AN EXPERIMENTAL STUDY OF A TYPEWRITER SHIFT KEY IN THE LOWER MIDDLE OF THE KEYBOARD OPERATED WITH THE THUMBS

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Considerable study and writing has been done in regard to the work of the fingers in operating the typewriter. Finger loads have been determined by counting and tabulating the letters of the alphabet that are most frequently used in ordinary English writing. Tapping tests have been made in order to arrive at the amount of physical endurance of the eight fingers.[1] Counts of the sequence of letters have been made and studied to determine the order in which the fingers were most used.[2] As a result of these researches, teaching methods and techniques were formulated and keyboards, different from the conventional one, were proposed.[3] Yet, little or nothing has been done as to the possibilities of utilizing the thumb.

Statement of Problem

It appears that the little or fourth fingers are overworked and thus become fatigued before the other fingers do. This is probably because they operate the shift keys in addition to striking their portion of the letter keys. The thumbs are strong and active and possibly can handle the work of

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[1] R. E. Hoke, The Improvement of Speed and Accuracy in Typewriting, John Hopkins Press, 1922, Studies in Education, Number 7, pp. 11-23.
Edwin Riemer, A Revised Keyboard for the Typewriter, Unpublished Master's Thesis, New York University, 1929.

[2] August Dvorak, N. L. Merrick, W. L. Dealey, and G. C. Ford, Typewriting Behavior, American Book Company, 1936.

[3] Related studies are reviewed at the close of this chapter.

shifting more effectively than the little fingers, if a shift key is placed in a convenient position which is easily accesible to either thumb. Such a shifting device was constructed and placed on a typewriter, which was used in this experiment. The shift key was located in a position below and midway between the ends of the space bar, and between the space bar and the protecting frame of the typewriter as shown in Figure I.

In Hoke's[4] proposed keyboard, the shift key is placed midway between the right and left banks of keys in a vertical space about an inch wide. This space is made possible by separating the right and left banks of keys. The back spacer key and the shift lock key are also located in this space, one above and one below the shift key; the shift key being in the middle of the vertical space and between the other two keys, in approximately the same position as that of the letter "h" on the universal or present keyboard.

Although Hoke did not make a study of the shift, he realized as a result of his finger study, that the little fingers should be relieved of the shifting. He assumed that the aforementioned place would be satisfactory and recommended these other changes in the keyboard, suggesting,[5]

> (1) The interposing between the right and left banks of keys of the shift lock, shift, and back spacer keys, and (2) the placing of the margin and tabular keys in the lower horizontal row of keys, one at either end.

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4 Hoke, op. cit., p. 40.

5 Ibid, p. 39, 40.

In general, it may be said, first of all, that both these changes are made in an effort to make the keyboard arrangement more compact, thereby bringing all keys within reach of the fingers without unnecessary hand movements. These keys are, for the most part, usually so placed on the typewriter as to require the operator to remove the fingers from the letter keys. Furthermore, the shift key, shift lock, usually lift either the carriage or the basket of keys. In either case, the operation of these keys requires far more force than the operation of the letter keys. It is felt, therefore, that these three keys should be placed in a central position as in Figure 3, so that they may be operated by the thumb or first finger rather than by the fourth finger, whose strength is scarcely adequate.

Need for the Study

Because of the relatively heavy burden placed on the fourth fingers and the light responsibility of the thumbs, it appears that Hoke's suggestion to utilize the thumbs more fully in typewriting is a reasonable one. The thumb normally rests toward the center of the space bar during the typewriting process. This is true irrespective of whether the typewriting is being done on the home row, on the third row, or on the first row. Thus the thumb remains relatively stationary near the center of the space bar.

A study of the anatomy[6] of the muscles of the hands and wrists reveals that it is more difficult to move the hand upward and forward, as would have to be done to reach a shift key in the center of the keyboard, than it would be to move the hand directly downward to contact a key directly under the thumbs. If Hoke's suggestion of placing the shift key in the center of the keyboard were followed out, this would result in a somewhat awkward situation. Because it is

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6 Henry Morris, Human Anatomy, pp. 1196-1202.

easy to move the thumb downward without dislocating the other fingers during the typewriting process, it seems that the shift key would be more easily accessible to the thumb if it were placed below and midway between the ends of the space bar.

Butsch[7] measured the time of the letter stroke, space bar stroke, capital shift, and carriage return of 75 students and concluded that the thumb stroke is quicker than a finger stroke. The time of these motions were measured in millimeters between imprints on paper moving through the typewriter at a uniform rate.

Table I shows the relative time of operating the space bar stroke, capital shift, and carriage return as compared to the letter stroke of fifteen fastest and fifteen slowest students.

TABLE I. Median Time Ratios for Four Strokes, 15 Fastest and 15 Slowest Students (by Butsch)

	Letter Stroke			Capital	Carriage
	Speed	Ratio	Space Bar	Shift	Return
Upper 15	33 mm.	1.0	.88	2.9	7.2
Median	43 mm.	1.0	.80	3.0	7.0
Lower 15	61 mm.	1.0	.64	2.7	6.3

For the upper fifteen students, the median time of the space bar stroke was .88 of that of the letter stroke. The

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7 R. L. C. Butsch, An Experimental Study of Progress in Typewriting, Unpublished Master's Thesis, University of Chicago, 1927.

time of the capital shift was 2.9 of that of the letter stroke and the carriage return was 7.2 of that of the letter stroke. The tape moved 33 millimeters during the letter stroke; this being the median of the group. The tape moved farther for the lower group, indicating more time being required to make the letter stroke. The space bar stroke is faster than the letter stroke for both groups as shown by Table I.

Thus, it appears that the thumb is a strong, active, and independent digit[8] and is capable of doing more work than striking the space bar.

It is common knowledge that the small fingers are overworked, especially the left one. Dvorak discusses the work of these fingers.[9]

> If you compare the weaker little finger of the left hand with the stronger middle finger of the right hand, you find 803 letter strokes plus heavy shifting key strokes all assigned to the weaker, but only 640 strokes assigned to this stronger second finger.

He points out further that the little fingers become fatigued before the other fingers do.[10]

> As you overview your fingers in a study of their fatigue and partial relaxation, do you discover a striking fact? Which finger is tiring first and which seldom tires? Do you watch, for instance, for a weaker typed imprint upon the paper? Clear-cut curves are drawn by Klockenberg to show that your little, or fourth, finger tires quickly. The next finger to tire is your third.

