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Studies in Typewriter Keyboard Modification: I. Effects of Amount of Change, Finger Load, and Copy Content on Accuracy and Speed

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Attempts to efficiently redesign the standard typewriter keyboard by basing modifications on selected typing parameters were investigated. Specifically, the effects of amount of change (1, 2, or 3 pairs of letter reversals), finger load (or proportion of typing performed by each finger), and the content of copy to be typed on typing speed and accuracy for 115 subjects experienced on the standard keyboard were examined. Analysis of variance of pretest trials on standard and modified keyboards revealed substantial decrements in speed and accuracy with the modified keyboards. Another analysis of variance comparing pretest and posttest trials on the modified keyboard revealed a significant ($p < .01$) amount of change effect which accounted for the greatest proportion of both the speed and accuracy variance. In general, decrements in typing performance increased with each additional key reversal.

Numerous researchers have demonstrated the shortcomings in the design of the original, or "universal," typewriter keyboard. However, more efficient designs, such as Dvorak's "simplified" keyboard (Dvorak, Merrick, Dealey, & Ford, 1936) have never been salable due to the reluctance of employers to equip their offices with totally different keyboards and to underwrite the expense of retraining their typists. Consequently, with no market for Dvorak's more efficient, but drastically modified typewriter, the keyboard configuration has remained basically the same for over 100 years.

Periodically, however, suggestions are offered for limited changes in the design of the keyboard which promise increased typing ease without concomitant retraining problems of the magnitude associated with the simplified keyboard. These suggestions have given rise to a few isolated empirical studies to test the efficiency of typing with slightly modified keyboards. The resulting research is generally unsophisticated and of limited generality. For example, Stutsman (1959) investigated the effects of reversing only the A and J keys with a sample of four typists.

Use of this strict empirical approach without the guidance of a general conceptual framework is fruitless at worst and inefficient at best. Trial and error experimentation involving desultory interchanges of letters does not provide the basis for explaining the dynamics underlying changes in performance associated with particular key reversals. Rather, the design of experiments on keyboard configuration should flow from more general considerations involving the variables underlying typing behavior. By the selection of letter interchanges that reflect different levels of certain crucial dimensions of typing, it will eventually be possible to describe the relationships among these underlying dimensions. That, in turn, may suggest an optimal strategy for selecting a few alterations for the universal keyboard configuration which promise the biggest increases in typing efficiency without simultaneously producing large-scale training problems.

The purpose of the present research was to determine the effects of different keyboard modifications on the performance of typists with established typing habits. The particular changes selected for study were related to major parameters of the typing habit. Specifically, the parameters of typing that were used as independent variables in this study

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were the magnitude of change, that is, the number of key reversals, and finger load, or the proportion of typing performed with each finger. Also, the meaningfulness of copy was studied to determine if there were disproportionate retraining problems associated with the character of the material to be typed.

METHOD

Experimental Changes

Six pairs of letter interchanges (shown in Table 1) were selected for study on the basis of information regarding typing parameters provided by the research of Hoke and Riemer reported in Dvorak et al. (1936, pp. 211–213). These researchers independently investigated the key-stroking load of each hand and the tapping rates of each finger. Because their results were very similar, only Riemer's findings are presented in Table 1.

Each experimental condition was defined by the number of pairs of key reversals and the normal load characteristics of the fingers involved in the change(s). Three levels of response modification were investigated, namely, one, two, or three pair(s) of letter interchanges. Two load levels, high and low, were also investigated. Six keyboard changes were identified by the combination of these two major experimental variables. These new configurations are described in Table 2.

These particular modifications were selected for study to control the degree of similarity between Task 1 (typing on the standard keyboard) and Task 2 (typing on the modified keyboard). Each of the six variations of Task 2 involved reversing the letters of the upper and home (or middle) rows for a given finger. Also, the tapping rates were closely comparable for the corresponding pairs of fingers involved for each interchange within the high- or low-load groupings (see Table 1).

TABLE 1

TAPPING RATE AND RELATIVE LOAD FOR FINGERS FOR LETTER INTERCHANGES ON THE TYPEWRITER

Letter interchange	Tapping rate[a]	Load[b] (%)
High-load keys		
J–U	70	19
F–R	66	22
D–E	63	20
Low-load keys		
K–I	69	8
L–O	62	12
S–W	57	9

[a] Tapping rate refers to the number of strokes a finger is capable of making during a 15-sec period.
[b] Load refers to the proportion of typing performed with each finger.

