COMPARISON AND EVALUATION OF FACTORS AFFECTING TYPING SPEEDS ON TOUCHSCREEN KEYBOARDS

Siddharth Ghoshal
Research Scholar, M. Tech, Manufacturing and Industrial Engineering, Mechanical Department, Suresh Gyan Vihar University, Jaipur, Rajasthan (303023)

Kshitij Shringi, Prashant Rattan and Kuldeep Gudhainiya
Student, B. Tech, Mechanical Engineering, Jaipur Engineering College and Research Center, Jaipur, Rajasthan (302022)

Antariksha Verma
Assistant Professor, Mechanical Engineering, Mechanical Department, Suresh Gyan Vihar University, Jaipur, Rajasthan (303023)

ABSTRACT
With the introduction of touchscreen keyboards, the world of typing has taken a fundamental shift. Touchscreen keyboards have not only decreased maintenance, but have also been of practical use in many devices that are being used in modern electronic market. Touchscreen keyboards have already been billed as the future of keyboards; hence it becomes vital to study the various factors that affect the speed of typists on touchscreen keyboards to make them better and more viable for them to replace hard keyboards in the future. The paper tries to examine the effect of home row positioning, tactile feedback and auditory feedback on the typing speeds of the users.

Key words: Typing Speed, Keyboard Ergonomics, Touchscreen keyboard, Hard Keyboard, Tactile Feedback, Auditory Feedback and Home row positioning.

1. INTRODUCTION
In my previous research paper, it was observed that the individuals typed faster on landscape layout than on the portrait layout. (Siddharth Ghoshal and Gaurav Acharya 2015, Comparison of typing speeds on different types of keyboards and the factors affecting it. International Journal of Mechanical Engineering & Technology (IJMET). Volume: 6, Issue: 6, Pages: 87-94.) This experiment was done to check if the addition of key stroke auditory feedback or home row positioning information (one or both) increased the speed of typing when used by experienced touchscreen keyboard users. In total there were two types of feedback and two types of positioning information (factor one and factor two). All these factors were crossed with each other leading to a total of four factors. They are:

1. Touchscreen keyboard with no position or no auditory feedback
2. Touchscreen keyboard with auditory feedback but no position feedback
3. Touchscreen keyboard with home row positioning and no auditory feedback
4. Touchscreen keyboard with both feedbacks

All the participants in the experiment were asked to type each set of sentences mentioned above, in all the four different set ups mentioned. The average speed of typing registered for all the set sentences were measured for and they were all averaged across the participants within the defined set of conditions.

To determine if auditory key strike feedback and home row positioning affects the performance of the typist; the movement time and the time difference between two strokes were measured. On one hand, it is hypothesised that typists using touchscreen keyboards with home row positioning information will check less frequently at the top row or the bottom row while typing. Also, they will be able to use this information to direct their hand movements. On the other hand typists who are using touchscreen keyboard without home row positioning will have to check evenly for their positioning on the top and the bottom rows. As such, with auditory key stroke information being important, touchscreen keyboards with this will process quicker for the typist, while touchscreen keyboards without this would have longer key stroke timings. This is in accordance with the fact that the typist would be assured that his finger has landed on the key. Overall both auditory information and the positioning information will reduce the scanning time and the typing speed of the subject.

2. METHOD
2.1. Participants
The total number of participants for the experiment were 24. The average age of the participants were between 22 to 35 years of age. All of the participants were experienced in touchscreen keyboard typing and hard keyboard typing. Yehene, Gopher, Erev and Yechiam in 2003 had reported that the average typing speed of touchscreen typists were 60 to 70 words per minute. Also, the corresponding figure for experienced, visually guided typists was between 30–40 words per minute. On the basis of given literature values it can be assumed that our subjects can type as much as 60 words in every minute using a standard keyboard used in office and their home premises. Also every participant had worked for at least five hours typing on an iPad touchscreen keyboard due to the nature of their job profile and systems provided to them from company.
2.2. Stimuli
A total of 5 sentences in four sets (W to Z) were used.

