the reader. In a limited period of practice, therefore, better time can be made in auditory listing than in simple listing, if the reader is clear voiced and reads with adequate speed.

It is possible that the interference between auditory listing and simple listing accounts for the fact that in every case but one, the idle hand during the auditory listing made better percentage of gain at the semi-final test than did the working hand of the training series.

Following the auditory listing and semi-final test, practice in simple listing was given to the idle hand of the auditory series, with the results set forth in table 6, in which the percentage of gain is calculated upon the basis of the time of the preliminary tests.

The percentage of gain of the idle hand in the simple listing process is less than that made by the practiced hand in three out of five cases, equals it in one case, and surpasses it in one case. In all cases, the idle hand makes improvement ranging from 4 per cent (T., having only two hours practice) to 24 per cent, (W.). The gains of the practiced hand were from 4 per cent (reactor T., two hours) to 16 per cent, reactor W.

Section D. Number reading without machine practice. To discover, if possible, the avenue of the so-called transfer, two reactors, R., and Ir. (Plates XVIII and XIX), were given the regular preliminary tests, and then, sitting at the machine, right hand on the work sheet to hold the place in the column of numbers, in the regular position for working, they were directed to read each four-place number on the work sheet, looking at the

TABLE 6

REACTORS	HOURS OF WORK	PER CENT GAINED		ORDER OF WORKING HAND	
		Practiced hand	Idle hand	Preliminary	Final
S.	9	13 L.	11 R.	L. R.	L. R.
T.	2	4 L.	4 R.	R. L.	L. R.
W.	9	16 L.	24 R.	R. L.	L. R.
K.	6	12 R.	10 L.	R. L.	R. L.
C.	9	15 L.	8 R.	L. R.	L. R.

keyboard to identify each number without touching the buttons. This gave practice to the visual processes in the performance of the regular work of the machine, but gave no manual or digital practice. The regular number of sheets was done each day and timed as usual. It was, of course, impossible in this phase of the work, to check for accuracy. The reactors worked very faithfully and diligently, and the experimenter is of the opinion that the visual processes were used in this training series fully as much as in the regular operation of the machine. Each of the reactors used the lips in reading the numbers throughout the entire test, and in this training course, they seemed to accompany the recognition and location of the appropriate digit buttons with a characteristic nod of the head. The semi-final test in simple listing followed this course of training in number reading. Table 7 shows the results of this training.

The practice in reading the numbers and locating them on the keyboard resulted in gains to both hands with both reactors. The hand which worked first in the preliminary and last in the semi-final tests, in both cases the right hand, made greater gains.

Following this number reading training, the reactors took a final practice series in simple listing, the right hand working in each case, the results of which are given in table 8, percentages in which are based on preliminary time records, not on semi-final record. In both cases, there was improvement in both hands, the idle as well as the practiced hands.

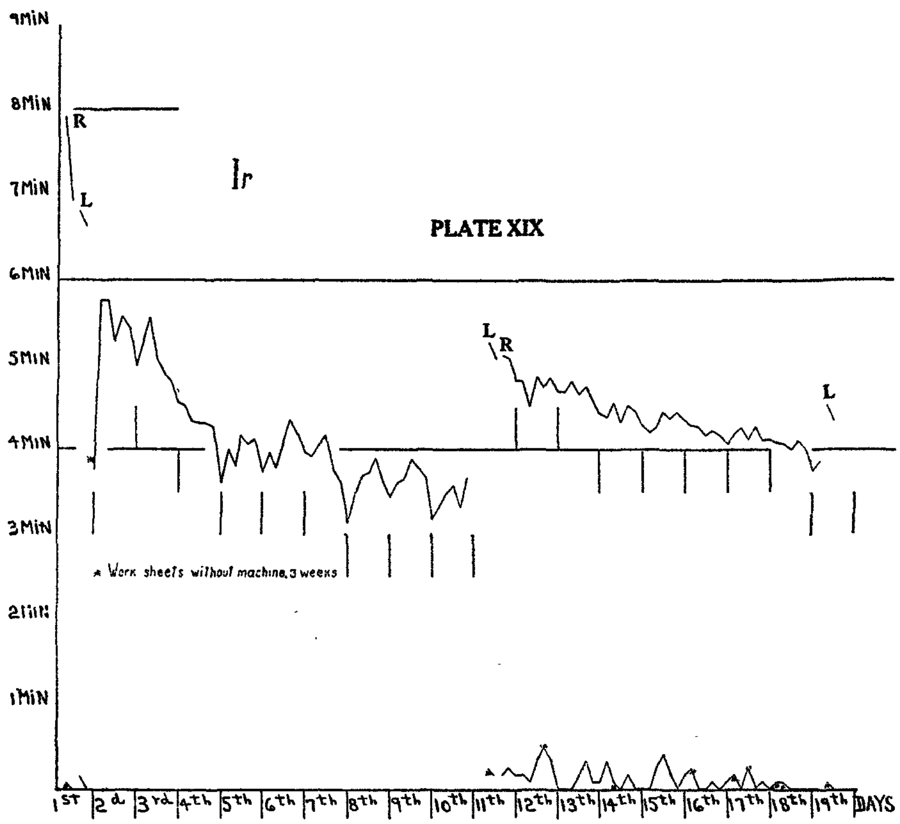
TABLE 7

REACTORS	HOURS OF NUMBER READING	GAIN		ORDER OF WORKING HAND	
		Right hand	Left hand	Preliminary	Semi-final
R.	8	31	18	R. L.	L. R.
Ir.	9	31	23	R. L.	L. R.