TABLE 2

SUMMARY OF EXPERIMENTAL KEYBOARD CONFIGURATIONS

Interchanges	Finger load	
	High	Low
1 pair	J–U (18)[a]	K–I (20)
2 pairs	J–U, F–R (21)	K–I, L–O (25)
3 pairs	J–U, F–R, D–E (15)	K–I, L–O, S–W (16)

[a] *N*s are in parentheses.

Subjects

Subjects were 115 experienced standard-keyboard typists enrolled in six classes of fourth quarter typewriting offered at the University of Tennessee during the 1971–72 academic year. Instead of attending their regular typing class, the subjects reported for two 1-hour periods of testing and practice during 1 week of the quarter. Two subjects participated in the study at each experimental session. The initial standard-keyboard speeds of the subjects on ordinary prose ranged between 47 and 90 gross words per minute (GWPM); $\bar{X} = 60.1$ GWPM. Gross words per minute was defined as the number of five-letter words stroked per min during a 3-min test,

$$\text{GWPM} = \frac{\text{No. of strokes}/5}{3}.$$

Apparatus

The internal selection mechanism was rearranged on two IBM Selectric typewriters (Machines A and B) to reverse the location of the pairs of letters selected for study. Typewriter A was used to test for the effects of low-load key changes, whereas Typewriter B was used for high-load key reversals. The first change was to reverse the location of Keys K–I on Typewriter A and Keys J–U on Typewriter B. The second change was the addition of a reversal of the locations of L–O on Typewriter A and F–R on Typewriter B. The third modification was the addition of the S–W interchange on Typewriter A and the D–E interchange on Typewriter B.

Test Copy and Practice Material

Two types of test copy were utilized. First, two 3-min *standard copy tests* of normal prose were selected from the eighth edition of *College Typewriting* by Lessenberry, Wanous, and Duncan (1969). The average work length (typewriter strokes per dictionary word) of this material was 5.2, and the syllabic intensity (speech syllables per dictionary word) was 1.3. The number of times each of the 12 letters involved in the key reversals occurred on these tests ranged from 1 (J) to 62 (E).

Second, special *contrived test copy* was produced (a) to provide more occurrences of the rarer letters and (b) to make the occurrences of the interchanged letters more nearly equal. This material was compiled basically from the Silverthorn (1958) word list. Two equivalent forms[1] of the specially contrived material were constructed. In both 3-min writings each of the 12 letters occurred from 25 to 30 times. The average word length of the contrived copy was 5.2, and its syllabic intensity was 1.2.

Practice material restricted to words which contained the letters involved in the experimental interchanges also was constructed. Special material was provided for each of the six experimental configurations. For example, if the students were concerned with only one pair of reversed keys (K–I or J–U), then the practice material was composed of words containing either one or both letters and of sentences with a high frequency of such words.

Data Collection

Because the two experimental typewriters permitted only two experimental conditions out of the six to be administered at any given time, it was necessary to collect data in a fixed sequence. Specifically, data were collected in an order minimizing the number of engineering changes that had to be performed. That is, data were collected first for the one-pair changes. Then, the typewriters were modified to permit data collection for the two-pair changes and then for the three-pair changes. Subjects were assigned randomly to the two load conditions (represented by Typewriters A and B) within each level of change (number of subjects used is shown in Table 2).

The following procedure was followed for each of the six experimental conditions:

1. Using the standard keyboard, each student took a 3-min pretest on the specially contrived material plus a 3-min pretest on standard copy.
2. The changes in the modified typewriter were then explained to the subjects, but no warm-up was allowed on the modified keyboard. Then, the alternate forms of the standard and contrived tests were administered.
3. These pretests were followed by one hour of practice each day for 2 days on the modified keyboard, using the special practice material.
4. Following the 2nd hour of practice, each student took a posttest on the modified keyboard using the specially contrived material plus a test on standard copy.
5. A posttest was administered on the standard keyboard immediately following the posttest on the modified keyboard. Again, both types of copy were used.
6. The first class meeting subsequent to the posttests was used for practice on the standard keyboard. Drill with the special practice material was used to bring the student up to her pre-experimental level of typing proficiency.