W (27 Words, 129 Characters)
- If you ask about their
- Education, they pin you to
- The wall. It’s one of those
- Things that run deep with
- How do you do this without

X (26 Words, 129 Characters)
- people. Am I right?
- Like religion and money and
- I, you and all of us have
- an huge interest in education
- children are very hard to

Y (25 Words, 134 Characters)
- because it’s one of those
- things that will lead us
- to the future. If you
- think of it, students starting
- pleasing anybody is never easy

Z (30 words 142 Characters)
- don’t know what the world
- will look in like five years
- time and tide waits for no one
- Yet we are getting educated
- for no one will and is coming
- Don’t know what the world

Table 1 Sentence Characteristics used for Second Experiment

<table>
<thead>
<tr>
<th>Passages</th>
<th>Number of Sentences</th>
<th>Sentence Min Length (Letters)</th>
<th>Sentence Max Length (Letters)</th>
<th>Sentence Average Length (Letters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>5</td>
<td>23</td>
<td>27</td>
<td>25.8</td>
</tr>
<tr>
<td>X</td>
<td>5</td>
<td>20</td>
<td>29</td>
<td>25.8</td>
</tr>
<tr>
<td>Y</td>
<td>5</td>
<td>22</td>
<td>30</td>
<td>26.8</td>
</tr>
<tr>
<td>Z</td>
<td>5</td>
<td>26</td>
<td>30</td>
<td>28.4</td>
</tr>
</tbody>
</table>

In the table above, all of characteristics of the sentences in all the sets are given. Maximum length referred to longest character count and minimum length to shortest
count and average length to average count in every set of sentences. All the other characteristics are shown in table 2. The table shows the comparison of sets in terms of letter counts in every word.

**Table 2** Sentence Characteristics in terms of Letters

<table>
<thead>
<tr>
<th>Passages</th>
<th>Total Words</th>
<th>Min Length Word(Letters)</th>
<th>Max Length Word(Letters)</th>
<th>Avrg Length Word(Letters)</th>
<th>Total Unique Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>27</td>
<td>2</td>
<td>9</td>
<td>5.74</td>
<td>24</td>
</tr>
<tr>
<td>X</td>
<td>26</td>
<td>1</td>
<td>9</td>
<td>5.31</td>
<td>24</td>
</tr>
<tr>
<td>Y</td>
<td>25</td>
<td>2</td>
<td>8</td>
<td>5.03</td>
<td>24</td>
</tr>
<tr>
<td>Z</td>
<td>30</td>
<td>2</td>
<td>8</td>
<td>5.37</td>
<td>25</td>
</tr>
</tbody>
</table>

It is essential in terms of the standpoint of being able to generalize the result that all the letter frequency of sentences in every set being more or equal to the letter frequency in the larger population (Mazyner & Tresselt in 1965). The table below (Table 3) provides the letter count in every set and correlation with the same in the corpus used by Mazyner & Tresselt in 1965. The results show a high degree of correlation with the minimum and maximum values. This shows that the behavior observed in the experiment will be same as in the outside world.

**Table 3** Results of Correlation between Passages

<table>
<thead>
<tr>
<th>Passages</th>
<th>Total Letters</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>129</td>
<td>0.9501</td>
</tr>
<tr>
<td>X</td>
<td>129</td>
<td>0.8909</td>
</tr>
<tr>
<td>Y</td>
<td>142</td>
<td>0.8969</td>
</tr>
<tr>
<td>Z</td>
<td>134</td>
<td>0.8399</td>
</tr>
</tbody>
</table>

All the letter frequency from the sets was added and chi-square test was done to compare the letter frequency of the sets with those of Mazyner & Tresselt in 1965. In particular Nij be the observed number of characters in i^{th} position of the alphabet for both the sets (j=1) or Mazyner & Tresselt (j=2). Also pij will show the predicted proportion of the alphabets (Mazyner & Tresselt in 1965), n will be the total number of characters which are in the sets. The chi-square can be calculated as follows...
Comparison and Evaluation of Factors Affecting Typing Speeds on Touchscreen Keyboards

\[ X^2 = \sum_{j=1}^{2^6} \left[ \frac{\sum_{i=1}^{2}(N_{ij} - nP_{ij})^2}{nP_{ij}} \right] \]

I will define the null hypothesis as given below.

