Evaluating Alternative Keyboard Layouts

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Finding a keyboard that is the most optimal and ergonomic for users is a question that has plagued HCI circles since the creation of the keyboard. From smartphones, tablets, and mobile gaming devices, to physical iterations of keyboards attached to laptops and slide-phones, the QWERTY keyboard continues to prevail in the global use of keyboards. This paper takes a look at a few alternatives to the QWERTY keyboard such as the Dvorak layout and evaluates their effectiveness against the QWERTY keyboard layout.

Additional Key Words and Phrases: keyboard layouts, optimization,

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1 INTRODUCTION

With the QWERTY keyboard layout being more than 100 years old [17] it is often discussed in HCI how to improve or change this keyboard layout to one that may be more efficient or ergonomic for the average user.

Keyboard optimization is the process of experimenting with unconventional keyboard layouts in order to establish more efficient use of keyboards as they are currently known. The topic of keyboard optimization has been discussed within HCI for a long time and many issues arise when this topic is discussed, including but not limited to: ergonomics of the layout, the efficiency of the layout, and fatigue generated by the layout among other issues. HCI greatly benefits this topic because the keyboard is one of the most focal points of technology interaction for humans and the use of HCI can allow us to study empirical differences in layouts. The goal of keyboard optimization within this study is to find a possible layout that allows one to write memos, emails, letters, etc more efficiently. Throughout the analysis of multiple studies, it has been well documented that the current popular keyboard layout (QWERTY) is not only sub-optimal but can cause issues such as fatigue [15]. Using 3 unique keyboard layouts, including the commonly seen QWERTY layout, this paper aims to evaluate possible alternatives in keyboard layouts that are both more ergonomic and more efficient when users type using these alternative layouts. This paper highlights experimentation performed in order to further a common understanding of a higher-performing keyboard layout that could benefit the technological sector greatly as the QWERTY layout has long been established an inefficient for typing by other related works. What this paper looks to analyze is the efficiency and error rate of the QWERTY keyboard when compared to other alternative keyboard

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layouts that could provide a better typing experience for keyboard users as technology becomes an ever-increasing important part of daily life around the world.

2 RELATED WORK

There have been various works that have focused on the design and development of keyboards in search of a more optimal layout that could be an improvement over the QWERTY layout, and many of them often are found to be more efficient than the QWERTY layout [25]. The proposed method for creating a superior layout lies around the way the user interacts with the specific layout.[8] This interaction between layout and user consists of the words per minute, amount of error, and consistency of typing without fatigue [6]. Other layouts would also take into consideration the fat finger problem when the user is typing on the display. To collect data on the user's progress on these aspects to later update the keyboard layout, the use of Fitts' Law played a large role. This provided the study with the amount of time it took each participant to complete an assignment on multiple layouts to determine the most optimal [16]. Works have also emphasized that the "fastest and most comfortable typing is assured when consecutive keys are not hit by the same hand." [4] . This has also been found to apply to fingers, as using the same finger to click two consecutive keys will never be the most optimal. The main issue with the touch screen or virtual keyboard is that the characters cannot be too large or else there is too much distance between characters.[7]. We should use the inflating type 1 error using MANOVA to get more accurate results when we run ANOVA [13]. We can also use MSD or Minimum String Distance Error which will help us calculate the error and also set the size of the keyboard so that it's reachable [20]. With these three we can enhance the results that we get from our project.

Other works have also found that with the introduction of new keyboard layouts to participants. Participants will often default to using their visual senses to find keys on the keyboard instead of using muscle memory as is often used by people who are more familiar with a certain layout, such as the QWERTY layout [10].

Many other studies have done a very similar experiment to us in that they have participants use unique keyboard layouts in order to determine which one may be an improvement on the QWERTY layout [24] among other reasons. These studies determine which layout tests appear to be the most efficient regarding WPM movement speed. The error rate is a metric that is often largely ignored in these studies as well [9] which will be addressed in this paper's experiment in order to get the most reliable data possible. Taking a look at machine learning to optimize keyboard layouts has also been a large part of prior work on the subject, including a novel approach to using a cyber-swarm method to generate experimental results that can outperform many traditional keyboard layouts and create both ergonomic and efficient keyboard layouts[23]. Some experiments have even gone as far as to test keyboard layouts in the context of a brain-machine interface which would enable people to interact with a computer hands-free while being able to use a virtual keyboard at the same time [18].

