# Comparing Different Keyboard Layouts: Aspects of QWERTY, DVORAK and alphabetical keyboards

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**Abstract**

Although developments in computer technology have been huge in the last fifty years the way we mainly communicate with the machine is still basically the same: the keyboard. Especially the layout of keys on a computer keyboard has had little revisioning. The QWERTY layout (which stemmed from the classic typewriter) can be considered the standard or "universal" design. This layout was chosen for mechanical reasons which don't apply for the modern keyboards. Many alternatives have been proposed, most notably the DVORAK system and the alphabetical ordering. The former was designed to help the expert user achieve maximum typing speed by placing the keys optimally, while the latter was supposed to support novice users by reducing search efforts.

This article gives an overview of the research that has been done concerning such comparisons. We conclude that the claimed Dvorak typing speed-up over QWERTY is rather limited and that unskilled typists can experience help from an alphabetically biased keyboard.

## 1 Introduction

Presumably the reader is familiar with the use of a computer, as the majority of the western society is faced with such a machine every day. Most computer users are also well-known with the QWERTY keyboard. Though it is safe to say that this layout is the standard keyboard mapping – it is often referred to as the universal keyboard– the rationale for this specific ordering is unknown to many. The key layout seems like a random configuration. Is this really the best keyboard layout? Wouldn't it be more convenient to just have an alphabetical arrangement?

In order to answer these questions we have to approach this theme from different directions. Section 2 gives an historical account of the QWERTY origin. This layout is older than many would assume: the inventor of the first commercial typewriter, Christopher Sholes, implemented this on his machine. The key mapping was chosen in order to avoid key jamming, which was a serious problem in the first models. Alternative keyboards were also proposed, like Dvorak's layout which was based on time-and-motion studies and thus had an ergonomic rationale, instead of the purely physical constraints that Sholes dealt with. In spite of its claimed superiority, for some reason the Dvorak Simplified Keyboard (DSK) never really got accepted.

A more psychological perspective is presented in Section 3. Here we address the basic human aspects of typing. The items we discuss are character recognition, storage buffer, the motor program, the keystroke and feedback. Also Fitts' law is explained which enables theoretical predictions of keyboard performance. The discussed subjects return in the next section.

Many comparison studies have been made in order to find out which keyboard mapping is best. In Section 4 we give an overview of such studies, focusing on the QWERTY layout, the DSK and an alphabetical layout. We look at typing speed, required finger movement and learning time. The DSK is generally regarded as the clear winner on all three fields, but this advantage might not be so evident when we regard the literature. Also we are interested in the question whether novice users are helped with an alphabetic layout. The final Section tries to draw up some conclusions.

# 2 History

In order to get an overview of the keyboard evolution and to understand why the QWERTY layout had so much popularity through the years we should get a clear historical overview. First some historical information is presented about the origin of the typewriter and the Sholes' (QWERTY) key layout. The second subsection is concerned with concurrent developments of typing machines in general and specifically the DVORAK layout.

## 2.1 The First Typewriters & Sholes

The history of typing machines reaches back to the year 1714 when the English engineer Henry Mill obtained the first patent for a contraption that can clearly be recognised as a typewriter. Unfortunately, no actual "writing machine" has ever been found, nor are there any remaining drawings of the design. Nevertheless the description of Queen Anne when she awarded him the patent leave no doubt that the nature of the machine is not so distant from $20^{th}$ century versions:

> ... by his great study, pains and expense, lately invented and bought to perfection an artificial machine or method for the impressing or transcribing of letters, singly or progressively one after the other, as in writing, whereby all writings whatsoever may be engrossed on paper or parchment so neat and exact as not to be distinguished from print ... the impression bing deeper and more lasting than any other writing, and not to be erased or counterfeited without manifest discovery. [5]

Many attempts at the creation of typing machines were made. The oldest working machine that is known would be Pellegrino Turri's typewriter, dated roughly 1808. The gap of almost a century since Mill's invention can have two reasons. Firstly, it was probably very difficult to produce such a machine robust enough to survive. Secondly, the printing techniques of that time were sufficient and there was no direct need for a typing machine. Turri's design and the writing machine (that was used by a blind woman) itself have been lost, but some documents printed by the machine have survived [1].