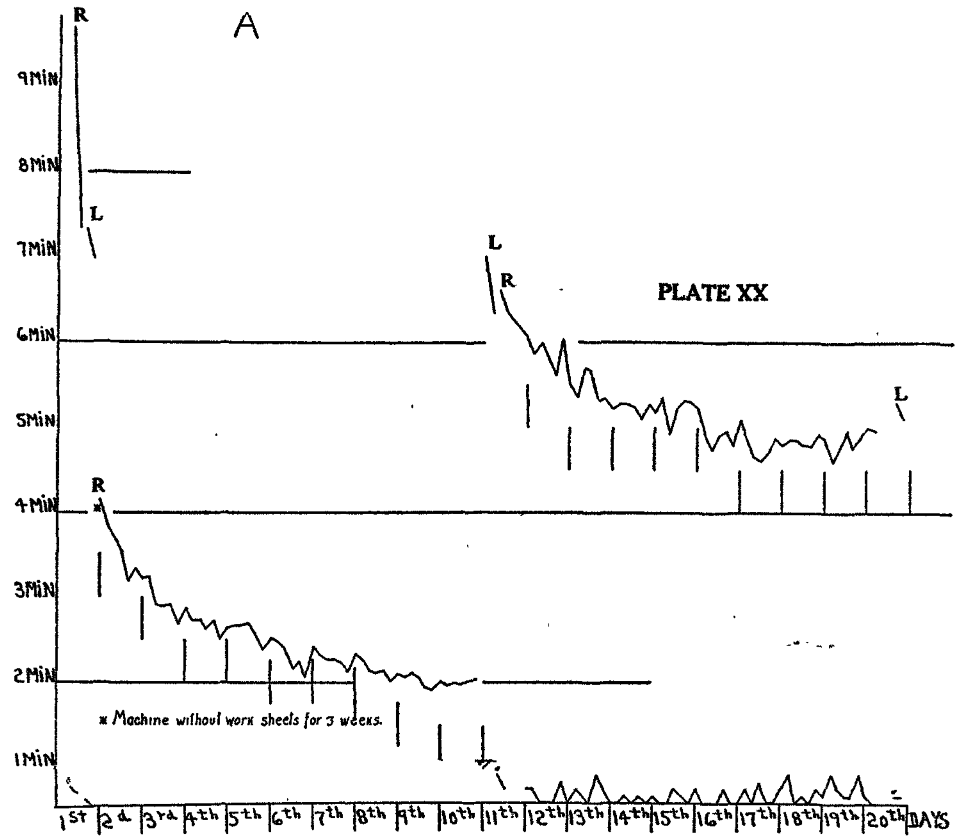
TABLE 8

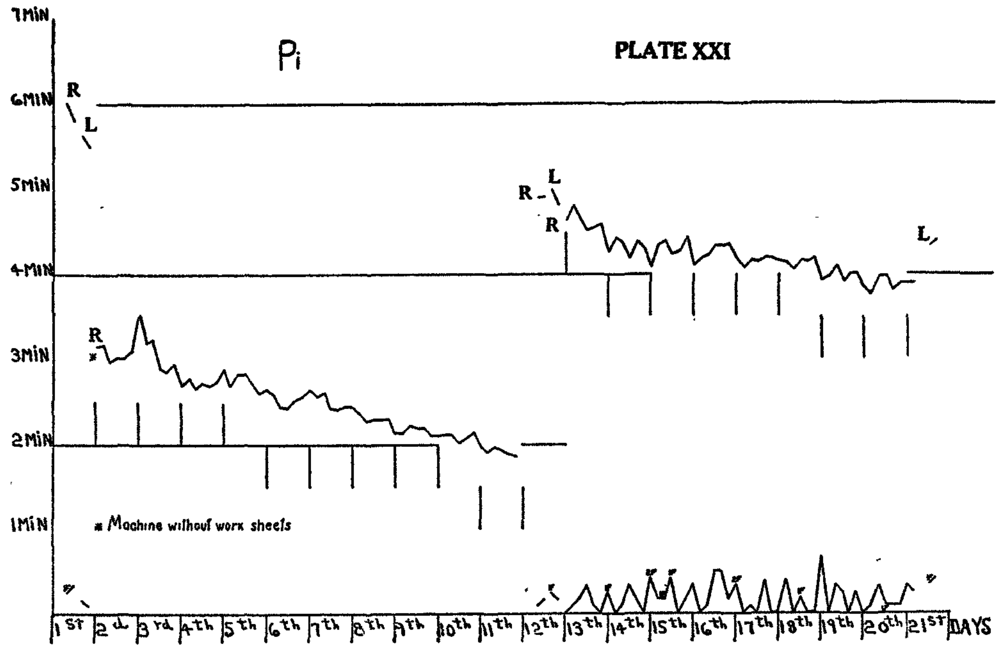
REACTORS	HOURS WORKED	GAIN		ORDER OF WORKING HAND	
		Practiced hand	Idle hand	Semi-final	Final
R.	9	11	12	L. R.	L. R.
Ir.	7	17	11	L. R.	L. R.