Moreover, a few related works have taken into consideration that the letter frequency is an important part of analyzing a keyboard to improve optimization. This letter frequency has to do with letters that appear consistently, as well as rarely. The consistently used letters, such as vowels should always be in plain view and easily accessible.[19]. the rarely used letters, on the other hand, could be placed in occupied places on the keyboard, such as places where the user's fingers mostly cover-up. The layout of each key also depends on the number of keys each finger is given to equalize the workload of each finger and maximize efficiency. For the quality of the layout, the little fingers are given fewer keys to reach to minimize their movement distance, which in turn decreases the delay of keystrokes. With a few other factors implemented, it was found that the Dvorak keyboard layout was the most comprehensive when the most frequent letters were in the home row position. This gave the user a greater freedom level with both hands, which almost produced a 50 percent use of each hand .[19]. This showed that the used layout on the Dvorak keyboard was almost in perfect balance when using both hands, which ultimately improved efficiency.

Another work that takes into consideration finger travel in keyboard layouts uses an optimization technique called Pareto front optimization. The finger travel like other works done before uses Fitts' law to record the speed of different layouts. Moreover, this optimization technique also relies on maximizing the familiarity of each key through the similarity of functions as the QWERTY keyboard .[3]. This similarity allows new users to adapt to the new keyboard layout quicker, which in turn produces more valuable data that can determine how well the optimized layout was. The rearranged keyboard also allowed for less neighbor key ambiguity, which included increasing the words per minute over time. This decrease in ambiguity also reduced the error rate, allowing the user to focus more on improving their performance. In the need, the new optimized layout performed similarly to the QWERTY layout which could change given a longer-term study.

There have been many performance limitations when it comes to implementing new virtual keyboard layouts. These limitations happen when researchers resize the keyboard, completely altering the arrangement of the keys, or even using different color schemes.[1]. This is done in hope of increasing typing speed and reducing error while still being comfortable for the user. The final layout that was incorporated to meet the criteria was the MT-TYPEHEX which had a layout that was different from the standard QWERTY layout. Even with the large difference the results of the research showed that it had a small learning curve. This allowed new users to become proficient in the new layout by investing a small amount of time in it. This was possible by arranging the keys in an easily accessible spacing and order for the user.

3 METHODOLOGY

The experiment involved implementing 4 keyboards, including QWERTY and Dvorak keyboard layouts. Each keyboard has a similar visual design but with specific key locations changed. The users will get a practice run to get familiarized with each format before we start collecting data on their input. A counter will catch any errors the user makes by keeping track of the times they use the backspace key. Below is a screenshot of the implemented QWERTY keyboard layout.

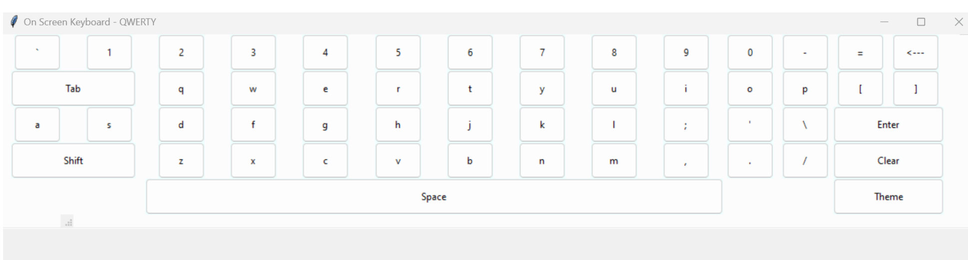

Fig. 1. QWERTY keyboard layout

The implemented QWERTY keyboard looks like a standard digital keyboard that might appear on a tablet or mobile phone in the QWERTY format. Compare this to the vowel keyboard layout below.

Fig. 2. Colemak Layout

As we can see in the Colemak layout and as mentioned in the paper the layout is slightly different but it has all the features that a normal QWERTY layout holds. If we pay close attention to our fingers we often go across the board and this layout is the newest among many to make the experience easier. Unfortunately, the shortcuts on normal QWERTY won't be applicable but after some practice, it turns into second nature.