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8 Henry Morris, <u>op</u>. <u>cit</u>., p. 358, 359, 362.

9 Dvorak, Merrick, Dealey, Ford, <u>op</u>. <u>cit</u>., p. 210, 211.

10 <u>Ibid</u>, p. 404.

When the fourth fingers tire, it is obvious that they are not going to keep pace with the stronger first and second fingers. The tired fingers may falter, lag, or possibly refuse to act at all. These effects might be lessened if the fourth fingers could have more time for rest or relaxation between strokes. If these fingers are relieved of the burden of shifting, they may not become fatigued as soon or possibly not any sooner than other fingers.

It is shown further that the little fingers are overworked. The data in Table II were taken from a study[11] made preliminary to the one reported herewith. Every tenth exercise up to Exercise 80 of the Twentieth Century Typewriting text book[12] was analyzed to determine the number of times that each character of the keyboard was struck and times that the shift was depressed when exercises were copied. These exercises are intended to give the typewriting students practice on content of general English usage, excluding any unusual matter that might involve capitalization or special characters.

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[11] R. G. Lehman, A Brief Scientific Study of the Universal and Simplified Keyboards with Regard to the Work of the Fingers of Each Hand and Their Ability to Do This Work Efficiently, Unpublished Study, Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma, 1940.

[12] D. D. Lessenberry and E. A. Jevon, Twentieth Century Typewriting, pp. 28, 48, 67-69, 79, 80, 98, 101.

TABLE II

Total Strokes for Each of the Fingers and Hands

Seven Exercises Analyzed

Total	Sh.	4	3	2	1	1	2	3	4	Sh.	Total
Ex. 10 and 20											
252	8	36	44	70	94	90	48	69	16	7	230
Ex. 40 to 70											
1335	44	192	207	467	425	447	206	331	63	35	1082
Ex. 30											
1505	72	220	232	515	466	446	249	318	71	25	1109
3092	124	448	483	1052	985	983	503	718	150	67	2421
Li 572											Li 217

This table is read as follows: In Exercises 10 and 20, the left hand's total strokes were 252. The shift was depressed 8 times, the fourth little finger made 36 strokes, the third finger 44, the second finger 70, and the first or index finger 94. The column for each finger is totaled. The total strokes for the left hand were 3092. The shift plus little finger strokes were 572.

By reference to Table II, it appears that the left little finger struck letters 448 times and shift 124 times, totaling 572 for both as compared with the right little finger which struck letters 150 times and shift sixty-seven times, totaling 217 times. Thus, there is a difference of 355 strokes in these totals, indicating that the left little finger had a heavier burden than the right one. The left small finger did

73 per cent of the strokes of these two fingers, including the work of the shift and 65 per cent when not including the shift. It does more work in strokes here than either of three other fingers. Twenty-eight per cent of the left finger's strokes were shifting; whereas, 45 per cent of the right finger's strokes were shifting. A higher percentage of the right hand's strokes are shifting because the left hand strikes more letters than the right.[13] From these data, it is evident that the left little finger, especially, has more than its share of work to do.

Purpose of the Study

The purpose of this study is to determine whether a change in the location of the shift on the keyboard from the present location to a location immediately below and midway between the ends of the space bar will make possible an increase in the net stroking speed of high school pupils in beginning typewriting; thus indicating whether further experimentation of the thumb shift is feasible.

The thumb shift is a shift key located in a middle position between the space bar and the front protecting frame of the typewriter. Thus, it is easily accesible to either thumb and is operated mechanically in a manner similar to that of the little finger shift.

It relieves the little fingers of any shifting and places this work on the thumbs. Furthermore, it does not interfere

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[13] Hoke, op. cit., p. 29.

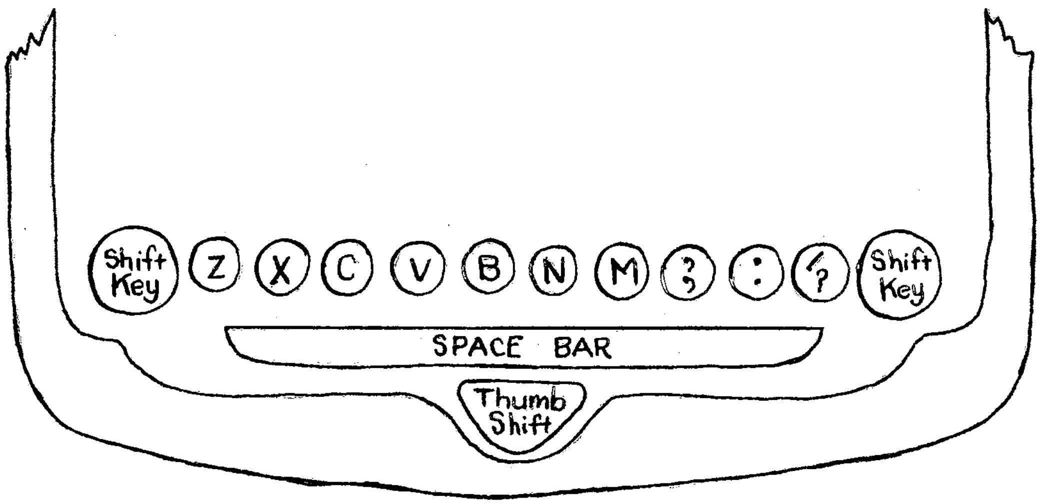

Figure I. The Thumb Shift

with the finger shifting mechanism. This thumb shifting device was constructed and placed on a model typewriter, which was used in this experiment.[14] See Figure I.

Procedure and Materials

Preceding the experiment reported herein, a test was made to find whether the thumb shift, because of its location next to the space bar, would interfere with the spacing operation by persons who had previously learned typewriting. The test was made as follows: Strips of white paper were cut to the exact length and width of the space bar. These were fastened on the bars with adhesive tape. The student then put a small amount of printer's ink on the thumb used in spacing. He was then told to type a few lines. Every time that he spaced a dark spot was marked on the white strip of paper which was fastened on the top of the space bar. By this means, the exact spot of striking the space bar could be determined. Of twenty students who had taken six months of typewriting, only one struck the space bar in the middle. All the others except one left-handed person, struck it on the right half of the bar; generally about the middle of the right half. The left-handed person struck it on the left half of the bar. It was concluded from this test that the thumb shift key would not interfere with the spacing procedure by the thumb. This study does not attempt to show where students strike the space bar; however, the conclusions of

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[14] The rights to this particular invention are claimed by the writer.

the test encouraged the idea of placing the shift key in the position illustrated in Figure I.