Section E. Working machine without "work sheets." Three reactors, A., Pi., and Pe. (Plates XX–XXII), after the regular preliminary tests with both hands, were worked on the machine putting four-place numbers into the machine without "work sheets" from which to read. The instructions were (1) to use any number they could think of; (2) varying the digits as much as possible; (3) covering the entire working keyboard, (4) always deciding upon the entire number before pressing any buttons, and (5) using no zero in the units column. The reactors worked diligently and conscientiously. There was, of course, no chance to check their work as to all points on which instruction was given, but the numbers were well scattered as to selection, and as varied as could be expected. After this series of practice periods, working the machine without work sheets to be read, the semi-final tests in simple listing were made, yielding the results showed in table 9. Gain was made by both hands of



every reactor. For reactor A., the gain of the practice hand was nearly four times as great as that made by the "idle hand;" for Pi., and Pe., the gains made by the idle hands were greater than the gains made by the practiced hand. The order in which the hands were worked in the preliminary and semi-final tests has significance in the understanding of these figures. For


A
PLATE XX
9MIN
8MIN
7MIN
6MIN
5MIN
4MIN
3MIN
2MIN
1MIN
R
L
* Machine without work sheets for 3 weeks.
1st 2d 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th 15th 16th 17th 18th 19th 20th DAYS


Pi
PLATE XXI
7MIN
6MIN
5MIN
4MIN
3MIN
2MIN
1MIN
R
L
* Machine without work sheets
1st 2d 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th 15th 16th 17th 18th 19th 20th 21st DAYS

