A Comparison of QWERTY and Alphabetical Layout on Small Handheld Devices

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Abstract. The QWERTY keyboard layout is originally designed to solve problems occurred in mechanical typewriters rather than the digital devices. The dis-ordered characters are not appearing in the order the user learns the alphabetic order. Hence, novice users need to learn the device until improving the typing performance to the acceptable level. Designing the key arrangement in a keyboard needs to consider balancing the load between the right and left hand and the fingers, distance between the keys, size of the key and frequency of character. However, some of these parameters are not applicable for designing key layout for small handheld devices. Hence, we intend to study the usability effect of QWERTY layout in comparison with alphabetically order layout. We measured the typing speed using QWERTY layout as well as alphabetical layout that we developed in the virtual keyboard for the experiment. Ten expert users have been selected for the evaluation and we run five tests with each *test-user*. We measured the typing speed in character per second then adjusted against the error. The adjusted character per second for both key layouts was 0.52 acps. This typing speed was improved in the fifth pass to be 0.78 acps and 0.68 acps for the alphabetical and QWERTY layout respectively. Regarding accuracy, during the first run 96.279% for the alphabetical and 97.674% accuracy for the QWERTY layout has been recorded. While the users were more accurate on the QWERTY than the alphabetical layout during the first run, this was changed after the fifth run having 98.837% accuracy for the alphabetical and 98.372% accuracy for the QWERTY layout.

Keywords: Keyboard layout · Usability · Character input · Handheld devices

1 Introduction

Looking to the historical background of the QWERTY layout on a standard keyboard, it is possible to note that the intention was to improve the efficient utilization of mechanical typewriters but not that of digital devices. The QWERTY layout was engineered to avoid the key-jam that occurs when a new key pressed before the previous key arm returns. Since the key-jam occurs as the result of the alphabetical key arrangement, Sholes [1] solved this problem by experimenting with the most common English two-letter sequences and assigning the most frequent couples to opposite sides

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of the key layout. The Sholes design had a great initial advantage to be known by many users [1]. Further, it paved the way for the QWERTY layout to become and known as the "universal" layout in 1893. Sholes' solution was sound and greatly reduced the key-jam.

The new key arrangement (QWERTY) slower the speed of the typist (user) as well; and this means efficiency is affected. This is in contrary to the principles of usability engineering. In usability term, as the user learns the new product through time (see Fig. 1), the user's efficiency should improve and higher productivity shall follow (2).

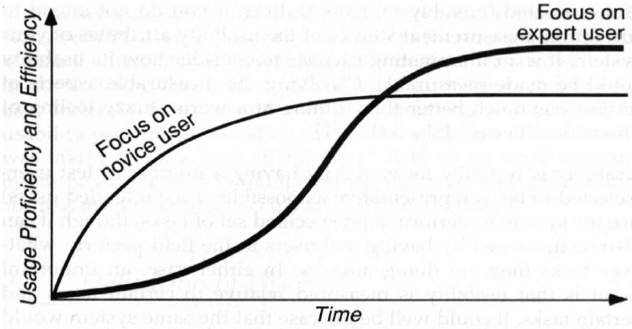

Fig. 1. Improvement on proficiency and efficiency over time [2]

In designing the key arrangement of a keyboard one needs to consider, at least.

- balancing the load between the right and left hand and the fingers,
- distance between the keys,
- size of the key and
- frequency of character (in particular language).

Some of these design goals are not applicable for designing key layout of small handheld devices. Also, the notion of the QWERTY design was to solve a problem in the context of mechanical machine (not digital). Regardless, the QWERTY layout has been adopted in digital devices; further to small handheld devices. Not only on the standard keyboard that is used with desktop personal computers but also in small handheld devices, as well as smartphones.

Hence, we intend to study the usability effect of QWERTY layout in comparison with alphabetically ordered key layout of small handheld devices. We consider comparing with alphabetically ordered layout since we hypothesize that users can perform well if the keys are arranged in the order they know. Knowing the alphabetic order would be a benefit from the cognitive perspective.

1.1 Designing Keyboard

As keyboard/keypad is widely used for inputting text in digital devices, its design might have positive or negative impact on the user interaction with the system – be it the software or the device itself. Primarily, the usability of a particular keyboard/keypad is the result of the key arrangement.

In addition to the QWERTY layout, various key layouts have been proposed. These proposals often consider the letter frequency with respect to a particular language as well as position of the control keys.

