Ergonomic Soft Keyboard: Keyboard Arrangement vs. Key Shape

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ABSTRACT
As touchscreen devices become readily available to the users, different input methods are required to improve text entry speed by improving either the keyboard arrangement, key shape, or both. Using hexagonally shaped keys there is a higher improvement rate in text entry because users are less prone to make errors while inputting text. Participants also indicated that using the hexagonal keys they were able to increase their typing efficiency without requiring to edit their input frequently, whereas for keyboard layout the users are all accustomed to the standard QWERTY keyboard and find it difficult to immediately adapt to a new keyboard arrangement.

Keywords
Ergonomic soft keyboard, keyboard arrangement, hexagonal keys, key shape, touchscreen, soft keyboard

INTRODUCTION
Over the last few years, touchscreen technology has been rapidly improving with the creation of various smartphone and tablet devices. Users are increasingly using their keyboards on their respective devices from physical text input on laptops, to virtual text input using soft keyboards on their touchscreen devices. With devices such as the Surface Pro by Windows, there is also a variety of hybrid applications available, which have both soft and physical keyboard applications.

The standard keyboard arrangement that has been around for a very long time is the QWERTY keyboard. Users learn to type with this keyboard from the beginning usually starting from a very young age. Initially, the speed is quite slow, and with frequent use, the users adjust to this arrangement on a physical keyboard. The text entry speed increases once users become accustomed to the design and through practice.

On a physical keyboard or a larger touchscreen device such as a tablet, users can use multiple fingers to input text, whereas when it comes to smaller devices such as smartphones, users are more accustomed to input text using either one finger or two thumbs. This is a slow learning process and users eventually adapt to the use of the keyboard and increase their typing speeds with experts being able to type without looking at the keyboard using their muscle memory.

Unfortunately, the QWERTY keyboard layout has flaws. The arrangement of the letters on this keyboard has a large distance between the commonly used characters in the English language, which causes a “back and forth lateral movement [that] is more frequent over a greater distance than necessary” [1].

On smaller devices, it is not efficient to use squared keys because the key size is smaller in their natural orientation, which is generally in portrait mode in smartphone devices. The current universal key shape is a square and it wastes a lot of space than necessary. Using another key shape will not only allow us to efficiently use the space but also allow users to have more surface area when touching the required keys on smaller devices.

To decrease the distance between characters, we must design a layout where all the commonly used letters are grouped nearby and the uncommon characters are further away from each other. This is known as “ATOMIK”[1], which means that our soft keyboard layout is “alphabetically tuned”[1]. The ATOMIK keyboard is alphabetically tuned, which means that the beginning of the alphabet is grouped starting from the top left corner till the bottom right. [website] This will not immediately allow users to enhance their performance, but the long-term optimization is greater than QWERTY. The ATOMIK keyboard is designed to allow the keyboard to be treated as a molecule, and the individual keys as atoms “to allow an “atomic” interaction among the keys.” [website]

Currently, on handheld devices, it depends on the natural orientation of the device with the way a soft keyboard may be used by the user. There are two ways the input may occur: one finger input, or the two-thumb input. Users can either use the device in landscape or portrait mode. For devices like smartphones, generally users input text in portrait mode, and for tablets, users use it in the landscape mode. The keyboard arrangement should be optimal for both orientations.

Devices have currently been getting bigger in memory, but also bigger in size with the demand of larger screens. This may become a problem for people with smaller hands. With devices like the Google Pixel XL and various tablets, typing in landscape mode using the two-thumb method may be uncomfortable for users with smaller hands. In this case layout of the keyboard becomes very important to help increase the typing efficiency to complete certain tasks, such as texting a friend, or writing an email. Applications being used are adapted to work in both portrait and landscape modes. Using the QWERTY layout in landscape is difficult because the users must stretch or lift their finger to reach the middle characters, which decreases typing efficiency. The standard layout also requires users to move a greater distance than required because the common letters are spread out inefficiently.

As these devices are going through enormous upgrades, text input efficiency is becoming an important concept to users because these devices are readily available everywhere and frequently used to complete the task at school or for work.