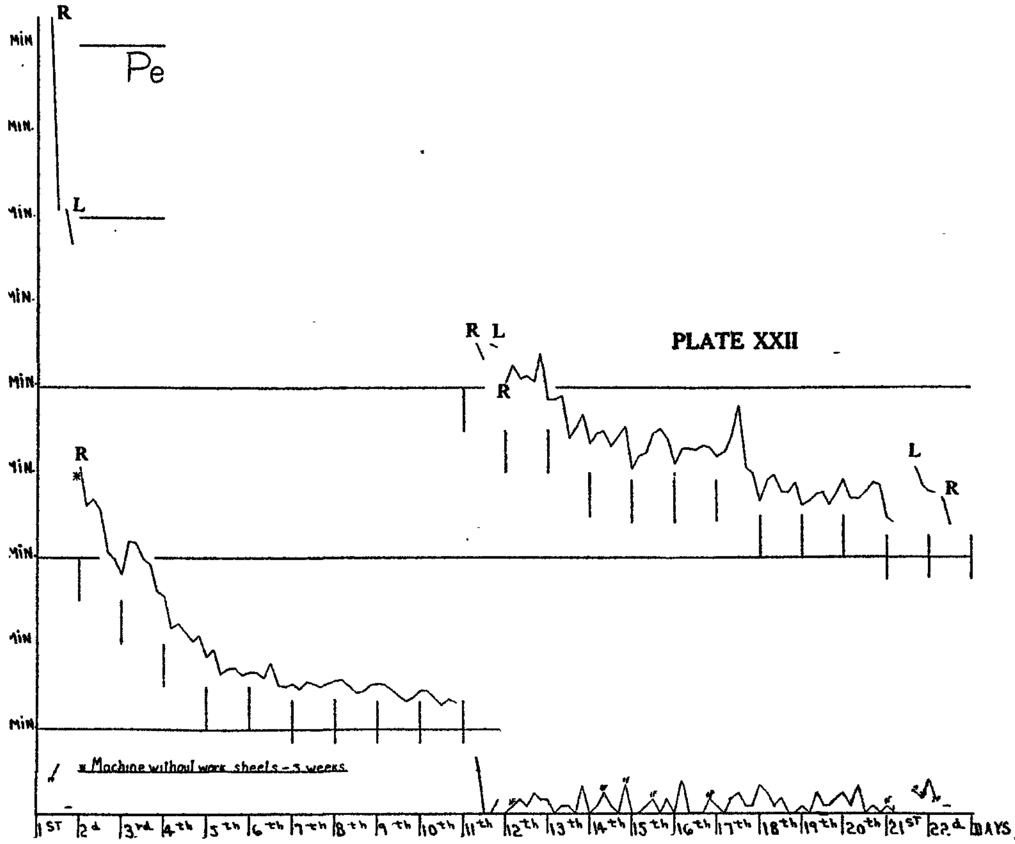


PLATE XXII

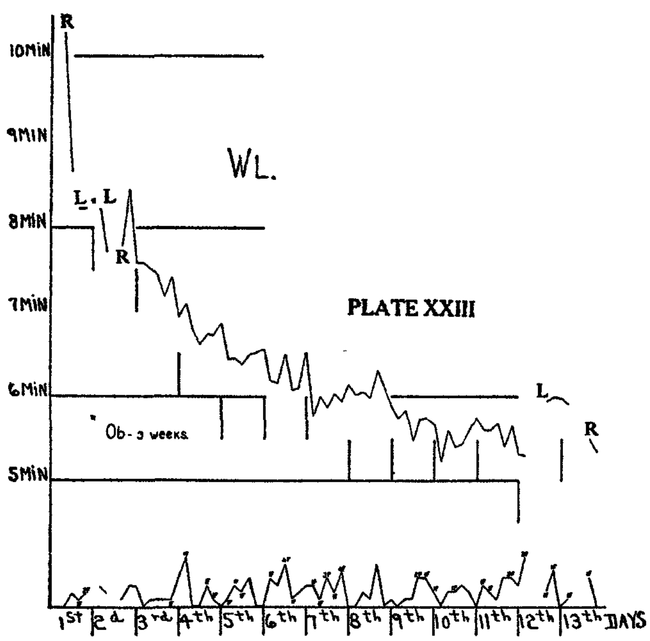


PLATE XXIII

reactor A., the order of working the hands was R. L., L. R. The right hand, being first in the preliminary test, made the poorest record, as would be expected. The left hand presumably shared some of the benefits of the right hand working in the preliminary test, and made a better record than the right hand. Following the working of the right hand on the machine without work sheets, the left hand was the first to work in the semi-final test, working on a test comparatively new. The right hand then followed, benefited by the practice of the left hand in the semi-finals, and made a better record than any

TABLE 9

REACTORS	HOURS WORKED	PER CENT GAINED		ORDER OF WORKING HAND	
		By practiced hand	By idle hand	Preliminary	Semi-final
A.	9	R. 24	L. $6\frac{2}{3}$	R. L.	L. R.
Pi.	10	R. 12	L. 17	L. R.	R. L.
Pe.	9	R. 13	L. 17	R. L.	R. L.

TABLE 10

Showing result of straight listing after "machine without sheets" work

REACTORS	HOURS WORKED	PER CENT GAINED		ORDER OF WORKING HAND	
		By practiced hand	By idle hand	Semi-final	Finals
A.	8	R. 17	L. 20	L. R.	R. L.
Pi	8	R. 18	L. 9	R. L.	R. L.
Pe.	9	R. 20	L. 22	R. L.	R. L.

Percentage calculated on records of preliminary tests.

in the preliminary or semi-final. Such was not the order of working the hands with reactors Pi., and Pe., and there is no corresponding gain. The idle hand of the training series was worked last in the semi-finals, and made larger gains than the hand working first in the semi-finals.

After this work on the machine without work-sheets, the reactors continued at simple listing, the results of which are shown in table 10. The idle hand gained more than the practiced hand in reactors A., and Pe., and less than the practiced hand with reactor Pi.

Section F. Observation without training in number reading. One reactor, Wl. (Plate XXIII), after the regular preliminary tests, acted as observer to Pi., in the work without work sheets, and consequently did not receive the benefits of training in reading the numbers as did the others who acted as observers.[3] After the semi-finals, Wl., worked at straight listing. Table 11 gives a statement of the results.

Following the period of observation, Wl., worked at simple listing and adhered to a system of fingering which he had planned while watching Pi. work. At the very first, the subject experienced no little difficulty with this system, but held to it tenaciously, and this doubtless accounts in part for the small percentage of gain made by the left hand in the semi-final test. This same system of fingering was maintained by the right hand in all subsequent practice. The gain of 25 per cent made by the idle hand, following a practice period which netted a gain of 33 per cent to the hand which practiced, is about the same as the improvements made by the other reactors. The small percentage of gain (3 per cent) following observations without reading work sheets, compared with gains made by reactors listed in the semi-finals of section B, suggests the value of number-reading training.

TABLE 11

Showing results of work of reactor W. L.

METHOD	NUMBER OF HOURS	PER CENT GAINED		ORDER OF WORKING HAND	
		By right hand	By left hand	Preliminary	Semi-finals
Observation	10	14	3	R. L.	L. R.
				Semi-finals	Finals
Simple listing	9	33*	25†	L. R.	L. R.

* Working.
† Idle.

[3] See Section B.

III. RÉSUMÉ AND DISCUSSION OF DATA

1. In every case of simple listing, there is improvement of the idle hand.

2. In every case of observation, there is improvement of both hands: and when followed by simple listing, there is improvement of the idle hand as well as of the practiced hand.

3. In every case of auditory listing, there is improvement of both hands, as shown by the semi-final test and specially of the hand which was idle in the auditory series. When followed by simple listing, the idle hand made improvements in the final tests.

4. The reactors reading the numbers without working the machine showed improvement in both hands in the semi-final tests, and in subsequent simple listing, the idle hand showed marked improvement in the final tests.

5. In the cases of reactors using the machine without work-sheets, the idle hand as well as the hand which worked showed improvement in the semi-final tests; and in the subsequent simple listing, both the practiced hand and the idle hand showed improvement in the final tests.

Every case, therefore, presents positive evidence of "bilateral transfer of training."

What is the explanation of this bilateral transfer of improvement? The following points may well be considered in answer to this question.

1. The emotional factor is probably responsible in part. The anxious, nervous attitude of the preliminary testing has given way to a definite "set" for record, and hence in the semi-final tests, better control of motor reaction is maintained.

2. General habits and conditions may have improved, e.g., more concentrated effort, greater ability to resist distracting factors, and less bodily fatigue.