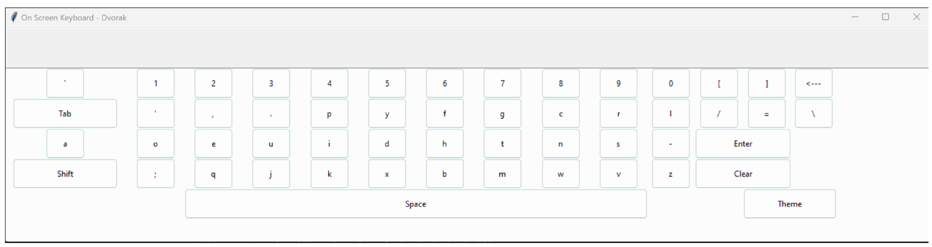

Fig. 3. Dvorak Keyboard Layout

The Dvorak keyboard layout is the complete opposite of the QWERTY layout in regards to which hand is mostly used for typing. Dvorak is designed for right-hand use, while QWERTY leaves most of the workload to the left hand. With the majority of people being right-hand dominant, the Dvorak layout would seem fitting and could potentially increase the user's words per minute, as well as limit errors once mastered.

There were a few early details that were changed as the experiment evolved. For example, it was originally decided that there would be three tasks for each participant to complete. However, after testing it ourselves we found that this took far too long with unfamiliar keyboard layouts and significantly cut down on the amount of actual typing on the digital keyboard for each participant in order to keep the experiment to a reasonable time frame.

Fig. 4. Dvorak Concise Keyboard Layout

We did have some alternative ideas when coming up with different layouts such as adaptive keyboard layouts[5]. Some of us even thought of breaking the barrier of traditional layouts and changing the dimensions completely[22]. While researching for the layout we stumbled upon a really interesting paper that had an interesting form of onscreen layout using a TV remote control [21] but since we were not sure how well it would gel with the theme we decided to mention it since the paper was pretty interesting in itself.

We also wanted to keep our layout keys size a bit more than 13mm [11] so we in fact hard coded it to a size that felt appropriate to use the layout at a good thickness.

3.1 Experiment Design

To begin the experiment each participant was given a physical content form which which allowed the subjects to provide their consent and allow us to proceed with the experiment for each individual subject.

Following the consent form, the participants were then moved to touch-screen laptops to begin the experiment. In order to effectively test the keyboards we gave each participant 10 minutes total to familiarize themselves with the keyboard layouts that were implemented in the experiment. This ensures that the participants are at least not coming into the experiment with zero experience in the keyboard layouts provided and know, to a small degree, about the placement of the keys in each layout. Following the 10 minutes of familiarization, the participants were asked to type text from a short story, called *"The Thirsty Crow"*, and recorded while doing this. The results of the typing were analyzed for accuracy (measured in the percentage of text not incorrectly typed) and speed (measured in time to complete the short story). All participants are given the same short story to type for each keyboard layout in order to not introduce noise into the experiment. The participants would do this 1-page test for each layout in order to gauge the speed at which the participant is able to type a page of information in addition to the accuracy in order to determine the keyboard with the greatest efficiency.

Following the typing portion of the experiment, the participants were given a digital form asking them questions about the experiment, including asking them to rate the layouts from best to worst, as well as subjectively comparing the layouts to the QWERTY layout. This enabled us to get an idea of the participant's preference for keyboard layouts.

4 RESULTS

4.1 Experiment Results

Completion of the experiment phase of this experiment led to some interesting data that was collected. This study took a look at three different metrics when collecting data from the experiment, those metrics being the average time taken to complete the short story provided to the participants as well, the number of errors each participant makes, and the accuracy of each user. The average time taken for each keyboard layout is as follows: QWERTY had an average time of 6:00.30, Dvorak had an average time of 10:01.30, and Colemak had an average time of 7:38.20. The accuracy of each participant on each keyboard is calculated by the following formula:

$$((TotalCharacters - Errors)/TotalCharacters) * 100 = Accuracy$$

The average accuracy for each keyboard layout tested is as follows: QWERTY with an average accuracy of 97.35%, Dvorak with an average accuracy of 97.57%, and Colemak with an average accuracy of 97.91%. The average errors for each keyboard are as follows: QWERTY with an average of 10.29, Dvorak with an average of 9.43, and Colemak with an average of 8.13.