For this study, users are assembled into two groups: experienced typists and beginners, which will be called experts and novices respectively. An experienced typist is someone who frequently uses devices that require text entry input such as laptops, smartphones, and tablets. Novices are defined as users who are learning to use these devices and have not been accustomed to the design. In recent years, novices are younger children who are still learning how to use these devices.

The design of the QWERTY keyboard has not been changed but there have been many research studies conducted to improve the efficiency of the text input for virtual keyboards to allow one hand typing or two-thumb typing. In the following section, we will be discussing the related work done on keyboard layouts.

RELATED WORK

Google’s swipe gesture has become a popular method of inputting text. The idea is to swipe across the keyboard to form a word. The user must lift their finger for the system to recognize the word and enter a space. This is a method to increase the efficiency of typing. The arrangement of the QWERTY keyboard is still a problem when it comes to swiping gestures because the user must swipe over a larger distance than required since the letters are spread apart in an inefficient manner. For beginners, this technique might be proved to be slow in adapting to not only the QWERTY keyboard design but also the method of inputting each word using swipe gestures. However, Google has been able to improve the error correction by designing the system in such a way that it will recognize the pattern of the gesture and output the word even if the user is making a lot of errors. “Determining the direction of a swipe gesture can include comparing a magnitude of a vertical displacement of the swipe gesture to a magnitude of a horizontal displacement of the swipe gesture” [4]. In this case, the key shape is not much of a big requirement, but the arrangement is. If the arrangement were to change and allow commonly used characters to be grouped together, then the vertical and horizontal displacement will decrease allowing faster input.

MacKenzie and Zhang discovered a way to predict the time it takes to tap a key given the previous key [3]. Keyboards generally use letters as well as the spacebar allowing us to use a 27 by 27 layout. To find the movement time one must use Fitts’s law[3] as shown in Figure 1.

$$MT = \frac{1}{4.9}\log_2\left(\frac{A}{W}+1\right)$$

Figure 1: Fitt's Law

They discovered that user’s entry rates are relatively higher in keyboards such as OPTI compared to the standard QWERTY keyboards once the user has practiced enough on the other keyboard arrangement. There is a 35% faster-predicted rate compared to the QWERTY keyboard.

Ronway and Sagaline [3] discovered that for gesture input the QWERTY keyboard design is inefficient as well as having a higher percent in error rates compared to the other available layouts. They also noticed that changing the key shape of the keyboard to hexagonal keys allow a better performance overall in all the keyboard arrangements.

Zhai, Hunter, and Smith also used hexagonal keys, which they discovered helped in efficiently using the given space in an application allowing a 50% improvement in the standard QWERTY keyboards, and also discovered a 100% improvement for the OPTI 2 keyboard. [14]

The Colemak keyboard shown in Figure 2 was designed for individuals who were accustomed to the QWERTY keyboards but frequently made many mistakes. The design is such that they replaced the caps lock key with another backspace key to allow users to be able to rectify their mistakes in a quicker and efficient manner [2]. This design will also help users to increase their input entry speed. The letters have also been rearranged to allow the more commonly used characters to be grouped closer together, and the least commonly used letters to be shifted further apart.

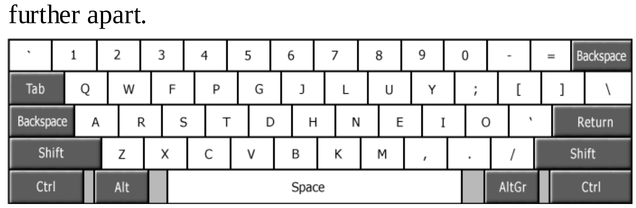

Figure 2: Colemak Keyboard

With the increase in smartphones and touchscreen technology, there has also been an increase in ways to input text. This can be ranged from using a stylus to write out the word, swipe gestures, or classical text entry with a soft keyboard. The idea is to make text entry convenient and efficient for all these methods of inputting text. A keyboard arrangement design should be created that works for all of these inputs.

With the creation of the Palm Pilot and the Graffiti digital alphabet, we note that it takes longer for users to input each word as well as to remember the new method of how each character should look like. The SHARK method is developed to create a minimum distance between characters to enhance the typing speed for users using the ATOMIK keyboard layout, which is proven to enhance the speed of the text input. “The atomic interactions among all of the keys drove the movement efficiency - defined by the summation of all movement times between every pair of keys, weighted by the statistical frequency of the corresponding pair of letters - towards the minimum.” [7].