3. Is the transfer in part due to the fact that a motor impulse from the "higher centers" leading to set reactions with one hand, has acquired influence on the other hand? (Wissler and Richardson (32), Davis (6)). The group practiced on the "machine

without work sheets" (section E) should give evidence on this point. Here the training was directly on hand manipulation, *plus* the learning of the keyboard. The average of percentages of improvement to the idle hands of the reactors in this series of training, evidenced at the semi-finals, was 13⅔ per cent. This group was trained on all the processes of simple listing except one, viz., the number-reading habit. They were directed to have in mind a definite number, and then put that number into the machine, and their statements are to the effect that the directions were followed. After the semi-final tests, simple listing was done by the hands which worked in the previous training series, resulting in improvement of 18 per cent as against 16⅓ per cent for the same hands in the semi-finals, but the idle hands in this last series made average gain of 16⅔ per cent, contrasting with the gain of 13⅔ per cent in the training series. This suggests that the training in the number reading habit leads to greater improvement with the idle hand than comes to the idle hand through practicing the other hand in working the machine, which is true also of the practiced hand.

4. Evidence that the influence of the "number reading" habit in improvement to the idle hand is even greater than hand training, is to be found in the record of the group who were trained in "number reading without machine" (section D). The average improvement of the reactors in this group, based on the records of the semi-finals, is for each hand (since neither hand was worked) 31 per cent R., and 20½ per cent L.: average of both hands of all subjects being 25¾ per cent. Following the semi-finals, the reactors worked at simple listing, R., nine hours, and Ir. seven hours. At the finals, these reactors showed average gains to the working hands of 14 per cent, to the idle hands 11½ per cent. Comparing these averages with those made by group E shows this fact: while in group E greater average improvement is made in the training course following the semi-finals, where number reading as well as hand manipulation was present, than was made in the training preliminary to the semi-finals where number reading was not present; in group D the greater average improvement was made at the semi-final following a training

course where number-reading was present in the training, though hand manipulation was absent, than was made in the finals, following a training course where both number reading and hand manipulation were present as elements in the task. The reactors trained in number reading without manipulation of the machine appear able to make better records when put to simple listing than reactors trained to manipulate the machine without number reading.

In considering the records of group B, observers who were so placed that they could read the work sheets and hence were trained in number reading and were able also to learn the keyboard and whose instructions were such that they would be led to identify the numbers of the work sheets with the digit buttons on the keyboard (section B), we find average of improvement at the semi-finals almost equal to the records of group D, viz., R., $23\frac{1}{3}$ per cent, L., $25\frac{1}{3}$ per cent, average of both hands of all subjects $24\frac{1}{3}$ per cent.

The average gain of the practiced hands in the simple listing following the semi-finals was 18 per cent, while the idle hand during this simple listing made average improvement of 17 per cent.

5. The reactors who were given auditory training (section C) made at the semi-finals an average improvement to the idle hand of $31\frac{4}{5}$ per cent; better percentage of improvement than that made by any other group, including those on simple listing. One reason that may be offered for this high percentage of improvement is the influence of the "urge" to speed due to the "pressure" of the reader. There is no time wasted between number listing in the auditory training and the habit of continuous working was apparent when change was made to simple listing at the semi-finals. Furthermore, while auditory training did not include visual perception of numbers or number reading, there was given training in number grouping and aural number perception and spatial location of number groups with reference to the keyboard. There was some increase in the time records at the semi-finals, and the simple listing following the semi-finals never reached as low a time record as that reached by auditory listing, but no subject trained in auditory listing noticed

any particular interference between the habit of auditory perception of numbers and visual perception of numbers, though all thought simple listing was slower than auditory listing.

IV. ERRORS

Each subject was told at the beginning of his work that he would be graded for speed and accuracy in evaluating his work. With one exception, however, each subject seemed to place more emphasis on the attainment of speed than on accuracy, and even when attention was called to the prevalence of errors, no apparent difference was noted.

There were nine kinds of errors made by the various subjects throughout the entire course of work.

a. Wrong digit, e.g., 5972 written for 6972.

b. Interchanging two digits, e.g., 3764 written for 3746.

c. Interchanging three digits, e.g., 3674 written for 3746.

d. Where wrong row of keyboard was used, e.g., 6606 written for 7707.

e. Omitting one digit.

f. Omitting an entire number.

g. Getting "out of bounds," i.e., not using the columns of digits prescribed for use but a column to the left or right of such prescribed columns.

h. Putting in some numbers not on the work sheet (occurred one time).

i. Repeating a number.

For drawing the error curve (on the sheet with the learning curve), it was advisable, if possible, to reduce these various errors to a common factor, and while the scheme used does not pretend to be perfect, it is the one appearing most available. All the errors listed above were reduced to terms of "a" excepting "f" and "i," which were held as equal and as of the same character.

In the scheme, then, *b* equals two *a*'s; *c* equals three *a*'s; *d* equals four *a*'s; *e* equals one *a*; *g* equals one *a*; *h* equals four *a*'s. The error curves are plotted accordingly, allowing one square for each *a*. Where *f*'s and *i*'s appear, the number are expressed in terms of *f*'s.