Dependent Variables

Both speed and accuracy criteria were used. The speed measure, gross words per minute (GWPM), was obtained for all pretests and posttests.

Two accuracy measures were employed. The first was the number of words containing one or more *stroking errors*. This index of accuracy was obtained for all pretests and posttests. A second, related accuracy criterion also was used for the pre- and posttests on the modified keyboards. This measure was the number of stroking errors observed only on keys involved in an experimental interchange, or *interchange errors*.

The results of a pilot study with the special copy confirmed that GWPM was a far more reliable criterion than a measure of net typing speed (NWPM) which was adjusted by subtracting stroking errors. The reliability of GWPM was .81, whereas the reliability of NWPM was .32.[2]

RESULTS

To establish the initial equivalence of the six experimental groups, the pretest means for GWPM and stroking errors on the standard keyboard were compared using a one-way analysis of variance. No significant differences ($p > .10$) in the original level of typing speed or accuracy were revealed among the groups on either the standard or contrived copy. Consequently, equivalent initial typing ability was assumed for all subjects.[3]

Immediate Effects of the Changeover

By comparing pretest performance on the standard and modified keyboards, the immediate impact of switching keyboard configurations was determined. To this end a $2 \times 2 \times 3 \times 2$ analysis of variance was per-

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[1] The equivalency of these two forms was demonstrated in a pilot study involving 21 students similar to the participants in the present research. The average speed and average accuracy did not differ significantly for the two forms on a series of statistical tests for mean differences. Furthermore, the interform correlation was .85 for GWPM on the standard copy tests and .86 on the contrived copy tests.

[2] These correlations are based upon the average of the reliability computed on both forms of both types of copy material. The formula for calculating net speed was

$$\text{NWPM} = \frac{(\text{No. of strokes}/5) - 10\ (\text{No. of errors})}{3}.$$

[3] Tables of means and standard deviations for the pretests and posttests for each of the six experimental groups using both types of copy are available from the senior author.

formed which incorporated the following independent variables: keyboards (i.e., pretest trials on standard or modified configuration), copy, amount of change, and load. The results of these analyses for GWPM and number of stroking errors are reported in Table 3.

The main effect of keyboards was the most important source of variation in both analyses. A substantial decrement in speed ($\bar{X}_{\text{diff}} = -20.4$ GWPM) and accuracy ($\bar{X}_{\text{diff}} = 15.61$ stroking errors) was indicated by the significant ($p < .01$) keyboard main effect. Computation of ω^2 revealed that more than 30% of the criterion variance could be accounted for by the changeover in keyboards.

The decrement in both speed and accuracy was found to be related to the number of keys reversed. The significant Keyboard × Amount of Change interactions observed in both analyses are plotted in Figure 1. Inspection of these plots revealed that the size of the decrements increases as the number of letter interchanges incorporated in the modified keyboard configuration increases. The ω^2s revealed that these interactions accounted for 6% and 7% of the speed and accuracy criterion variance, respectively.

The finger load variable did not emerge as an important factor in these two analyses. Although there was a slight tendency for better speed and accuracy on high-load keys, the load variable did not represent a significant influence on the results.

Finally, the main effect for copy was statistically significant ($p < .01$) for the GWPM only, and accounted for approximately 11% of the speed variance. Also, the copy factor entered into a number of statistically significant interactions with the load and amount of change variables on the GWPM criterion. However, the ω^2s revealed that less than 1% of speed variance could be accounted for by these second-order interactions.

TABLE 3

ANALYSIS OF VARIANCE ON PRETEST DATA FOR STANDARD AND MODIFIED KEYBOARDS USING GROSS WORDS PER MINUTE (GWPM) AND NUMBER OF STROKING ERRORS

Source of variation	df	GWPM		Stroking errors	
		F	ω^2	F	ω^2
Between subjects					
Amount of Change (A)	2	18.66*	.06	18.73**	.08
Load (L)	1	3.66		.84	
A × L	2	1.15		1.30	
Error	109				
Within subjects					
Copy (C)	1	922.68**	.11	.00	
C × A	2	7.03	<.01	.93	
C × L	1	6.46	<.01	.13	
C × A × L	2	1.82		1.07	
Error	109				
Keyboards (K)	1	989.62**	.48	198.89**	.33
K × A	2	66.91**	.06	23.34**	.07
K × L	1	0.42		1.07	
K × A × L	2	2.02		2.31	
Error	109				
C × K	1	42.23**	<.01	1.21	
C × K × A	2	25.83**	<.01	.52	
C × K × L	1	2.52		1.04	
C × K × A × L	2	.61		.74	
Error	109				

* $p < .05$.
** $p < .01$.