4.2 Analysis of Results

When taking a look at the data collected from the experiment videos there are some conclusions about some pros and cons regarding each keyboard layout that can be drawn. Taking a look at the times specifically we can see that QWERTY had a fairly large lead on the other layouts in this category, being 1.5 minutes faster than Colemak and being over 4 minutes faster than Dvorak. One explanation for this large discrepancy can be attributed to QWERTY being the most used keyboard layout on keyboards sold today and in the last century. However, this doesn't explain the large gap between the Dvorak and Colemak layouts. Colemak is likely the better layout in this capacity as it clearly is easier to pick up than Dvorak due to the 2.5-minute average difference in the time that it took each participant to test the Dvorak and Colemak layouts.

When we take a look at the number of errors made on average for each of the keyboard layouts we find an interesting trend that deviates a bit from what one might guess which keyboard makes fewer mistakes. The QWERTY layout produced an average of 10.29 errors for the duration of the experiment. This is contrasted to the Dvorak and Colemak which made 9.43 and 8.13 errors respectively. This is surprising because even through QWERTY has long been established as the standard for keyboards it falls behind in the errors statistic that was collected. This suggests that Colemak are Dvorak are better keyboards for accuracy, Colemak is better than Dvorak in this regard. This data would be then funneled into accuracy which would show us that the QWERTY layout has a lower accuracy of 97.35% compared to Dvorak's 97.57% and Colemak's 97.91%. Based on the data presented above, it seems like QWERTY is currently the fastest keyboard layout due to its time, but Colemak is the better keyboard for accuracy. However, if we assume that each mistake takes a second or two to fix, it becomes clear that QWERTY is still a better keyboard in with the current information collected, though this would likely change if there was more time allocated to making sure that there was ample time to adapt to each keyboard layouts in a more long-term experiment.

4.3 Post-Experiment Questionnaire Results

The questionnaire that we provided to all participants of the experiment asked 12 questions to the participants about the experiment following their involvement in the experiment. Participants were asked to let us know what their thoughts on each of the keyboards based on ease of use and a few other questions. When participants were asked to rank the ease of each keyboard on a scale from 1 to 10, 10 being the easiest and 1 being the hardest the following was the average number that participants selected for each keyboard layout: QWERTY averaged an ease of use of 7.1, Dvorak averaged an ease of use of 4.6, and Colemak averaged an ease of use of 6.2 based on participant responses.

Participants were also asked the following questions: "Which layout did you find easiest to use?", "Which keyboard caused the most discomfort if any? (Physical or mental)", "Would you consider switching to any of the layouts you used?", and "How often did you find yourself hitting two or more consecutive keys with the same finger?". The "Which layout did you find easiest to use?" question received an unsurprising majority (6 out of 10) of participants selecting the QWERTY keyboard, likely due to familiarity with the layout. However, 3 of the 10 participants had selected Colemak as the easiest which is somewhat surprising considering that all participants were already familiar with the QWERTY layout and we had expected it to be almost unanimous that participants would respond with QWERTY. This can be likely attributed to the more balanced and less spread-out keyboard layout that Colemak is. The question "Which keyboard caused the most discomfort if any? (Physical or mental)" led to a unanimous response from participants that Dvorak produced the most discomfort, this was surprising as it was anticipated that there would be a more even split between Colemak and Dvorak due to them both being generally unfamiliar layouts for each participant. Asking the participants "Would you consider switching to any of the layouts you used?" received a fairly resounding no, with 6 people answering no, 3 answerings maybe, and only one answering yes. This was unsurprising as there was not enough time allocated to the experiment to give each participant a chance to truly become familiar with the layouts that were being tested (aside from QWERTY). This response set would likely change with more time given to familiarize participants with each keyboard layout.

5 ISSUES AND LIMITATIONS

There were were several issues encountered when the experiment was being conducted and it would be beneficial to discuss these in order to improve future studies regarding keyboard layouts.

When recording the screens of each participant we used a program called OBS (Open Broadcaster Software) to see how each participant was doing following the completion of the participants' experiments. This caused a couple of issues to arise later when reviewing footage and analyzing the data provided by these. One of the most notable of these issues was that for the first 2 participants, we forgot to click the record button on the software in order to go back and analyze the error count and accuracy, this was only realized after the participants had left so it would have been unrealistic to ask the participants to come back and spend another 40 minutes redoing the experiment. This likely would have also generated bad data as they would have been more familiar with the layouts already and that exposure would have led to slightly biased times and error rates. We still recorded the time for the participants but were unable to capture the error rate data for these two participants. One other issue that we ran into with the software was that there was a participant where the video that was used to collect the error rate data was corrupted for the first 2 layouts that the participant used. This led to us being unable to collect information for this participant for QWERTY and Dvorak error rates. We treated this data point as one similar to the aforementioned forgetting to record an issue in that we counted the time taken but did not take the error rate data from this participant as we did not have it. These issues could be negated by creating a program that has native functionality that would be able to record error rates. This would also save time that would be needed to go back and watch the videos of the participants, especially if the study has a larger participant pool than this experiment.