Causes of errors

The main cause of the inaccuracy in the work appears to be the desire to acquire and maintain speed. Hence, when the wrong digit was put in the machine, the power to inhibit the movement to press the print bar and to correct the mistake was frequently lacking, because of the compulsion of the "set for speed." Irrespective of speed, it was no difficult task to lose one's place on the work sheet, which accounts for the *f*'s and *i*'s. Why there should be any interchanging of digits, e.g., *b*'s and *c*'s, is a more complicated question. There is a tendency to group the digit pressing: e.g., 1928 is frequently written by pressing the digit of the thousands column 1, next the digit of the tens column 2, both at the bottom of the keyboard, and then 9 and 8 which are at the top of the keyboard. (This is the usual bank clerk's method.) In this manner of working the keyboard, may be found in part the reason for *b*'s and *c*'s. Failure to see the number as a unit group and reading it as a group of units without stressing the order of the units is also partly responsible for *b*'s and *c*'s.

Errors *d*, *e* and *g* were undoubtedly due largely to the impulse for speed, *d* and *g* being very rare and *e* occurring at times when the button for the proper digit had been pressed before the printing of the previous number was fully completed, and the button pressed by the reactor was released by the printing operation, without the knowledge of the reactor. This error is not really so chargeable to the reactor as it is due to the lack of speed of the machine. Accurate work was relatively rare.

In estimating the accuracy of the work of each sheet, the same scheme was followed as was used in plotting the error curves. Since each day had from four to six sheets, there are, as the largest number of grades of accuracy for each day, four to six according to the number of sheets used. If every sheet were accurate the minimum number of grades of accuracy would be one. (All the sheets were graded for relative accuracy by days and were compared with the speed grades of the same sheets.) The sheets of each day's work were graded for speed by the day.

It is obvious that the greatest number of speed grades would be six and the smallest number would be one for each day's work. The relative speed and accuracy grades are for each particular day's work and not intercomparable. Grade "1" in speed means that such a sheet was done as rapidly as, or more rapidly than, any other or all other sheets for that day, and grade "1" in accuracy means that such a sheet was as accurate as, or more nearly accurate than, any or all other sheets done that day. Accuracy grades, therefore, are relative for each day, and are not based on absolute accuracy as a standard.

TABLE 12

SPEED GRADES	RELATIVE ACCURACY					
	1	2	3	4	5	6
1	184	78	31	41	12	0
2	121	106	73	39	11	4
3	131	105	67	39	9	3
4	114	103	44	35	15	1
5	98	74	67	27	11	1
6	45	46	44	22	4	1

TABLE 13

Summary of speed and accuracy scores. Total of 312 days

SHEET	MOST ACCURATE	LEAST ACCURATE
Fastest......................	184	82
Slowest......................	103	75

Table 12 presents the totals, the columns marked "S" indicating the relative speed grades for the day's work, and columns marked "A" indicating the relative accuracy for the same sheets. From this table, it is apparent that 184 received first grade in accuracy and speed for their individual days: the highest score made in comparative speed and accuracy. The sheets having the highest speed grades, i.e., which were the slowest done, included also the smallest number graded accuracy first grade. That is to say, the slowest sheets included the smallest number receiving the most accurate grade.

Table 13 is based on the work of 312 days on which but one hand, either right or left, was worked, and the same amount of work was done by each hand with the exception that one day one subject was able to do only five instead of six sheets. While no sheet graded "1" in speed was graded "6" in accuracy according to the preceding table, this does not mean that at no time was the fastest sheet of the day the most inaccurate, since it was relatively rare to have six grades of accuracy in a day's work. Only ten times in a total of 1871 sheets, requiring 312 days, did this occur. But, while the fastest sheet was scored 184 times as having the highest grade of accuracy, it was scored 82 times as having the lowest score of accuracy, and the slowest sheet actually was the most accurate 103 times. The fastest sheets were most inaccurate 82 times and the slowest sheets most inaccurate 75 times. The apparent but not real discrepancy in the table is due to the fact that many times in the work of the various days there were ties in the accuracy and speed scores. Particularly was this true with reactor H., who cared more for accuracy than for speed, and made by far the least number of errors.

A comparison of the errors made in the succeeding days' work reveals this fact: increase of speed is accompanied with a slight improvement in accuracy in the work of thirteen reactors; five reactors tend to increase in inaccuracy as speed increases; the error curves of five reactors are fairly level. The percentage of improvement in accuracy in the thirteen cases cited above, however, is very much less than the percentage of improvement in speed.

If we take the error record of the first day's work of each reactor, and compare it with the error record of the last day's work of each reactor, the following facts appear: twelve reactors made fewer errors on their last day than on their first day; eleven reactors made more errors on that last day's work than on their first day's work. In the aggregate there were made on the first day's work 209 *a*'s and 23 *f*'s, and on the last day's work, 233 *a*'s and 72 *f*'s. The difficulty of keeping the proper place on the work sheet is made apparent in this increase in the errors marked *f*, nineteen out of twenty-three reactors having made this kind of error at least once on their last day of work.

It is clear that special effort to attain speed results in increased inaccuracy with eleven out of twenty-three reactors, working on the adding machine, and absolute accuracy was realized by none of the reactors. Though in the instructions, emphasis was laid as much upon accuracy as upon the speed, the increase in speed was much greater than the increase in accuracy. Wells (30) concludes that when attention is aimed at excessive speed in typewriting, more errors occur: and likewise, with extreme carefulness, errors increase: but there appears to be a general positive correlation between speed and accuracy.