H\(_0\): There is no significant difference statistically between the corpus used in Mazyner & Tresselt in 1965 and the one used in second experiment.

Chi-square statistics were calculated for all the four sets and, in all the four sets the value of \( p \) is greater than 0.05. As a result, the null hypothesis cannot be rejected (even though the passage W is mildly significant). In every case the relation is shown to be very strong, this implies that the sample data taken is reliable on the basis of previous study by Mazyner & Tresselt in 1965. A 95\% confidence interval was used during the test. Table 4 shows the results. All the sets show a higher \( p \) value, than our level of significance. The last column (Cramer’s V) shows the correlation strength between the letter frequencies used by Mazyner & Tresselt in 1965 and the text sets letter frequency.

<table>
<thead>
<tr>
<th>Passage</th>
<th>Value</th>
<th>Df</th>
<th>p</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>368</td>
<td>320</td>
<td>0.049</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>419</td>
<td>394</td>
<td>0.101</td>
<td>0.979</td>
</tr>
<tr>
<td>C</td>
<td>368</td>
<td>351</td>
<td>0.150</td>
<td>0.976</td>
</tr>
<tr>
<td>D</td>
<td>393</td>
<td>371</td>
<td>0.210</td>
<td>0.972</td>
</tr>
</tbody>
</table>

2.3. Apparatus
In the tests an Apple iPad 2 Touchscreen Keyboard and a standard Hard Keyboard have been used. Small dotted stickers were put in on the touchscreen keypad to show home row positioning. The audio feedback was enabled by turning on the audible key click feature.

2.4. Design of Experiment
In all the four conditions (the conditions were obtained by crossing present and absent of both tactile and auditory feedback).

1. Audio feedback and positioning information (F-P)
2. No audio feedback with positional information (no F-P)
3. Audio feedback with no position information (F-no P)
4. No audio feedback and no position information either (no F-no P)

It is important that the conditions are counter balanced across all the participants. With 24 different possibilities coming out of 4 different conditions; one condition was used for every participant. In the same way, it was necessary that the sets were all
counter balanced so that all the sets appear equally often in both positions and conditions. The table below shows in what exact way the sets were given to the participants. As we can easily observe that every set occurs equally in every position. In every condition the participant had to type the sets W and Z in a different ordering as a result, all the twenty sentences were typed in every condition mentioned.