Effects of 2 Hours of Practice on the Performance with the Modified Keyboards

To assess the effects of the 2 hours of practice provided each subject on the modified keyboard, a 2 × 2 × 3 × 2 analysis of

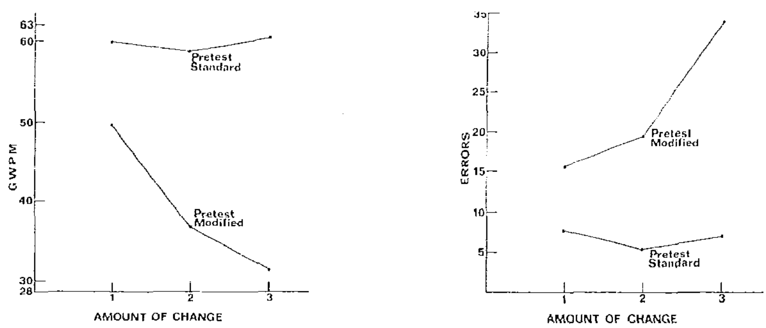

FIGURE 1. The Keyboard × Amount of Change interactions for both the gross words per minute (GWPM) and stroking errors criteria on the pretests with the standard and modified keyboards.

TABLE 4

ANALYSIS OF VARIANCE ON PRE- AND POSTTEST DATA ON THE MODIFIED KEYBOARDS USING GROSS WORDS PER MINUTE (GWPM) AND ERRORS

Source of variation	*df*	GWPM		Stroking errors		Interchange errors	
		F	ω^2	*F*	ω^2	*F*	ω^2
Between subjects							
Amount of Change (A)	2	65.36**	.33	30.75**	.19	53.89**	.26
Load (L)	1	3.47		.31		.59	
A × L	2	1.14		1.23		1.60	
Error	109						
Within subjects							
Copy (C)	1	737.75**	.15	1.77		1.07	
C × A	2	32.48**	.01	4.85**	<.01	4.28	<.01
C × L	1	7.32**	<.01	.00		1.88	
C × A × L	2	1.87		1.29		.16	
Error	109						
Keyboard Trials (K)	1	180.47**	.09	66.46**	.12	88.07**	.13
K × A	2	8.44**	<.01	6.81**	.02	11.74**	.03
K × L	1	1.37		1.95		3.29	
K × A × L	2	3.41*	<.01	3.24*	<.01	5.45**	.01
Error	109						
C × K	1	9.17**	<.01	.07		.31	
C × K × A	2	4.55*	<.01	.97		.66	
C × K × L	1	2.20		.43		1.91	
C × K × A × L	2	3.40*	<.01	.37		.11	
Error	109						

* $p < .05$.
** $p < .01$.

variance was conducted. The independent and dependent variables were the same as in previous analyses except that the keyboard variable represented the pretest and the posttest trials on the modified keyboard. The results of these analyses with the GWPM and stroking errors criteria are reported in Table 4.

It is apparent that the most significant influence on the speed and accuracy of typing on the modified keyboards was the amount of change variable. The differences among these means in terms of GWPM ($\bar{X}_1 = 51.6$; $\bar{X}_2 = 41.0$; and $\bar{X}_3 = 35.5$) were significant ($p < .01$), with amount of change accounting for 33% of speed variance. Amount of change accounted for 19% of accuracy variance as defined by stroking errors. Lower speed and poorer accuracy were the results of each additional key reversal.

The 2 hours of practice resulted in significant overall improvement in both speed and accuracy. The average increase of 6.6 GWPM revealed on the posttest was significant ($p < .01$) and indicated that the keyboard trials accounted for 9% of speed variance. Similarly, 12% of accuracy variance was accounted for by a significant ($p < .01$) average decrease of 8.81 errors following practice.