Then the following experiment was made to test the effectiveness of the thumb shift. Twenty high school students, ten boys and ten girls who did not know how to typewrite, were taken from the eighth, ninth, and tenth grades. The first twenty were selected who consented to practice thirty minutes a day each at noon hour or after the regular school session. The practice was under the supervision of the investigator. They were taught on ordinary typewriters for two weeks or ten school days at approximately thirty minutes a day, making about five hours practice each. During the first half of the course, they were taught the letters of the keyboard and the proper technique of striking the keys. During the last half of the course, they learned to write the test copy, except for shifting, which was not taught or allowed to be practiced. Their practice copy did not contain capital letters. Otherwise, it was the same as the copy on which they were finally tested.

After they had finished the ten lessons, each was given the test,[15] on a typewriter equipped with both the thumb shift and the ordinary finger shift. Each student was timed on how long in minutes, it took to write the entire copy. The first student was carefully instructed orally by the tester on how to use the finger shift, and then, including the time of instruction, he was allowed ten minutes to become familiar with

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[15] Test copy is shown on Plate I of the Appendix.

the finger shift. Immediately after this finger shifting test was finished, he was instructed how to use the thumb shift and a similar period allowed him to become familiar with the thumb shifting; then the test was repeated using the thumb shift. Opposite thumbs were used on the thumb shift in the same manner as opposite fingers are used on the finger shift. The second student to take the test first began using the thumb for shifting and repeated the test, using the little finger on the shift. As each person had to take the same test twice, this alternating procedure of one person using the finger shift first and the next person using the thumb shift first, made allowance for practice acquired as a result of writing the first copy. The same material was used on both the thumb and finger tests. The test for both thumb shifting and finger shifting required approximately fifty minutes.

The test was given to each student in a quiet room with no distractions of any kind to obstruct his attention from the test. All students were given the same instructions, and with the exception of two students, each took the entire test at one sitting. A definite set of rules was made by which to check the test papers. See Plate II in the Appendix.

Construction of the test. The test copy used in this experiment consists of the most frequently used beginnings and endings of words in general English usage as shown by

Rowe's combinations.[16] He determined the frequency of use of the two, three, four, and five letter combinations of the 1,000 most commonly used words. The test copy was made of 91.9 per cent of Rowe's two letter or two stroke combinations beginning with space and 93.2 per cent of his two letter or two stroke combinations ending with space. Rowe counts the space as a letter or stroke. These combinations are shown in rank of frequency of use in Table III.

Each word of the test copy was made from a two letter beginning and a two letter ending (space being counted as a letter by Rowe); thus making a digraph or word such as, os, sn, ale, and it. (See test copy in the Appendix, Plate I). For instance, space a has the highest frequency in Rowe's list of two letter combinations beginning with space and space e has the highest frequency of the two letter combinations ending with space. The word made from this is ale, beginning with an a and ending in an e. The first letter of each word was then begun with a capital. This was arranged to test the students' ability to operate the shifts. Since a has the highest frequency beginning, it is likely to be capitalized more times than any letter of the alphabet in writing ordinary discourse. This may not hold true in connection with proper names, and addresses. The first line of

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16 C. E. Rowe, Improvement of Two, Three, Four, and Five Letter Combinations on the Basis of Frequency in a Word List, p. 152, 153.

TABLE III

The Most Used Two Letter Combinations
Beginning with Space and Ending with Space

(Space is counted as a letter by Rowe[17])

Beginnings with Space		
Rank in Frequency of use	Number of Words Containing the Combination	Letter, Including Space
1	85	a
2	31	i*
3	71	t
4	60	w
5	33	o
6	108	s
7	44	h
8	10	y
9	45	b
10	56	m
11	58	f
12	76	c
13	42	d
14	23	u
15	26	g
16	40	l
17	60	p
18	51	r
	919	

Endings with Space		
Rank in Frequency of Use	Number of Words Containing the Combination	Letter, Including Space
1	186	e
2	133	t
3	107	d
4	82	r
5	92	s
6	76	n
7	11	o
8	95	y
9	1	i
10	38	l
11	7	f
12	5	a
13	1	u
14	73	g
15	25	h
	932	

[17] Rowe, op. cit., pp. 152, 153.

* Including capital I.

the material tests this shifting process of making capital a while writing the word Ale. From the ending e, the fingers play back to the capital a shift again, thus going through the actual motions of practical writing. The rest of the lines of the test were made in a similar manner.

The capital letter to the right of each line of the test designates the hand used with the shift. No penalty was made for length of lines, number of lines or vertical spacing. In addition to the instruction on how to use the shift keys, the students were told merely to copy the exercise and to stop at the end of the line when the bell rang. The reason for making a simple test is that it must fit students of approximately five hours training each, and yet it must test the manipulation of the keyboard, that is, striking the keys with the proper fingers and the shifting process.

Review of Related Studies

No similar studies can be found but some related studies are reviewed here.

A study made in 1922 entitled The John Hopkins University Studies in Education, Number 7, by Roy Edward Hoke, had for its purpose to determine the frequencies of the various letters of the alphabet during ordinary writing and to find out the abilities of the fingers.[18] Hoke attempted to discover this by conducting an experiment of tapping tests. The words

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[18] R. E. Hoke, "The Improvement of Speed and Accuracy in Typewriting," Studies in Education, Number 7, John Hopkins University Press, 1922, pp. 3-5.

used were the one thousand most used words from The Ayres Spelling Scale.[19] As a result of the study, he proposed a keyboard which was intended to equalize the loads of the various fingers to their ability to do the work.

In 1929, Edwin Riemer of New York University wrote a thesis entitled A Revised Keyboard for the Typewriter.[20] His purpose was practically the same as Hoke's. However, he studied a larger and more representative group of words. He also used tapping tests to determine the ability of the fingers, and as a result of the study, devised a keyboard. He placed the most used letters in the middle of the keyboard for the first and second fingers; thus reducing considerably the loads of the third and fourth fingers.