Letters Frequency in the Language. In older times, the Caligraph [3] has been designed with more keys than we know in QWERTY since there is separate key for both the uppercase and lowercase alphabet. This might improve the performance as the user doesn't require pressing additional key while shifting between the uppercase and lowercase. In the case of Dvorak keyboard, the key arrangement aims to identify most frequently used letters (A, O, E, U, I, D, H, T, N and S); and these letters are arranged in the middle row. In addition, common letter combinations are positioned in such a way that they can be typed quickly [1]. Colmak as well considers the frequency of letters in the text and puts the ten most common English letters on home row [4].

Letters Used as Control Key. While the frequency of letters in a particular language can be considered as one parameter for deciding the position of the key in the key layout, the letter function as a control key is also another dimension. For example, Colemak's design puts the ten most common English letters on home row considering their frequency in the language but keeps WAZXCV in place for the sake of shortcuts [4]. On the other hand, the Capewell design aims to reduces finger movement compared to Dvorak and designed Capewell-Dvorak. However the Capewell design, in addition to the frequency of the letters in the language, it also considers the function of the letters as a control key. As a result the modification of Dvorak moves ZXCV into QWER positions for the sake of the Undo/Cut/Copy/Paste shortcuts [1].

These kinds of design considerations are language dependent. For instance, the letters frequency varies between languages. Similarly, the use of uppercase and lowercase letters may not follow the same rule in all languages.

1.2 Performance and Accuracy of Keyboard Layouts

Norman and Rumelhart [5] present plausible explanation as performance measurement criteria and identified three factors that play a role in speed optimization:

- The loads on the right and left hands shall be balanced
- The load on the home row is maximized, hence most frequently used keys shall be placed at the home row
- The frequency of alternating hand sequences is maximized and the frequency of using the same finger for typing different characters shall be minimized.

The first factor is useful to improve the ergonomically design of the key layout. It is important to note that one of the HCI goals is making the system usable. That is, enabling the user to accomplish a task safely as well as easily, naturally, securely [6] and also with satisfaction. The other two factors are more related to efficiency and accuracy attributes of the Nelson model [2].

Efficiency is attributed to expert users and can be often valued to the experience and knowledge developed by the user while using a product. As the result, it is important to consider the user profile in the development of interaction modalities [7]. The user profile, however, not only related to the knowledge and experience but also attributes related to the psychological, social and physical state of the user.

Therefore, it is important to take into account the motor capability of the user in designing products (i.e., hardware or software). Such consideration can be useful to improve the efficiency as well as accuracy. In this regards, though it was originally meant to model movement in the physical world, Fitts's Law can be useful for designing. Fitts's Lawt provides a model of human movement, to explain and accurately predict the amount of time a human user needs to accurately select a target [8]. Fitts's Law has been formulated mathematically in a number of ways; and in designing the arrangement of keys in the keyboard it can be used to model the time that a person needs to touch a key accurately [9, 10].

This model is used to predict movement time and also to quantify the difficulty of a target selection task, which is termed as index of difficulty (ID); and it is shown in Eq. 1

$$ID = log_2\left(\frac{D}{w}\right) \tag{1}$$

The ID is determined using the variable D that is the distance between the current position and the target; and W, which is the size (width) of the target object. Considering this model in the design of key layout, for example, in order to type the letter 'v' and then 't', if the distance (center to center) between these keys is 4.0 cm; and if the width of the keys is 1.0 cm. Then ID will be 2.0. Similarly, if the width increases we get a smaller ID, indicating that the task is easier. If we apply a greater distance the ID will increase, meaning that the task has become more difficult. Therefore it is apparent that the performance and accuracy of the user can be equated to the way the key layout is designed. O'Riordan et al. [11] as well, indicates through their experimental research that users perform well on larger size computer keyboard than the smaller ones, but for the same key layout – QWERTY.

In summary, as keyboard is widely used being one form of text input modality, its usability apparently would have an impact on the system usability. Thus, it is worth to consider usable key layout design. Regardless, the adoption of the QWERTY layout to computers and then to small handheld might not consider the design factors above. In particular to the small handheld devices.

- Balancing the load between the two hands (eight fingers) may not be logical since users often use one or two finger/s (see Fig. 2).
- The size of the keys will be much smaller in small handheld devices and this would increase the ID.
- The frequency of the letters varies between languages but the order of the alphabetic order of the letters is similar, especially for those using Latin alphabet.