METHOD

We conducted an experiment to test the different layouts for two-thumb typing method, which includes the standard QWERTY keyboard, the ATOMIK keyboard, and the QWERTY keyboard in landscape with a space in between as shown in Figure 4.

There are two versions of the keyboard, one has square keys and the other has hexagonal keys. This is to see if changing the key shape will help in improving the error correction rate and allow users to increase their typing speed for small, handheld devices. The hexagonal key shape design is implemented to help easily touch the surface of the required key without mistaking it for another key.

Participants

The experiment included 8 participants with the average age being 26 years. The users are all accustomed to the QWERTY keyboard layout because of the ubiquitous design available in every technology and operating system. The participants tested each of the keyboard designs with 5 trials per keyboard design to see the learning efficiency. Half of the participants own Android devices, and the rest own Apple iPhones of various generations. There was no incentive given for the participants to join the study.

Apparatus

The apparatus being used for this user study is a smartphone. The device was a *Google Pixel XL* running the *Android version 8.0.0*. The size of the phone is 6.0 × 2.9 inches [4], which does not include the size of the smartphone’s protective case.

The soft keyboard application was used as a demo program for EECS 4443, Mobile User Interfaces course at York University and was developed by Scott MacKenzie. The application for this experiment is using the demo program as a skeleton with additional details added to it such as the option to change the key shape, as well as additional keyboard arrangements like ATOMIK and the two QWERTY applications we are using for this study.

For the experiment, when the user opens the application they are prompted to the main settings page to enter their information as shown in Figure 3. The user is asked to input their initials and choose the keyboard layout along with the respective key shape, which the user will be testing.

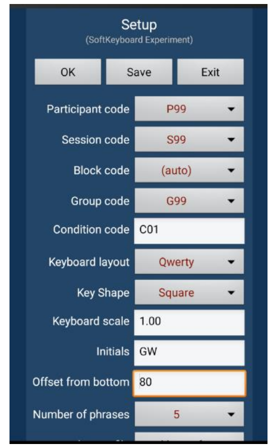

Figure 3: Settings Page of Application

This is one of the simplest stages because the program is just retrieving the user’s information as well as setting up the keyboard style by choosing the key shape, which could be either a hexagonal shape or a square shape. The keyboard layout has the styles discussed in the introduction, which includes the standard QWERTY layout, ATOMIK, and a landscape version of the QWERTY to make it easier for two thumbs typing as shown in Figure 4.

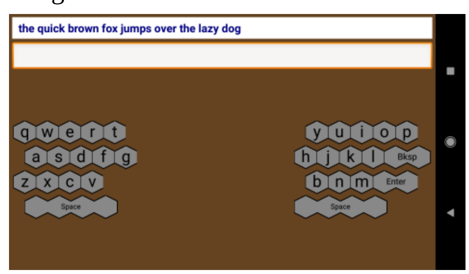

Figure 4: Landscape QWERTY2 With Hexagonal Keys

Once the user has completed testing the first trial of the keyboard layout, the user will obtain a dialog box which would indicate their typing speed in words per minute (wpm), as well as their error rate as shown in Figure 5.

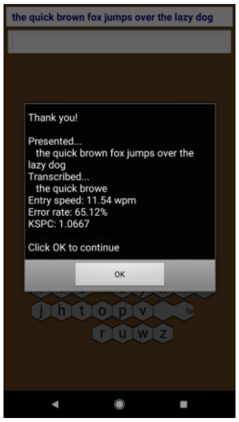

Figure 5: Dialog Box to Show Efficiency

Procedure

The participants were explained about the goal of the research, which is to determine if the keyboard arrangement is required to increase efficiency or the key shape and which have a quicker learning scope.

Once the participants completed the setup page, they were prompted to the keyboard layouts. Each participant had to do 5 trials per layout in both hexagonal and square key shapes.