An Experimental Study of Progress in Typewriting,[21] by R. L. C. Butsch was made at the University of Chicago in 1927. He measured the time of the key stroke, space bar, capital shift, and carriage throw by means of a tape moving through the typewriter at a uniform rate.

Dvorak and Dealey patented a typewriter keyboard in 1932, the result of a study in which they made use of the experiment and research of others and combined with their own.

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19 L. P. Ayres, "The Spelling Vocabularies of Personal and Business Letters," New York: Russell Sage Foundation, 1921.

20 Edwin Riemer, A Revised Keyboard for the Typewriter, Unpublished Master's Thesis, New York University, 1929.

21 R. L. C. Butsch, An Experimental Study of Progress in Typewriting, Unpublished Master's Thesis, University of Chicago, 1927.

Their principal objective was to perfect the rhythm[22] of typewriting so that there is a steady working co-ordination of both left and right fingers. They arranged the keys so as to accomplish this rhythm. They assert that this better rhythm increases speed and decreases errors. Several experiments with their keyboard bears out this fact.[23] With the assistance of Merrick and Ford, and others, and a donation of several thousand dollars from the Carnegie Foundation for the Advancement of Teaching,[24] an extensive program of experimentation was carried on to test methods of teaching typewriting. The experimentation with Dvorak-Dealey keyboard was included in this program. A book, Typewriting Behavior is a product of this work.

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22 Dvorak, August, "Developing Rhythm in Typewriting," The Journal of Business Education, February, 1935, p. 3-5.

23 Dwight Davis, "An Evaluation of the Simplified Typewriter Keyboard Through an Analysis of Student Typewriting Errors on the Universal and the Dvorak-Dealey Simplified Keyboard," Journal of Business Education, May, June, September, October, 1935, (reprint), pp. 5-12.

24 Dvorak, op. cit., p. 3.

CHAPTER II

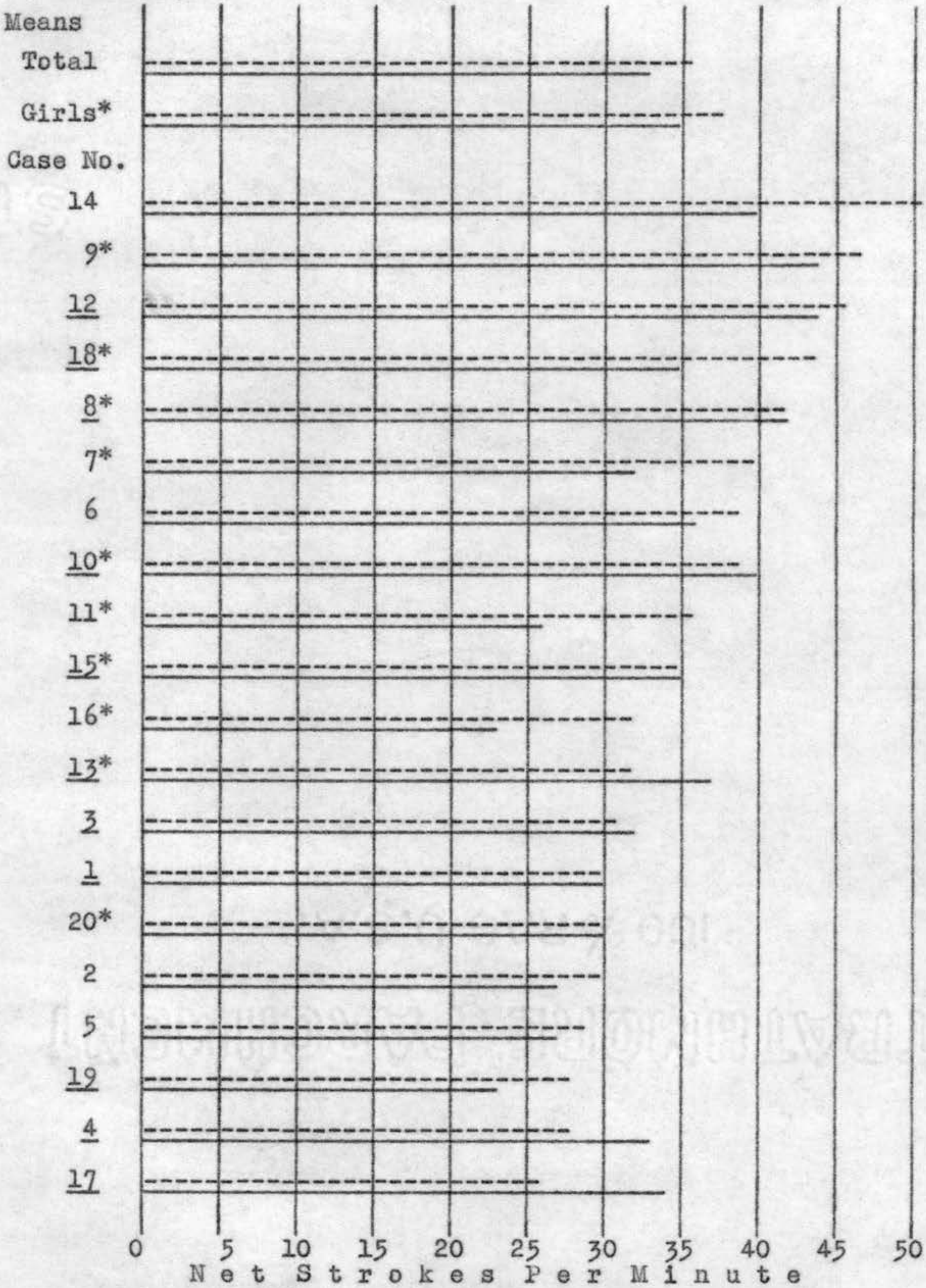
FINDINGS AND INTERPRETATIONS

Each of the twenty students included in this experiment received approximately five hours of training under the direction of the investigator, after which they wrote two identical test copies on a typewriter equipped with both the thumb and the finger shifts. An alternating procedure was used in that one student used the finger shift in the first test and the next student used the thumb shift in the first test. Eleven students used the thumb shift first when writing the test copy and nine students used the finger test first.