The adoption of QWERTY to the digital world is more of a coincidence but not founded on researched justification and it was without the profound consideration of the usability attributes. Or the adaptation has some logical flaw regarding the typing speed optimization.

(a) (b) (c)

Fig. 2. Text input – common hand-orientation (a) two hands one finger (b) one hand one finger (c) two hands two fingers

Therefore, it is worth to inquire the usability of QWERTY over the alphabetically arranged key layout to propose justified design factor for deciding the key layout. In particular, we focused on small handheld devices and experimented to compare the usability impact, regarding the efficiency and error attribute, between the QWERTY layout and an alphabetical layout. Furthermore, we hypothesize that the text input performance can be improved if the letters on the key layout are ordered as per the alphabet order that the users already learnt; and the error could be reduced.

In the next sections, first the method we applied to measure the performance as well as the error is presented. Then the result obtained and discussion of the result is presented consequently.

2 Methodology

Experimental research has been followed to evaluate the performance of QWERTY against the alphabetically ordered key layout. In the experiment, we first developed android application for smartphone that measures the time elapsed for typing a text. In the application, while the built-in virtual keyboard with standard QWERTY layout is used in one hand, we also developed another virtual keyboard with alphabetical layout for comparison. In the process, we also give due consideration on selection of the *test-users* as well as the *test-input*.

2.1 Test-Users

The main usability attributes considered in the experiment were efficiency and error. Hence we were supposed to select expert users for the test. By expert, we mean users who frequently use the standard key board designed for two hands (eight fingers) use. Therefore, we use purposive sampling and considered users who give secretarial services around secretarial shops that are found around courthouse; where typing is their daily job on which they earn their income. The sample is then further filtered by considering users who are experienced with QWERTY layout. Then, we evaluated users for 35 min using Mavis Beacon. This first experiment has been conducted in four sessions.

Three of the sessions were to measure the consistency of the typing speed as well as accuracy. Measuring the consistency was important since the selected *test-input* is shorter than the preliminary evaluation used for selecting the *test-users*.

On the fourth session, users were actually tested to evaluate their experience on the QWERTY layout, where users are asked to identify for the position of a letter in blindfold. Finally for the experiment, ten of the top scorers are selected as expert users.

2.2 Test-Input

As the objective of the experiment is to compare the QWERTY layout with the alphabetically arranged one, the appropriate text that should be used for test need to contain all the English alphabet while it gives some meaning to the user. The intention of using meaningful text is not to bias the psychomotor concern related to our case which intersects the cognitive functions and physical movement. Therefore, the *test-input* is selected to be "`the quick brown fox jumps over the lazy dog`".

Each *test-user* entered the *test-input* using both QWERTY and alphabetic of key layout in five passes but at different time interval. At each pass, the speed and the error were directly measured in the application we developed for this purpose. After collecting the physical measurement, the learnability as well has been analyzed based on the result obtained during the five passes for each layout.

2.3 Key Layout and Design Considerations

The conventional rectangular arrangement of key layout on a standard keyboard, which is roughly with three rows and 10 columns (forming 3 × 10 matrix) is meant to support typing with two hands (eight fingers for the letter and two fingers for space bar). This however is not optimal for small handheld devices as users enter text mostly using one-hand-one-finger, two-hands-one-finger or two-hands-two-fingers (see Fig. 2-a to Fig. 2-c respectively). If a 3 × 10 key matrix is kept, the distance between the key would increase. This means, the ID that would be calculated using Fitts' Law would increase (as discussed in Sect. 1.2) and the task would be more difficult.

Therefore, while designing the new key layout, we considered a 6 × 4 key matrix to minimize the maximum inter-key distance (see Fig. 3).

Fig. 3. Alphabetically arranged key layout

Also, as the thumb finger can be used for entering the letters, the *space bar* and other control keys, we placed the *space bar, delete* and *enter* key to be accessible from both the right and left side of the key layout.

3 Results of the Experiment

After *test-users* entered the *test-input* that contains 43 characters, the total time used for completing the task is measured and the errors has been counted for every wrong key the *test-user* entered. The *test-users* entered the *test-input* in five passes, at five separate time interval; and the average of the result of the ten users for each pass is calculated as shown in Table 1.

Table 1. Table captions should be placed above the tables.