The data of the trials were recorded using the timer in the application, and the averages were calculated manually. The user would have to complete the quick brown fox phrase perfectly and their time would be recorded. The user would be required to double check their sentence to ensure that if there is a typing error they rectify it immediately so only the typing speed could be seen.

Once the testing was complete the participants were asked which arrangement they enjoyed most, and what key shape they preferred.

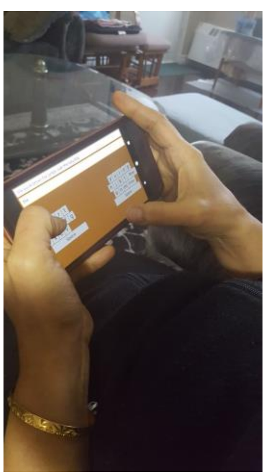

Figure 6: Participant using application

Design

The study was a 6 × 5 within-subject design. There were six independent variables:

- Input method (Key shape – square, hexagon, and keyboard arrangement – ATOMIK, QWERTY1, QWERTY2)
- Trials (1, 2, 3, 4, 5)

The dependent variables were the time of completion to write the quick brown fox phrase, and the error rate (number of errors made by the user to finish the phrase). One group was tested first on the square and then hexagonal key shapes. The other group was tested first on hexagonal then square key shapes. The keyboard arrangement was permuted as well with one user starting with the standard QWERTY design and then moving down the list, whereas another use was asked to start with the ATOMIK design.

The testing took approximately 20 minutes to complete per participant. The total number of trials was 8 × 6 input methods × 5 trials = 240 trials.

There were 4 male participants and 4 female participants.

RESULTS AND DISCUSSION

The users were given different orders to test out each of the keyboard layouts along with the key shape. This just helped to offset the balance of learning for the different types of keyboards. In the next few sections, the results for the entry speed per key shape and layout are given along with the improvement rate using the comparison between squared keys and hexagonal keys.

Entry Speed for Different Layouts

The overall mean for entry speed for all the layouts was 21.9 wpm. The three layouts that were used were Standard QWERTY and a thumb version for QWERTY that includes a space in the middle as shown in Figure 4.

There was not much of a difference between the two QWERTY keyboards, but we could see in Figure 7 that comparatively, the ATOMIK keyboard had a slow learning process.

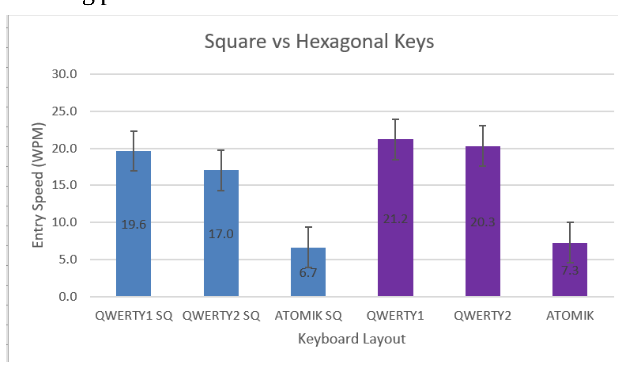

Figure 7: Keyboard Layout - Square vs. Hexagonal Keys

As shown above, we can see that there was a higher error rate in making mistakes using the square keys comparatively to the hexagonal keys, which are shown in purple, for all the given layouts.

Both Qwerty keyboards are faster compared to the ATOMIK keyboard design. Looking at Figure 8 for the learning progressing rate we can see that given the hexagonal keys, the users made fewer mistakes allowing them to learn faster compared to the squared keys. Another thing to note about the layout is that the rate for both the QWERTY designs seems to show similar entry speed rates. If the participants were given more time to adapt to the new ATOMIK layout, we would be able to see if there is a difference between the arrangements, and if the ATOMIK design has a faster performance rate. This is because the layout of the ATOMIK keyboard was designed to be more efficient and ergonomic compared to QWERTY since the keyboard is almost arranged in an alphabetic order starting from the top left corner to the bottom right corner.

Noticing how the efficiency was always greater using the hexagonal keys, we could see how this could be a huge improvement in increasing the user performance in text entry. This is a huge requirement for virtual soft keyboards because unlike physical keyboards, the users cannot use more than two fingers on smaller devices such as smartphones and are more likely to use two thumbs or one finger typing. On larger devices, the application has more space, which allows users to be able to accurately touch the squared keys, but on smaller devices applications must not waste a lot of space to increase efficiency, which is why squared keys do not work well with smaller devices such as smartphones.