Table I, of the Appendix, shows the number of the student, gross strokes, misses or errors, net strokes, net strokes per minute, and difference in net strokes per minute for each student. For example, this table shows that student number one typed 1,071 strokes or gross strokes while using the thumb shift, when he had finished the first test copy. He made thirty-seven misses or errors which are deducted from the gross strokes to get the net strokes, or 1,034. The net strokes were divided by the time which he required to finish the test, to obtain net strokes per minute which in this case amounted to 60.8. There is a difference of 6.5 net strokes per minute in favor of the thumb shift procedure over the finger shift procedure. Some variation in the total number of gross strokes made by the different students is caused by slight variations in the length of the lines made when the test copy was typed during each of the two tests.

Chart I on the following page gives a graphical representation of the results in net strokes per minute of all students, with boys and girls shown individually. The means are shown at the top of the chart. The broken lines indicate the strokes made while using the thumb for shifting and are arranged in order from the highest score (represented by the longest broken line) to the lowest score (represented by the shortest broken line). The continuous lines indicate strokes made while using the little finger for shifting. These horizontal lines are scaled one stroke to each two strokes made by the students on the tests. The case numbers of the students are given in the left hand column of the chart. The students, whose case numbers are underlined, first took the test using the thumb for shifting and repeated the test using the finger for shifting. The remaining students first took the test using the finger shift and then repeated the same test copy using the thumb shift.

CHART I. Test Results in Net Strokes Per Minute of the Twenty Students, Ranked According to Results of the Thumb Shift



-------- Represents strokes when using thumb.

________ Represents strokes when using finger.

*Girls who took the test.

Cases, whose numbers are underlined, took the thumb test before the finger test; others took the finger test first.

It might be argued that the students who took the test using the thumb shift first would benefit by the practice of the shifting procedure, and thus might make better scores on the second test which immediately followed and in which the finger shift was used. In only five cases, numbers ten, thirteen, three, four, and seventeen were there test differences in favor of the finger shift. No appreciable differences are observed in these scores except in cases number thirteen, four, and seventeen. The scores of the remaining cases, numbers twelve, eighteen, eight, fifteen, one, and nineteen, are equal or better for the thumb shift procedure rather than for the finger shift procedure. All nine students who first took the test by using the finger shift made better scores with the thumb shift, except number twenty, whose achievement was the same in both tests.

In the case of five students, case numbers seventeen, four, three, thirteen, and ten, did the test results with the finger shift exceed the test results with the thumb shift by one or more strokes. Not much difference is shown in any of these except in cases number thirteen, four, and seventeen. The seven fastest operators made better scores when using the thumb for shifting than when using the finger for shifting. The score of student number eight is slightly more as shown by Table I in the Appendix. Eight out of ten girls who took the tests, made scores on the test with the thumb shift which were equal to, or better than, scores made on the test with the finger shift.

The means in net strokes per minute of the girls, boys, and both groups combined, are shown in the following table.

TABLE IV

The Arithmetical Means and Differences in Strokes Per Minute for Girls, Boys, and All Students as a Group On Tests Using the Thumb and Finger Shifts

	Thumb	Finger	Difference
Girls	75.50	68.76	6.74
Boys	67.26	65.00	2.26
All	71.40	66.90	4.50

For all students the arithmetical means of the test scores with the thumb shift exceeded the test scores with the finger shift by 4.5 net strokes per minute or about seven per cent of the finger strokes. The thumb shift procedure of the girls exceeded the finger shift procedure by 6.74. The difference of the boys in favor of the thumb shift was 2.26. The significance of these results is explained later with relation to the statistical data.

The data in Table V are treated statistically as explained by McCall.[1] Only two variables are dealt with in this experiment, that is EF_1 (first experimental factor or the net strokes per minute obtained when using the thumb shift) and EF_2 (second experimental factor or the net strokes per minute obtained when using the finger shift). An effort

TABLE V. Statistical Computation of EF_1 and EF_2 in Strokes Per Minute[2]

	EF_1 (Thumb)			EF_2 (Finger)		
S.	EF_1	x	x^2	EF_2	x	x^2
1	60.8	10.2	104.04	63.1	2.5	6.25
2	59.8	11.2	125.44	53.3	12.3	151.29
3	62.1	8.9	79.21	63.9	1.7	2.89
4	54.1	16.9	285.61	65.6	0.0	0.00
5	57.1	13.9	193.21	53.9	11.7	136.89
6	78.8	7.8	60.84	71.6	6.0	36.00
7	79.6	8.6	73.96	63.4	2.2	4.84
8	84.2	13.2	174.24	84.1	18.5	342.25
9	93.2	22.2	492.84	88.4	22.8	519.84
10	78.0	7.0	49.00	81.0	15.4	237.16
11	72.3	1.3	1.69	50.0	15.6	243.36
12	91.6	20.6	424.36	87.3	21.7	470.89
13	64.1	6.9	47.61	73.7	8.1	65.61
14	101.0	30.0	900.00	80.3	14.7	216.09
15	71.0	0.0	0.00	70.2	4.6	21.16
16	64.3	6.7	44.89	47.0	18.6	345.96
17	51.6	19.4	376.36	67.8	2.2	4.84
18	87.3	16.3	265.69	70.3	4.7	22.09
19	55.7	15.3	234.09	45.0	20.6	424.36
20	60.8	10.2	104.04	59.6	6.0	36.00
	M_1=71.4		Sx^2=3993.02	M_2=66.9		Sx^2=3287.77
	AM = 71.0			AM = 65.6		
	c = .4			c = 1.3		

$$SD = \sqrt{\frac{3993.02}{20} - (.4)^2} \qquad SD = \sqrt{\frac{3287.77}{20} - (1.3)^2}$$

$$SD = 14.12 \qquad SD = 12.75$$

$$SDM_1 = \frac{14.12}{\sqrt{20}} = 3.2 \qquad SDM_2 = \frac{12.75}{\sqrt{20}} = 2.9$$

Summary

EF_1	EF_2	D	SDD	EC
71.4	66.9	4.5	$\sqrt{(3.2)^2 + (2.9)^2} = 4.25$	$\frac{4.5}{2.78 \times 4.25} = .38$

Meaning of Symbols:

- M_1 arithmetical mean of EF_1 (Experimental Factor)
- M_2 arithmetical mean of EF_2
- SD standard deviation of the EF's
- SDM standard deviation of the mean
- SDD standard deviation of the difference of the means
- Ec experimental coefficient
- AM assumed mean
- S student number

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[2] William A. McCall, <u>How to Experiment in Education</u>, The MacMillan Company, 1926, p. 140.

has been made to equalize or keep constant all other factors. The standard deviations of the EF's, means, and differences are computed and shown in Table V. The EC (experimental coefficient) is also computed.