**Table 5 Condition Counterbalancing**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Order of Sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I) (II) (III) (IV)</td>
<td>X Z W Y Z Y X W W X Y Z Y W Z X</td>
</tr>
<tr>
<td>(I) (II) (IV) (III)</td>
<td>X Z W Y Z X W Y Y W Z X W X Y Z</td>
</tr>
<tr>
<td>(I) (III) (II) (IV)</td>
<td>X Z W Y W X Y Z Z Y X W Y W Z X</td>
</tr>
<tr>
<td>(I) (III) (IV) (II)</td>
<td>X Z W Y W X Y Z Y W Z X X Z W Y</td>
</tr>
<tr>
<td>(I) (IV) (II) (III)</td>
<td>X Z W Y Y W Z X Z Y X W W X Y Z</td>
</tr>
<tr>
<td>(I) (IV) (III) (II)</td>
<td>X Z W Y Y W Z X W X Y Z X Z W Y</td>
</tr>
<tr>
<td>(II) (I) (III) (IV)</td>
<td>Z Y X W X Z W Y W X Y Z Y W Z X</td>
</tr>
<tr>
<td>(II) (I) (IV) (III)</td>
<td>Z Y X W X Z W Y Y W Z X W X Y Z</td>
</tr>
<tr>
<td>(II) (III) (IV) (I)</td>
<td>Z Y X W W X Y Z Y W Z X X Z W Y</td>
</tr>
<tr>
<td>(II) (III) (I) (IV)</td>
<td>Z Y X W W X Y Z X Z W Y Y W Z X</td>
</tr>
<tr>
<td>(II) (IV) (I) (III)</td>
<td>Z Y X W Y W Z X X Z W Y W X Y Z</td>
</tr>
<tr>
<td>(II) (IV) (III) (I)</td>
<td>Z Y X W Y W Z X W X Y Z X Z W Y</td>
</tr>
<tr>
<td>(III) (I) (II) (IV)</td>
<td>W X Y Z X Z W Y Z Y X W Y W Z X</td>
</tr>
<tr>
<td>(III) (I) (IV) (II)</td>
<td>W X Y Z X Z W Y Y W Z X Z Y X W</td>
</tr>
<tr>
<td>(III) (II) (I) (IV)</td>
<td>W X Y Z Z Y X W X Z W Y Y W Z X</td>
</tr>
<tr>
<td>(III) (II) (IV) (I)</td>
<td>W X Y Z Z Y X W Y W Z X X Z W Y</td>
</tr>
<tr>
<td>(III) (IV) (I) (II)</td>
<td>W X Y Z Y W Z X X Z W Y Z Y X W</td>
</tr>
<tr>
<td>(III) (IV) (II) (I)</td>
<td>W X Y Z Y W Z X Z Y X W X Z W Y</td>
</tr>
<tr>
<td>(IV) (I) (II) (III)</td>
<td>Y W Z X X Z W Y Z Y X W W X Y Z</td>
</tr>
<tr>
<td>(IV) (I) (III) (II)</td>
<td>Y W Z X X Z W Y W X Y Z Z Y X W</td>
</tr>
<tr>
<td>(IV) (II) (I) (III)</td>
<td>Y W Z X Z Y X W X Z W Y W X Y Z</td>
</tr>
<tr>
<td>(IV) (II) (III) (I)</td>
<td>Y W Z X Z Y X W W X Y Z X Z W Y</td>
</tr>
<tr>
<td>(IV) (III) (I) (II)</td>
<td>Y W Z X W X Y Z X Z W Y Z Y X W</td>
</tr>
<tr>
<td>(IV) (III) (II) (I)</td>
<td>Y W Z X W X Y Z Z Y X W X Z W Y</td>
</tr>
</tbody>
</table>
Comparison and Evaluation of Factors Affecting Typing Speeds on Touchscreen Keyboards

2.5. Procedure
All the experiments were done with a total of 24 participants. The experiment was conducted in the following method:

1. All the participants were given a brief look into how the experiment is going to unfold.
2. The typing speeds on hard keyboard was measured and recorded.
3. All the subjects/participants were then judged on the four conditions that have been described above. An iPad 2 was used.
4. All the participants were to type the sets that were displayed on a graphical user interface and the resultant data related to every key press; key release and intervals between them were gathered. Every set was shown on the iPad screen placed above the keyboard. A total of three integrant were interacting with the participant.
5. Every event was shown using a flash card.
6. Every event noted down to ensure that inter keystroke timing, movement timing and task completion timing can be measured.
7. On completing a task a new condition booted for the subjects.
8. All the conditions were counter balanced and every set was presented in a random order to reduce the effect of practise.

3. RESULTS
For a short span of time, expert level typists on iPad behavior were judged in all the four given conditions. The conditions were:

1. Audio feedback and positioning information (F-P)
2. No audio feedback with positional information (noF-P)
3. Audio feedback with no position information (F-noP)
4. No audio feedback and no position information either (noF-noP)

The position information will be taken as a physical input which was provided by the dotted display that was put on the iPad. The beep sound provided by the iPad every time the figure hit the key was used for audio feedback. The software programming that has been done helps in returning every key stroke time. After a thorough data collection, tests were taken to evaluate various hypotheses. Finger movement and task completion times were thoroughly checked immediately as below.