Although statistically significant ($p < .01$) in terms of both dependent variables, the Keyboard Trials × Amount of Change interaction did not account for much criterion variance. However, examination of plots of these interactions revealed that the biggest improvements in both speed and accuracy were made by subjects assigned to the keyboards with three pairs of interchanges.

The main effect for copy was statistically significant ($p < .01$) only in terms of GWPM (for standard copy, $\bar{X} = 47.4$; for contrived copy $\bar{X} = 38.7$), and it accounted for 15% of the speed variance. The copy variable entered into a variety of significant second- and third-order interactions, but these interactions did not account for more than 1% of criterion variance.

Table 4 also contains the results of the analysis of variance using the number of interchange errors as the dependent variable. The pattern of results observed was virtually the same as that obtained using the previous accuracy criterion.

Discussion

The presentation of results was organized around discrete analyses on portions of the data. However, certain patterns of significant relationships emerge when the three major analyses are viewed together. Clearly, the amount of change variable was the most important keyboard feature in determining initial decrements in speed and accuracy when subjects were transfererd to experimental typewriters. Also, the relative recovery of original levels of typing speed and accuracy was a function of the number of keys reversed on the typewriter on which the subject practiced for 2 hours. The posttest GWPMs on the modified keyboard were 89.0%, 76.2%, and 64.1% of the pretest GPWMs on the standard keyboard for the one-, two-, and three-pair reversals, respectively. Similarly, accuracy scores (stroking errors) on the posttest with the modified keyboard were 144.8%, 210.6%, and 277.0% of pretest errors on the standard keyboard for the one-, two-, and three-pair reversals, respectively.

Therefore, the amount of change variable deserves additional research, especially studies designed to determine the effects of more than three pairs of key reversals. Furthermore, alternate methods of operationalizing the amount of change should be tested. The present study dealt only with reversals of keys normally typed by the same finger, that is, "intrafinger" changes. Other studies should focus upon the impact of change(s) across fingers, that is, "interfinger" change.

Taken as a whole the results suggested that the load factor is not an important consideration in selecting letters when designing a modified keyboard configuration. Although the overall means for speed and accuracy on the high-load interchanges reflected in every case slightly better performance than the corresponding means for the low-load interchanges, the load main effect was not involved consistently in any important statistical interactions of variables. Consequently, it appears as though finger load should not be a major consideration when choosing the keys to incorporate into the design of a modified typewriter keyboard.

The means of both criterion measures reflected better typing performance on the standard prose copy than on the contrived copy. However, the copy variable had its most important influence on speed, not errors, as revealed by the relative magnitudes of the ω^2s computed. In addition, significant Copy $\times$ Amount of Change interactions on both criteria suggested that differences between standard prose and contrived copy as measured by speed and accuracy were larger for one-pair than for three-pair changes. Therefore, the kind of copy may not be an important consideration for typists attempting to learn new stroking habits on keyboard configurations involving substantial modification (e.g., three or more pairs of key reversals). It is possible that the particular content of the contrived copy, that is, the number of occurrences of each of the interchanged letters, might have an effect on the results. Future researchers might wish to investigate this possibility.

Finally, a number of issues involving the variables investigated in the present study require additional research. First, the generality of the observations documented in this study is open to question until further empirical work tests for the same relationships among the same independent and dependent variables. Specifically, the levels of the variables investigated in the present study were confounded with the particular keys selected for change. So, for example, the one-pair change was implemented by interchanging only a particular set of keys (the J–U for the high-load condition and the K–I for the low-load condition). Other studies should be conducted which utilize a variety of keys at each level of the amount of change variable to insure that the observed relationships are not specific to the particular experimental keyboard configurations utilized in this investigation.

Second, complete information regarding the important issue of retraining could not be supplied in the present work. The 2 hours available to conduct the experiment did not provide sufficient time to observe the amount of practice required to regain original levels of speed and accuracy. Since the matter of retraining experienced typists on simplified keyboards is a crucial factor in the marketability of a revised typewriter, experiments on the parameters of typing should be of longer duration in order to plot the recovery time and to investigate whether the revised keyboards permit users to surpass their original levels of proficiency.

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