The symbol x is the traditional symbol for deviation. Thus the x for Student number two is 11.2 because his EF_1 of 59.8 deviates or differs from the AM (assumed mean, which is arbitrary can be any number) of seventy-one by 11.2 points. The column labeled "x^2" is found by squaring all the x's. Sx^2 is the sum of all the x^2 column. In the left half of Table V, the Sx^2 is 3993.02. The SD means standard deviation and is one of the several conventional measures of variability. Its computation is shown in Table V. The SD of EF_1 is 14.12. This means that 68.26 per cent of all the EF's will fall between $M_1 - 14.12$ and $M_1 + 14.12$ or between 57.28 and 85.52 when plotted on a normal distribution curve.

The SDM, standard deviation of the mean or standard error of the mean, and the SDD, standard deviation of the difference or standard error of the difference, are measures of reliability respectively of the mean (M) and difference (D). One SD or one sigma on either side of the mean includes 68.26 per cent of the area of a normal curve of distribution. The SD or sigma of the scores for EF_1 is 14.12, thus 68.26 per cent of all successive means for similar groups of students, who are selected at random from a large group, have a

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[1] McCall, _op_. _cit_., pp. 15, 140.

two to one chance of falling between 71.4 minus 14.12 and 71.4 plus 14.12 or between 57.28 and 85.52. But the SD of EF_1 of 14.12 is not reliable since the chances are only two to one that the means will recur between 57.28 and 85.52. To be highly reliable, 99.73 per cent of all the scores should fall between limits set by plus or minus 3SD. Thus, the chances are about 365 to one that the possible scores made by successive groups of students, chosen at random on the same tests, would occur between 71.4 minus 42.36 and 71.4 plus 42.36, or between 29.04 and 100.44. This variation of scores is above zero and within the upper limit of the observed scores in the distribution of scores on the tests for EF_1.

The SD of EF_2 is 12.75. Then 3SD is 38.25. The variation of the scores from the mean for 3SD is 66.9 minus 38.25 and 66.9 plus 38.25, or a total variation of 28.65 to 105.15. This shows that the scores will probably continue to occur above zero for similar groups of students.

The SDM of EF_1 is 3.2. Then to test reliability 3SD is 9.6. Thus, the limits of variation become 71.4 minus 9.6 and 71.4 plus 9.6, or 61.8 and 81.0. These are reliable limits because they fall within the sigma limits of the scores 57.28 to 85.52. To state the test of reliability differently, the SD of 14.12 divided by the SDM of 3.2 is more than three.

As to the reliability of the mean of EF_2, the SD is 12.75 and the SDM is 2.9. To test the reliability of the mean, the SD of 12.75 is divided by the SDM of 2.9 which gives a quotient of 4.4, which is more than three. Therefore, the mean is reliable.

In like manner, it is shown that SDD, standard deviation of the difference, is an index of reliability. It represents the reliability of the difference of the means. The difference of the means of the EF_1 and the EF_2 is 4.5 and the SDD is 4.25. This difference does not show a high reliability statistically because the difference is only 1.06 times the SDD. To be highly reliable the D must be 3 times the SDD. To have chances of ninety-nine to one that a difference will occur in favor of the thumb shift for similar groups of students, the D must be 2.58 times the SDD, which is considered a reliable figure by Holzinger.[2] However, a difference of nothing to nine in favor of the thumb shift has a chance of about 2.5 to one of recurring for similar groups of students. The EC (Experimental coefficient) has been devised by McCall[3] to interpret the SDD. McCall interprets this coefficient as follows:

> Whenever the EC is less than 1.0, the experimenter should state that one of his EF's is probably more effective than the other. The less the EC becomes, the more wary the experimenter should be. This does not mean that the experimenter is justified in advising practical

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[2] Karl J. Holzinger, <u>Statistical Methods for Students in Education</u>, Ginn and Company, 1928, pp. 235-7.

[3] McCall, <u>op</u>. <u>cit</u>., p. 156.

action on the basis of his experiment only when the EC is 1.0 or above. So long as the EC is above zero, the true D more probably lies in the direction of the obtained D than in the opposite direction.

The statistical treatment of data is valid only to the extent that there has been a genuine random sampling representative of a large group. Chart I shows that there is good distribution of scores. They range from forty-five to 101 strokes per minute. This seems to indicate on the basis of this factor that there was a random sampling of cases.

A summary of the statistical data for the girls and boys separately, and for both combined, is shown in Table VI.

TABLE VI

Summary of the Statistical Data in Net Strokes Per Minute for Girls and Boys Separately, and For Both Groups Combined

	EF_1 (Thumb)		EF_2 (Finger)	Difference
		Girls		
Mean	75.50		68.76	6.74
SD	10.25		13.16	
SDM	3.20		4.10	
SDD		5.20		
EC		.47		
		Boys		
Mean	67.26		65.00	2.26
SD	16.25		12.04	
SDM	5.10		3.80	
SDD		6.36		
EC		.13		
		All		
Mean	71.40		66.90	4.50
SD	14.12		12.75	
SDM	3.20		2.85	
SDD		4.25		
EC		.38		

As shown in Table IV, the thumb shifting results or the EF_1 for the girls was the highest. The mean of the EF_1 is 75.5 and the mean of the EF_2 is 68.76, making a difference of 6.74. The SDM's of both EF_1 and EF_2 are reliable because the SD of each is more than three times the SDM. As to the difference, the D divided by the SDD is 1.3, or 6.74 divided by 5.20 is 1.3 which is not a reliable figure statistically because it indicates only a four to one chance that a difference of zero to 13.48 will recur in favor of the thumb shift for similar groups of students. The EC is .47 and according to McCall's technique of interpretation of the reliability of the difference, there is a chance of about nine to one that the true difference is above zero and in favor of the thumb shift.