3.1. One Finger Typing Movement Interval
As fore-mentioned this time is defined hereby as, the time taken to launch from $i$ to reach $j$ to reach the same finger. It doesn’t include the time used to press and release a key. As a result, it is not equal to task completion time. It is to be noted that the finger movement time was calculated across all the types on keys on a keyboard, which includes characters; numeric keys and pace keys as well. An attempt was made to calculate the time used when the participant was typing with both the single figure and multiple figures.

The outcome of one figure tying is shown below. The hypothesis stated that, audio feedback would have a strong effect on one figure tying, but position information could not matter. The table below shows that the fastest movements were recorded when key stroke auditory feedback was present and no home row positioning was involved whatsoever.
Table 6 Stats for Finger Movement

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-P</td>
<td>133.7</td>
<td>21.5</td>
<td>17</td>
</tr>
<tr>
<td>NoF-P</td>
<td>134.6</td>
<td>14.9</td>
<td>17</td>
</tr>
<tr>
<td>F-NoP</td>
<td>127.4</td>
<td>13.1</td>
<td>17</td>
</tr>
<tr>
<td>NoF-NoP</td>
<td>139.7</td>
<td>20.3</td>
<td>17</td>
</tr>
</tbody>
</table>

3.2. Multiple Fingers Typing Movement Interval

All the participants did not use only one figure during typing, in fact many of them used multiple fingers typing all at once while typing. This made it tedious and difficult to check the finger movement times of the participants. To understand this, it becomes important to break finger movements into three different ways.

1. The participant presses key 1 with 1 finger ($P_1$) and releases it ($R_1$) with the same finger and then reaches the second Key, Key 2 ($P_2$) using the same figure.

2. The participant presses Key 1 with 1 Finger, presses Key 2 with another finger, releases Key 2 with second figure and then releases Key 1 from 1st finger. It can be clearly seen that $P_2 \rightarrow R_1$ does not give the finger movement time, which by the way, comes out to be negative anyways. This happens because both the fingers of the participants/participant are working at the same time.

3. The participant uses the first finger to key 1, uses second finger to press Key 2, releases Key 1 and then releases Key 2. Again the value comes out to be negative and not correct thusly.

The figure shows all the three cases below:

![Figure 1 Illustration of the Cases Considered](image)

The sequence of the pressing and releasing of keys is an important aspect in the calculation of figure movement time. In the case which is same to the first case mentioned above, the calculation could be done as key press time for second key subtracted from the releasing them for the first key ($p_2 - r_1$). In other cases, it can be calculated in the way mentioned below.

One way to do this would be by calculating RFMT (Residual Finger movement Time). It will be equal to the time the participant spends between pressing $i$ & $j$. 

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moving their finger, by assuming that the typist has removed their fingers from \( i \) at a time, which would be equal to key depression time for \( i \). All the transition were checked and were grouped together under the first pattern to calculate the average finger movement time. A simple computation of the key depressing time was done using a simple algorithm.

Were

\[
i = \text{Rank of word} \\
N = \text{Number of character (total)} \\
P_i = \text{Key press time for } i. \\
\text{Total Occurrence} = \text{Number of times certain case comes in a task.} \\
\text{Total Depressing time} = \text{Key depressing interval} \\
\text{Average Key Depressing Time} = \text{Average time spent on pressing key}
\]

On obtaining the average, RFMT can be computed for all the transitions.

\[
\text{Data: Letter press time and release time} \\
\text{Result: Average key depressing time} \\
\text{while } i < N \text{ do} \\
\quad \text{if } P_{i+1} > R_i \text{ then} \\
\quad \quad \text{totalDepressingTime} = \text{totalDepressingTime} - P_i + R_i; \\
\quad \quad \text{totalOccurrence} += 1; \\
\quad \quad i++; \\
\quad \text{else} \\
\quad \quad i++; \\
\text{end} \\
\text{end}
\]