Pass	Alphabetic layout				QWERTY layout			
	Time (S)	CPS	ACPS	Errors (%)	Time (S)	CPS	ACPS	Errors (%)
1	79.80	0.54	0.52	3.72%	80.90	0.53	0.52	2.33%
2	67.70	0.64	0.62	1.86%	69.10	0.62	0.60	3.95%
3	67.00	0.64	0.63	1.40%	69.00	0.62	0.60	3.26%
4	58.10	0.74	0.73	1.63%	63.80	0.67	0.66	2.33%
5	54.80	0.78	0.78	1.16%	61.80	0.70	0.68	1.63%

For comparing the typing speed, characters-per-second (CPS) is used as the unit or raw speed. The raw speed is calculated by dividing the length of the *test-input*, which is 43, by the average time. In this calculation 0.54 cps for the alphabetical layout and 0.53 cps for the QWERTY was recorded during the first pass.

However raw typing speed could be misleading. Hence it is important to consider only the accurately entered characters and this gives us the adjusted CPS (ACPS). As a result, for both the alphabetic and QWERTY layout, the ACPS was equal on the first run, while on the fifth run the result was found to be 0.78 acps and 0.68 acps for the alphabetic and QWERTY layout respectively.

4 Discussion

Looking on Table 1, it seems users perform well on the QWERTY layout than the new design during the first pass. However, it has to be noted that usability is not a one dimensional attribute. Other dimensions we need to consider is the learnability aspect.

The test-users are expert to the QWERTY layout and novice to the alphabetical layout. And, it is natural if the users are not performing well at the beginning (2). Novice users do not perform efficiently and could have more error when they are introduced to new product for the first time (see Fig. 1).

Therefore, it is important to discuss the result by looking on the change in performance through time. To do this, we computed the change in performance *(P)* by equating the improvement on the adjusted speed as the difference between the ACPS (i.e. denoted as S_n) measured at the each pass and the initial ACPS (i.e. denoted as S_0) that is measured at the initial pass. Thus the performance of a user with the alphabetic layout *(P_A)* is given by:

$$\Delta P_A = S_{An} - S_{A0} \quad (2)$$

And, the performance of a user with the QWERTY layout *(P_Q)* is given by:

$$\Delta P_Q = S_{Qn} - S_{Q0} \quad (3)$$

The initial ACPS *(S_0)* in both Eqs. 2 and 3 is 0.52 acps (see Table 1) but the value used for S_{An} and S_{Qn} for each pass varies so that the value of P varies in the rest of the passes.

After computing the performance for each pass to both the alphabetic and QWERTY layout, we have noted that the performance of the users improve more on the alphabetic layout as they learn more the layout (see Fig. 4).

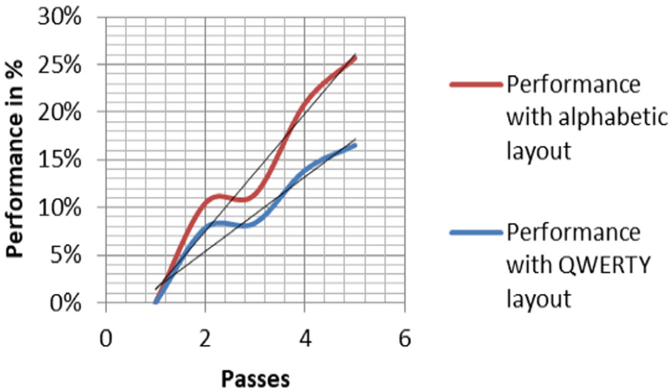

Fig. 4. Performance comparison made through time

Regarding the error, while the users were more accurate on the QWERTY than the alphabetical layout during the first pass, this was changed as they learn the alphabetic layout more; and on the fifth run, the users have performed well on the alphabetical layout having 98.837% accuracy while having 98.372% accuracy for the QWERTY layout.

5 Conclusion

Designing text input method using alphabetic order could improve the usability of the device, especially on small handheld device. Though we have used the English alphabet in our work, each language may have its own different character and order.

Hence, due consideration shall be given to the language structure while deciding the alphabetic order. Also, even if expert users (experienced with QWERTY) has well performed in our test, usually the new layout could be more appealing to novice user (new to the device or typing). Therefore, in the future designers may improve the usability of their product by introducing both type of layout and giving the option to the user on the selection of the layout.

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