The results for the boys show a difference of 2.26 of the thumb shift procedure over the finger shift procedure. The SDM's of both the EF_1 and the EF_2 are reliable because the SD of each is more than three times the SDM. However, the difference does not show reliability. The D divided by SDD is .36 which shows by the probability curve that there is a two to one chance against a difference of $-$ 4.10 to $+$ 8.62 recurring in favor of the thumb shift. The EC is .13, which indicates according to McCall that the true difference in favor of the thumb shift has a two to one chance of its being above zero.[4] McCall states that so long as the EC is above

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[4] McCall, _op. cit._, p. 156.

zero, the true D more probably lies in the direction of the obtained D than in the opposite direction. This difference is not reliable statistically because the difference is not three times the SDD. However, 4.50 divided by 4.25 is 1.06, which indicates that a difference of zero to nine for the thumb shift, has a chance of 2.5 to one of recurring if this experiment were repeated an indefinite number of times with similar groups of students. The EC is .38 which indicates according to McCall that the true difference in favor of the thumb shift has a four to one chance of its being above zero.

These differences are not statistically conclusive as measured by the normal distribution curve or as measured by McCall's experimental coefficient. To be conclusive, the difference must have a chance of ninety-nine to one, or D divided by SDD must be at least 2.58, according to Holzinger.[5] To be highly reliable, the difference must be three or more times sigma. Three sigma or 3SDD gives a chance of about 365 to one that a difference in favor of the obtained difference will recur for similar groups of students.

Summary. Of the eleven students who took the thumb test first, only five made better scores with the finger test than with the thumb test. No appreciable difference is shown in these except cases, number thirteen, four, and seventeen. All nine students who took the test first with the finger

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[5] Karl J. Holzinger, Statistical Methods for Students in Education, p. 236.

made a better score with the thumb, except one whose achievement in both tests was equal. The finger results exceeded the thumb results by one or more net strokes per minute in only five cases.

The differences of the means are shown for all students and for boys and girls separately. The difference of the means for the girls was 6.74 net strokes per minute. The reliability or D divided by SDD is 1.3, indicating that the chances are four to one that a difference of zero to 13.48 in favor of the thumb shift will recur if this experiment were repeated on similar groups of students. The EC is .47, which according to McCall means that the true difference has a chance of nine to one of its being above zero.

The differences of the means in favor of the thumb shift for the boys is 2.26. This is not a reliable difference because D divided by SDD is only .36, which means that there is a two to one chance against a difference of -4.10 to +8.62 recurring in favor of the thumb shift. The EC is .13 and is interpreted by McCall to indicate that the true difference for the thumb shift has a two to one chance of its being above zero.

The differences of the means for all students combined was 4.5 net strokes per minute. This is not a reliable difference statistically because the D divided by the SDD is not three. Four and fifty one-hundredths divided by 4.25 is 1.06 which gives a chance of 2.5 to one that a difference of zero to nine will recur for similar groups of students.

The EC is .38 and is interpreted by McCall to indicate a chance of four to one that the true difference in favor of the thumb shift is above zero.

Although the thumb shift procedure resulted in more rapid stroking by a small amount than the finger shift procedure as shown by Chart I, the differences for the girls, boys, and both combined are inconclusive statistically. This is probably due to the fact that there were not enough cases to show a reliable figure when each difference was divided by the sigma of the difference, or when D was divided by SDD, the result was not large enough to make three. The girls showed more success with the finger shift than the boys.

CHAPTER III

SUMMARY AND CONCLUSIONS

Little or no work seems to have been done toward utilizing the thumb for shifting. Hoke placed the thumb shift in a center position between the right and left banks of keys, but he did not determine by experiment, whether this was a convenient place so that the shift could be used successfully. The small fingers are also overworked. The left little finger has a heavier load than the right because of having to strike more letters than the right finger. The thumb is strong and active, and is capable of operating the shift; thus, relieving the little fingers of this work. For these reasons, a thumb shift was constructed and placed on a typewriter in a middle position below and midway between the ends of the space bar.

Twenty high school students who volunteered to practice approximately two weeks each, outside the regular school session, took the test. They were beginning students and were taught on ordinary typewriters and under the direction of the investigator. They did not practice shifting. The practice was begun by learning the position of the letters and the proper letter-stroking technique of the keys. The latter part of the training was for the purpose of learning to write the test copy which contained no capital letters; however, the test copy that the students wrote for the purpose of this experiment contained capital letters. After the two-weeks course was finished, each student took the test on the shifts.

The copy was written twice by each student; once using the thumb for shifting and once using the finger for shifting. The procedure was alternated so that one student wrote the finger test first and the next student wrote the thumb test first. Each student was timed to determine how many minutes was required to write the entire test copy and the time was recorded on the sheet. The test papers were checked by a definite list of rules and the results were tabulated. To get net strokes the misses or errors were deducted from the gross strokes and to get net strokes per minute, the net strokes were divided by the time required to write the test copy. The final results of this experiment were computed from the net strokes per minute.

The test copy used in this experiment was made from Rowe's two-letter combinations ending with space and two-letter combinations beginning with space. Space is counted as a letter by Rowe. The first word of the test was begun with the highest frequency beginning and was ended with the highest frequency ending. Each word was begun with a capital. This was arranged so as to test the student's ability to operate the shifts. The second word was made of the second highest frequency beginning and highest frequency ending, and each succeeding word was made in a similar manner.

The mean for the girls was 75.50 net strokes per minute for thumb shifting and 68.76 for finger shifting, making a difference of 6.74 net strokes per minute in favor of the thumb shift. The difference divided by sigma of the difference was 1.3, which means that the chances are four to one that a difference of zero to 13.48 would probably recur if this experiment were repeated an indefinite number of times for similar groups of students. The chances are four to one that a difference from zero to 13.49 would be in favor of the thumb shift. The EC is .47 which according to McCall means that the true difference has a chance of nine to one of its being above zero.

The mean for the boys for thumb shifting was 67.26 net strokes per minute and for finger shifting, 65.00, making a difference of 2.26 net strokes per minute in favor of the thumb shift. According to the normal probability curve, the chances are two to one against the thumb shift procedure that a difference of -4.10 to +8.62 will recur. The EC is .13 and is interpreted by McCall to indicate that the true difference for the thumb shift has a two to one chance of its being above zero. McCall states that so long as the EC is above zero, the true difference more probably lies in the direction of the obtained difference than in the opposite direction.