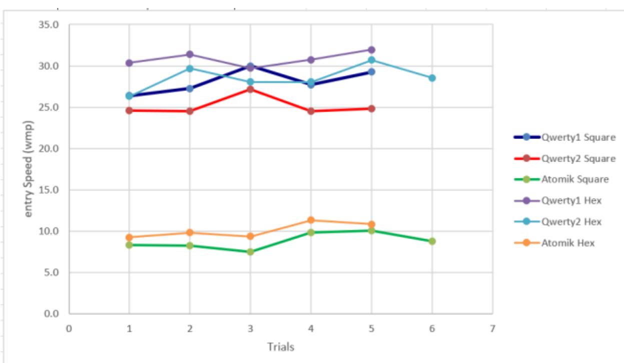

Figure 8: Learning progress for keyboard layouts

Compared to the squared keys, there was a 9.6% improvement rate for the standard QWERTY keyboard 13.94% improvement rate for the QWERTY2 design and a 14.77 improvement rate for the ATOMIK keyboard design using hexagonal keys.

Questionnaire

The users were asked a few questions regarding their usage of their mobile devices. It is seen that the users typically are all experts in using mobile devices, and type using the soft keyboard daily. The mean age group is 26 years of age, and most of the participants were in their early 20's. Their computer usage is an average of 4.5 hours a day, and the average of sending text messages or using their smartphone's keyboard is 71.25 messages per day.

Of all the users most use either iPhone, Samsung or Google devices and are familiar with the Android layout. Out of the 8 participants, 4 use Android devices and rest use iPhones.

At the end of the experiment, the users were asked which keyboard layout and key shape they preferred. All the users preferred the standard QWERTY layout, and prefer the QWERTY2 layout only for landscape mode, but also answered that they are least likely to use their keyboard in landscape mode because of their regular use of their mobile phones in their natural orientation.

In regards to the key shape, users were happier in using the hexagonal keys because they felt that they were making fewer mistakes than before and easily became comfortable with the new key shape. This helps prove that using a rounder shape, such as the hexagon, users are able to accurately press the desired key.

CONCLUSION

In this user study we noted that to create ergonomic soft keyboards for mobile user interfaces, it is more efficient to create keys that are hexagonal in shape. This is because it allows users to obtain surface space for their fingers, allowing them to accurately touch on the desired key. This can help novices who are in their early stages of adapting to the given keyboard arrangement, allowing them to easily enter text with fewer errors.

The keyboard arrangement showed no progress. Users required more time to adapt to the ATOMIK keyboard, so we could not see a higher learning curve than expected. However, the user study did conclude that to type in landscape mode, users require a different layout which decreases the amount the thumb needs to stretch for the keys in the center.

IMPROVEMENTS

The user study requires many improvements. To allow soft keyboards to be ergonomic and universal in nature, users must adapt to the other arrangements to show a better learning curve compared to the standard QWERTY keyboard. The user study should show the progress throughout a certain time period when the user has adapted to the other keyboard style, which could be the ATOMIK keyboard amongst others as well. This is because currently, all the users have adapted themselves to the standard QWERTY keyboard and it will take time for them to adapt to a newer layout to help improve efficiency.

Another improvement required for this user study is to test the layouts in both portrait and landscape mode to help determine which keyboard arrangement is more acceptable and has universal properties.

FUTURE WORK

Once the user study is improved, we can then use the new layouts and key arrangements to increase user efficiency for text entry. This is because smartphones and touchscreen devices are now available everywhere and we require a different way to input more data in a faster and efficient manner. The key shapes will allow the users to have less error and have a higher improvement rate, whereas the layout will help users to allow their fingers or thumbs to not move large distances across the keyboard.

The user study has determined that using hexagonal keys on smaller devices allows users to efficiently input text using the standard QWERTY keyboard. In future updates of the Android operating system, the keyboard design may change the key shape from square to hexagons allowing users to have more surface area to enter their desired key.

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