When choosing a testing location we were somewhat limited in our ability to acquire multiple rooms and as such we decided to run 2 experiments simultaneously for the majority of the participants. This did prove to introduce some noise into the experiment as there were a couple of times that we were conversing and occasionally the participant responded and was distracted by us and others outside the room where the experiments took place. We identified this as a couple of the participants did the experiment outside the original testing room and they performed generally better than those that did the experiment inside the testing room. The experiment would have likely produced less noise if there had been separate rooms for the participants and if we did not have conversations that may have distracted the participants.

Originally, there was going to be a pre-survey to ask people what experience they had using alternate keyboard layouts as well as how comfortable they are using virtual keyboards. This became an issue as, during the experiment, all of the experiment runners forgot to ask the participants to fill out the pre-survey that would give us this information so the idea of having one was scrapped from the experiment. It would be better to have one to get an idea of participants' ideas and preconceived notions of what the experiment would entail, leading to better data that could be collected.

Originally there were going to be 4 total keyboard layouts that would be tested for the experiment. However, communication between experiment runners occasionally faltered. This caused the experiment runners to implement two identical keyboards and this was only found out about halfway through the list of participants that would be tested for these layouts causing general improvement on the second test of the identical keyboard. This caused us to need to cut down on the number of keyboards that we would test from 4 to 3 and throw out some of the data that was already collected on the duplicated keyboard in order to prevent as much noise from entering the experiment as possible.

One of the major limitations in the effectiveness of this experiment was that there was simply not enough time to design, implement, and test this experiment to get optimal data from the experiment. In an ideal world, this experiment would take place over multiple days, perhaps even multiple weeks while asking the participants to use the keyboards as much as possible in order to have each user familiarize themselves with the layouts as much as possible. This would give a more concise idea of which keyboard is truly the most efficient and better if a user can be efficient in all keyboards tested because there would be familiarity with all of them and the participants would be able to type from muscle memory more reliably versus the one finger while constantly searching for the correct letter approach we saw with this experiment. A greater allocation of time would produce better and more reliable data that can be used to draw a better conclusion in a study similar to this.

This study did struggle to recruit participants to do the experiment, it was greater than some studies, like the study done by Anson et al regarding word completion and predictions using On-screen keyboards which recruited 7 participants [2]. Though we lack numbers compared to other studies, such as "*The Effect of Key Size of Touch Screen Virtual Keyboards on Productivity, Usability, and Typing Biomechanics*"[14] which has 21 participants and "*Influence of virtual keyboard design and usage posture on typing performance and muscle activity during tablet interaction*"[12] which has 18 participants. The study would greatly benefit from a expanded participant base in order to get more solid data. This experiment's 10 participant data set is not bad but certainly could be better

6 CONCLUSION

Having tested the three different keyboard layouts, it has been made clear that for this experiment the QWERTY layout remains superior in a sense of having the quickest time to complete a block of text. This can likely be attributed to having the layout be the most common layout among commercial keyboards since the keyboard has been invented. When accounting for mistakes (where the Colemak layout reigns supreme) and time to complete (where QWERTY dominates), it shows a clear divide in the current ecosystem that allows for the QWERTY to come out on top in a dramatic manner. Our hypothesis that QWERTY would not be the best keyboard in the study was mostly proven wrong but not completely proven wrong as the Colemak layout had a lesser degree of errors when tested on the participants. It would be beneficial for any following experiments to carry out a longer-term study on a greater participant population in order to truly get a solid understanding of which layout is the best for the end user, instead of following the status quo. This paper has highlighted that there is a case to be made for saying that the QWERTY layout is not the best layout overall because of the performance of the other layouts in the accuracy statistics. Overall, it was hard to call the experiment a success, yet it also is wrong to call it a failure, this paper has uncovered that the possibility of showing that QWERTY needs to have another look taken at it for the sake of the efficiency and ergonomics that the end user of the keyboard that may be getting fatigued and less efficient while using the well-established QWERTY layout.

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