For the boys and girls combined, the thumb shift mean was 71.4 and the finger shift mean was 66.9, making a difference of 4.5 net strokes per minute in favor of the thumb shift. This is not a reliable difference statistically because the difference divided by the sigma of the difference is not as much as three. But the chances are 2.5 to one that a difference of zero to nine will recur for similar groups of students. The EC of .38 is interpreted by McCall to indicate a chance of four to one that the true difference in favor of the thumb shift is above zero.

Although the results are not conclusive statistically, this experiment indicates that the thumb shift resulted in a slightly faster stroking by 4.5 net strokes per minute than the finger shift. This is probably due to the fact that there were not enough cases to show a reliable figure when the difference was divided by the sigma of the difference, or when D was divided by SDD, the result was not large enough to make three. The seven fastest students made more net words per minute when using the thumb shift than when using the finger shift. The difference for the girls in favor of the thumb shift was larger than that of the boys; thus indicating that they had better success with the thumb shift than the boys.

Further study of the thumb shift seems justifiable.

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A P P E N D I X

TABLE I. Record of Results of Test Made by Twenty Students

	THUMB						FINGER					
Subject Number	Gross Strokes	Misses (Errors)	Net Strokes	Time in Minutes	Net Strokes Per Minute	Plus Difference s. p. m.	Gross Strokes	Misses (Errors)	Net Strokes	Time in Minutes	Net Strokes Per Minute	Plus Difference s. p. m.
1	1071	37	1034	17	60.8		1065	23	1042	17	61.3	.5
2	1065	48	1017	17	59.8	6.5	1055	43	1012	19	53.3	
3	1163	107	1056	17	62.1		1161	74	1087	17	63.9	1.8
4	999	25	974	18	54.9		1063	13	1050	16	65.6	11.5
5	1070	41	1029	18	57.1	3.2	1065	41	1024	19	53.9	
6	1062	37	1025	13	78.8	7.2	1116	42	1074	15	71.6	
7*	1146	32	1114	14	79.6	16.2	1129	115	1014	16	63.4	
8*	1126	31	1095	13	84.2	.1	1154	61	1093	13	84.1	
9*	1170	51	1119	12	93.2	4.8	1164	103	1061	12	88.4	
10*	1108	94	1014	13	78.0		1090	118	972	12	81.0	3.0
11*	1146	62	1084	15	72.3	22.3	1118	167	951	19	50.0	
12	1053	45	1008	11	91.6	4.3	997	36	961	11	87.3	
13*	1137	175	962	15	64.1		1121	89	1032	14	73.7	9.6
14	1166	56	1110	11	101.0	20.7	1162	38	1124	14	80.3	
15*	1029	106	923	13	71.0	.8	1052	139	913	13	70.2	
16*	1053	89	964	15	64.3	17.3	1054	113	941	20	47.0	
17	1065	33	1032	20	51.6		1081	64	1017	15	67.8	16.2
18*	1071	111	960	11	87.3	17.0	1082	98	984	14	70.3	
19	1133	74	1059	19	55.7	10.7	1111	120	991	22	45.0	
20*	1050	78	972	16	60.8	1.2	1053	100	953	16	59.6	
Total	21883	1332	20551	298	Mean		21893	1597	20296	314	Mean	
					71.4	4.5					66.9	
	*Girls				75.5	6.7					68.76	
	Boys				67.26	2.26					65.00	

PLATE I. Test Copy

R. Ale Ale Ale Ale Ale Ale Ale Ale Ale Ale Ale Ale Ale Ale Ale

L. It It It It It It It It It It It It It It It It It It It It

R. Tid Tid Tid Tid Tid Tid Tid Tid Tid Tid Tid Tid Tid Tid Tid

R. Wir Wir Wir Wir Wir Wir Wir Wir Wir Wir Wir Wir Wir Wir Wir

L. Os Os Os Os Os Os Os Os Os Os Os Os Os Os Os Os Os Os Os Os

R. Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn Sn

L. Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho Ho

L. Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye Ye

L. Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki Ki

L. Mul Mul Mul Mul Mul Mul Mul Mul Mul Mul Mul Mul Mul Mul Mul

R. Fif Fif Fif Fif Fif Fif Fif Fif Fif Fif Fif Fif Fif Fif Fif

R. Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu Cu

R. De De De De De De De De De De De De De De De De De De De De

L. Nag Nag Nag Nag Nag Nag Nag Nag Nag Nag Nag Nag Nag Nag Nag

R. Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh Gh

L. La La La La La La La La La La La La La La La La La La La La

L. Per Per Per Per Per Per Per Per Per Per Per Per Per Per Per

R. Rey Rey Rey Rey Rey Rey Rey Rey Rey Rey Rey Rey Rey Rey Rey

PLATE II. RULES THAT WERE USED FOR CHECKING THE TEST PAPERS OF THE TWENTY STUDENTS

These rules are concerned only with letters and spaces. No attempt was made at having the students set up the work on the page, which was not essential to the study.

ONE MISS IF:

(1) There is more than one space between words or failure to make space when there should be one.

(2) Two letters are transposed. Two misses if transposition is at the beginning of word and word is not begun with a capital letter. If two letters at the beginning of a word are transposed, but the first one is begun with a capital letter, only one miss is counted.

(3) A double impression of the letter is made being caused by improper shifting or showing part of the upper case and part of the lower case letter.

(4) There is space between letters in word.

(5) There is a strikeover.

(6) An extra letter or other character is inserted where it should not be.

(7) There is a capital letter any place except at the beginning of the word.

NO MISS IF:

(8) All letters are in the same order of sequence as in test copy Plate I; each word is begun with a capital letter, only one space between words and no space between letters in words.

(9) Most of the letter can be seen so that it would not be mistaken for another letter.

(10) Letters are in proper sequence but one letter is omitted at the beginning or end of the word, and there is only space left after or before the word.

Not more than one error is charged to a single stroke.

The net words per minute were figured as follows: The misses were deducted from the gross strokes to get the net strokes. The net strokes were divided by the time to get net strokes per minute. The strokes and misses on each test were counted and totaled on each sheet and were then tabulated. See Table I in the Appendix.

TYPIST: Ruby Cochran Davis