Thorndike (24) finds that the slowest reactors working in addition make more errors than reactors who are most rapid. "The same individual may lose in precision by increasing his speed (though he will not always do so), but the sort of individual who is rapid, will tend to be accurate also." Woodworth (33), in relating speed to accuracy, thinks there is a lower limit beyond which decrease in speed does not conduce to accuracy in voluntary movements, and at the upper end, there is a limit beyond which increase in speed does not produce further increase in inaccuracy. The analysis of the data of this investigation agrees with these general conclusions.[4]

By averaging the time records and the error records of each reactor's work, and applying the Spearman method of rank, the correlation of grades of speed and accuracy is 0.1147 (18).

Optimal phase

1. Distribution of sheets according to speed in each day's work. In grouping the work on the basis of relative speed for the sheets of each day's work, the preliminary, semi-final and final tests were eliminated because on these days (a) only four sheets were used, and (b) both hands were practiced on the machine. Consequently, table 14 presents data of those days'

[4] For absence of correlation of speed and accuracy, see also Thorndike and Woodworth (25).

work, with one hand, on which six sheets were worked, with the exception of E., who, on one day, worked only five sheets. Each sheet in each day's work was graded for speed for that day, according to the time in which it was done. Since there were six sheets for each day, there may be six speed grades for that day, or less than six speed grades, if the time required for any of the sheets tied. The fastest speed is graded "1," which means as fast as, or faster than, any other for that day. Succeeding digits represent grades of decreased speed.

The first sheet worked was the fastest the next to the least number of times. It was the slowest the greatest number of times. The last sheet was the fastest the greatest number of times, and the slowest the least number of times.

TABLE 14

SHEET	SPEED GRADES						TOTAL
	1	2	3	4	5	6	
1	52	51	50	63	72	62	350
2	61	58	78	74	56	23	350
3	44	60	91	74	55	26	350
4	72	75	74	44	52	33	350
5	72	94	58	54	49	23	350
6	97	65	63	59	45	20	349
Total in each speed grade...	398	403	414	368	329	187	

Because of ties, 62 in the sixth grade does not represent all of the first sheets that were actually the slowest of the day's run, for actually 110 times the first sheet took the longest time of 350 days; and for the same reason, 20 does not count all the "sixth" sheets that actually took the longest time of the day on which they were done, that number actually being 44. It is obvious that if two sheets of one day's work were done in the same time, they would tie for a speed grade. Such ties make the number of speed grades more or less than the number of sheets used.

If we group the sheets in respect to speed in two classes, the fastest and the slowest, and include in the fastest the sheets which received speed grades 1, 2, 3, and include in the slowest the sheets which received speed grades 4, 5, 6, the distribution of the sheets in these two speed grades totals as in table 15.

From this it is apparent that the tendency for greatest speed is found toward the end of the hour's work rather than at its beginning. This tendency was noted by Swift (22), who found that a "warming up process" was usually necessary, and consequently, the best scores as a rule were not the first scores of a day's series. Commonly, when the score was low enough to eliminate the effect of fatigue, the one or more high scores after the "warming up" period were followed by poorer scores, which again yielded to higher scores toward the end of the series. Book (3), in analyzing the drum records of typewriting practice, finds that for the middle or last part of the writing of almost

TABLE 15

SHEET	SPEED GRADES						TOTAL
	1	2	3	4	5	6	
Fastest	153	197	195	221	224	225	1215
Slowest	197	153	154	129	126	125	884

every test, strokes come closer together on the records: while daily relearning and warming up were usually present, still, the first and last minutes were most productive.

2. Spurts. Marked variation in the speeds of operation of the machine in simple listing of separate sheets was apparent. Initial spurts, medial spurts and final spurts, occurred in the work of all reactors. Accurate account of these variations in speed was taken in the cases of the following reactors: E., F., Li., Mc., N., P. A time record in seconds, on a motor-driven kymograph, was made by the Johns Hopkins' Psychological Laboratory pendulum. The print-bar operations, marking the completion of the listing of one four-place number were registered on a kymograph's drum by an electro-magnetic marker. The electro magnet was in circuit with a simple contact attachment fastened to the under side of the print bar. When the print bar was pressed down to print the numbers, the circuit was

broken and the stylus made its record on the kymograph, on a line parallel to the line, and separated from it by about one-fourth of an inch. The work-unit in this part of the test was the work strip, i.e., forty-five four-place numbers (see page 322). It was thus simply a matter of counting the seconds required to list the first, second and last thirds of the work strip. Each day's work consisted of six work sheets, i.e., twelve work strips. Time was counted from the word "go" to the last print bar impression. In table 16, the figures at the head of the column represent the order of durations of the thirds of each strip, e.g.,

TABLE 16

	E.	Fi.	Li.	Mc.	N.	P.	TOTAL
1 < 2 < 3	22	26	5	30	36	35	154
1 < 3 < 2	22	27	7	37	31	21	145
2 < 1 < 3	9	17	2	25	20	19	92
2 < 3 < 1	5	9	1	15	18	7	55
3 < 1 < 2	8	9	3	17	27	8	72
3 < 2 < 1	3	7	2	10	17	12	51
1 = 2 < 3	6	7	1	11	16	6	47
1 = 3 < 2	5	2	0	6	16	6	35
2 < 1 = 3	4	5	0	4	5	6	24
1 < 2 = 3	7	5	4	9	17	1	53
2 = 3 < 1	2	4	0	5	12	0	23
3 < 1 = 2	1	2	2	3	9	1	18
1 = 2 = 3	0	1	0	0	4	1	6
Total...........	94	121	27	172	228	133	775

1 < 2 < 3 mean that the first third was the fastest third of the strip, and the last third was the slowest third; the other conventional signs are easily understood. The numbers in each column represent the number of times the rank order of thirds signified by the signs at the head of the columns occurred in the work of the various reactors.