\textbf{Figure 2} Algorithm Used to find Key Pressing Time Derivation

Different factors and corresponding interaction on the finger movement time were evaluated using ANOVA (Analysis of variants). The presence of a variable 2x2 experimental design means a total of three hypotheses have to be tested. One is the interaction of effect of factors, while the other two are the main effect of them. The table below shows the result of the analysis. It can be seen that there is no effect of audio feedback, while it can be observed that a significant amount of effect has been registered due to position information. Therefore, it can be concluded that the braille display that was used (dot stickers) helped the participants/subjects, and reduced the finger movement interval. This is an important consideration for the two factor test. Although not significant in terms of data, it can be used to identify the source of the difference. From the results, it can be said that the participants performed the worst in the fourth condition, and the best in the first condition given to them. When we have only one cue; the physical cue is more helpful than the audio.

The interaction seems to have a strong influence on the figure movement interval. The line graph below shows the interaction. When the interaction is present, in some cases, it can veil the effect of one factor on different levels for the second factor. In the study it was observed that the strong interaction takes away the fact that audio

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feedback plays a significant role when home row positioning is present, but fails to do so when it is not the case.

Table 7 ANOVA Test Results for Residual Finger Movement Interval

<table>
<thead>
<tr>
<th>Source</th>
<th>Position</th>
<th>Audio</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Level 1 vs. Level 2</td>
<td></td>
<td>6.315</td>
<td>.019</td>
</tr>
<tr>
<td>Audio</td>
<td>Level 1 vs. Level 2</td>
<td></td>
<td>3.340</td>
<td>.076</td>
</tr>
<tr>
<td>Tactile * Audio</td>
<td>Level 1 vs. Level 2</td>
<td></td>
<td>4.050</td>
<td>.053</td>
</tr>
</tbody>
</table>

Figure 3 Line Graph for Interaction of Finger Movement

4. LIMITATIONS AND DISCUSSIONS

We opted for a different way of measuring the effect of both, the audio feedback and the home row positioning information. The measures were task completion interval (inclusive and excluding space bar), residual figure movement interval and figure movement interval. We could easily determine that position information had a significant effect in three out of the four (all excluding figure movement interval). Also, in three out of the four measures, auditory feedback had a large effect when it was coupled with home row positioning, rather than when it was not present at all.

The point to consider here is that if the figure movement intervals are an aberration then we need to consider the various types of feedback for every set of people. It must be recalled that the figure movement interval was checked for only one figure typist. An explanation as to why it had no effect or so when position information is present and a larger effect when it was not present can be given. It may be because of the condition that, when the subjects used only used one figure for typing, the combination of audio and tactile feedback is more confusing than, when compared with people who use two or more fingers. The combined feedback would have no effect for the typists who used two or more fingers when they were positioned on the home row. Also, to note is that when the fingers are placed on the home row, the typist already has position feedback, in such a case then, striking the key would not have any tactile feedback of use, only audio feedback. Now, when
talking about the one figure typist participant/s, when the home row key on striking would give both audio and position feedback, which can be confusing for them. This explanation though is post hock and cannot be evaluated though a design.

In my earlier paper we could see that clear limitations were created by the confusion of device with practice. In this, it did not happen, but we could see that there is a related limitation which has proven to be difficult in unravelling. All the participants in this experiment may possibly not have reached in between the sets because there were continuous changes amongst the four different kinds of conditions all together. What was observed here is the fact that the typist was switching continuously between different keyboards with different levels of feedback. We can state no conclusion as to whether the typist could have been faster or slower, if they were given an unchanged keyboard for a long period of time.

The second limitation we can talk about is the fact that only iPad 2 was used for a touchscreen keyboard. We already know that there are factors that affect the performance of every typist and these vary amongst touchscreen keyboards. As an example we can state that every key board manufacturer in the market uses its own footprint while creating a touchscreen device. The key size and the display quality all vary across the brands. As a result of which it could not be generalized with complete assurance that if position information is helpful and if at all audio information is more helpful with position information or without.

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