Table 16 shows that the first third of the work strip was faster than the second and third thirds 352 times out of 775 work strips, clearly indicating the presence of initial spurts. The second third is faster than the first and third thirds 171 times, and the third third is faster than the first and second thirds

141 times out of 775 work strips. The first third is faster than the second third 459 times, ties the second third 71 times, and is slower than the second third 245 times out of a total of 775 strips. The first is faster than the last third 491 times, ties the last third 65 times, and is slower than the last third 219 times out of 775 strips. The second third is faster than the last third 372 times, ties the last third 82 times, and is slower than the last third 321 times out of 775 strips. The evident conclusion is that the fastest speed is reached in the initial third of the work-units of the period, and the tendency to slow down persists through the entire work-unit, though in many cases, the medial and final spurts are present. This agrees with Wells (29) in his findings in the tapping test, and likewise with Chapman (4) in his investigation in addition, and with the results of the study on making hand-movements by Leuba and Hyde (13).

Comparing these results with the results of section 1 (*supra*), the following conclusions are warranted: 1. When the work of a period consists of an equal number of similar units, there is a tendency to perform the units toward the close of the period more rapidly than at the beginning of the period; 2. There is a tendency to perform the initial thirds of these individual units of the work more rapidly than the second and last thirds, the speed decreasing toward the close of the unit, though medial and final spurts are present.

The learning curve

Each large square on the base line of the curves signifies one day's work. The smaller squares indicate the separate sheets done on each day. The vertical line is the time line, each small square signifying five seconds. On the base line also the error curve is plotted according to the scheme detailed on page 351.

The learning curves are discontinuous, the breaks in the lines occurring when a change is made (a) from one hand to the other, or (b) from a special kind of training to simple listing. The letters "R" and "L" stand at the beginning of the curves for the right and left hands respectively.

One characteristic of all the curves is the rapidity of descent for the first day's work, irrespective of the order of working the hands. The improvement of the first day is frequently much more than the total improvement of all succeeding days. After the first day's work, the curve has a very gradual descent.

Considerable irregularity in the records of the individual sheets for the individual days is apparent. Since the time for the sheets was measured in minutes and seconds, relatively slight variations of absolute time, e.g., fifteen seconds, would make considerable deviation in the curve. The general trend of succeeding days is downward in spite of apparent irregularity of the curve of the individual days.

Evidence for "plateaus" is not very strong. In the cases of twelve reactors, very slight suggestions of leveling occur, lasting only three to four days, except with reactor N., when the last seven days' work was fairly on a time level. Reactor P., in the last two days' work, actually registered a loss in speed.

The practice period, in most cases being from nine to ten hours, was not long enough to reach a definite level of attainment which would require special effort to surpass. Reactors N., and P., whose practice included many more hours than the usual amount of work, did reach such levels.

Reactors at the beginning of a period occasionally reported headache, cold, etc., but such conditions did not seem to affect the speed records of that day. For example, H., did not sleep well the night preceding his eighteenth day, because of conditions in the boarding house, and had a headache on that day; but his work for that day did not seem to have been affected thereby when compared with the previous and following days.

GENERAL OBSERVATIONS

1. The reactors showed a noticeable degree of nervousness, exception Lo., who had had considerable experience in laboratory experiments prior to serving as a reactor in this experiment. This nervousness was greatly reduced by the end of the first day's work, and rarely increased thereafter. The change from

a training course to the semi-final test in sections B., C., D. and E. aroused to a small degree an element of nervousness which disappeared before the end of the day's work.

2. Each reactor began the work of simple listing by reading the numbers, with marked lip movements, some even audibly pronouncing the words. Lo. stopped this practice by the end of the first day's work, showing rare recurrences of the same. With the other reactors, it persisted to varying lengths, continuing throughout the work with reactors Pe., Ir., K., H. and Wl. Coincident with the change in lip movements in reading the numbers, there appeared the practice of reading the entire number at one glance. This habit was developed quite fully by all reactors except Mc., who regularly took the second glance to complete the reading of the numbers.

3. Each reactor, excepting Lo., used the forefinger to press the digit buttons on the first day of the work, Lo. using several fingers from the beginning. In every case except two, F. and H., the progress of the work was accompanied by learning to use two or more fingers, one reactor, C., using the thumb and all the fingers in a regular manner before the close of the practice period. F. and H. never used any finger other than the forefinger. The adoption of new fingering habits was concomitant with marked slowing of work in the cases of We. and W., in their semifinals, who had devised their own system of fingering while observing. Less noticeable results accompanied the habit of using more than one finger with the other reactors.

4. Reactors are not good judges of the speed of their work; frequently reactors would say that they felt they were not making as good speed on particular sheets as they had made on previous sheets of the day or the previous days. In most cases where such comments were made, the reactor was mistaken. Speculations about speed attainments were discouraged, but when they were made, they were almost invariably wrong, even though they seemed to be sincerely offered, and not for the purpose of learning about the speed record.

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