In 1829 William Austin Burt received the first US patent for his typographer. Though the machine was destroyed in a fire a photo of the design has been saved (see figure 1a). It doesn't look much like the modern typewriter. the typing bar as we know it is not yet present and the paper flow does not seem fluent. Progin's design (figure 1b), stemming from circa 1833) also looks peculiar to modern eyes. Its shape does not indicate great usability. The machine by Charles Thurber (figure 1c) in 1843 was much more compact and was –as opposed to its predecessors– very useful: Thurber made it for blind people. It was described in the patent as "an artificial machine or method for impressing or transcribing letters singly or progressively one after another" [3]. The Beach typewriter (figure 1d), circa 1856) deserves attention because it introduced the universal typing bar that we are so familiar with today.

In 1868 Christopher Latham Sholes (a Milwaukee publisher, politician and philosopher) patented his typewriter, see figure 1e. Because he was assisted by Carlos Glidden it was named the "Sholes-Gliden" machine. In 1873 it was first produced by the gun makers E. Remington and Sons, who sold only 5,000 machines in 5 years. Remington had also started to produce sowing machines, which explains the design. It also came with a foot treadle for the carriage return. In the following years the device was enhanced, resulting in the "Remington No 2", introduced in 1878. See figure 1f. The major improvement was the possibility of printing both upper and lower case, using a shift key – The previous version only printed in upper case. One of the major drawbacks of the

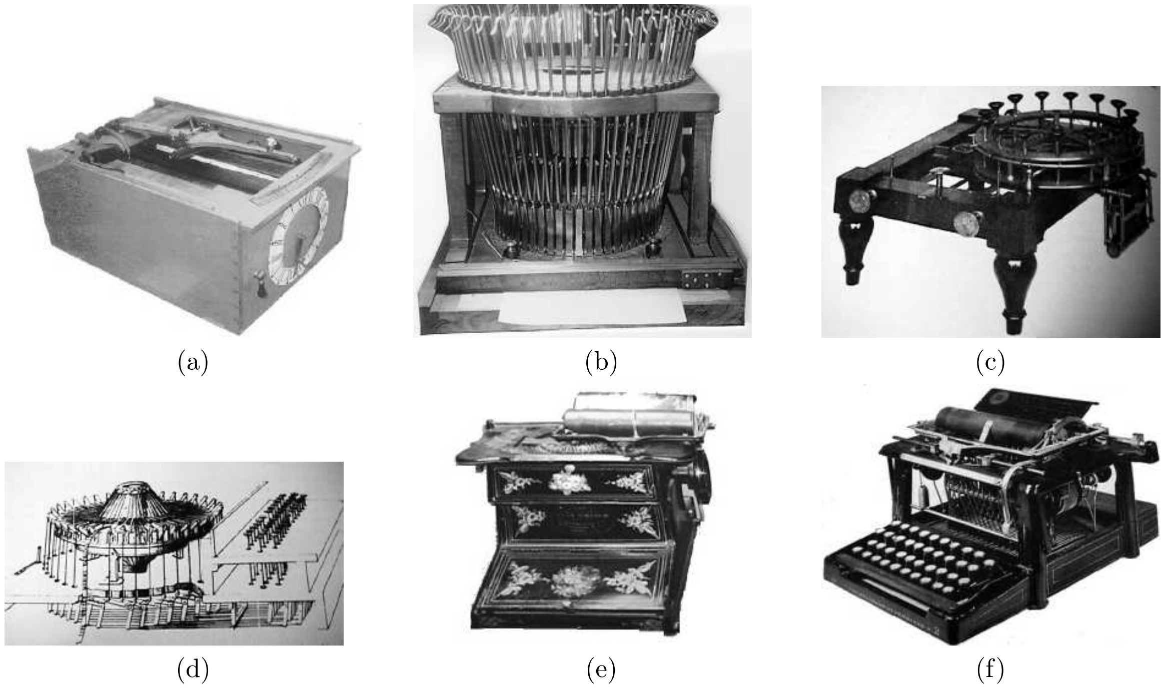


Figure 1: The first typewriters. In (a) we see Burt's invention, followed by The Progin (b) and Thurber (c) machines which all look rather alien. Figure (d) displays Beach's model featuring the typing bar. Then in (e) we see the Sholes-Glidden machine: the first commercial typewriter. Its successor the "Remington No. 2" (f) was much more successful though. Pictures adapted from [23], [3] and [1]

design was still that the actual printing was done on the back of the paper, so the writer did not see what he was actually typing. This was solved in 1883.

A problem with the printing mechanism was that the key slugs would easily get jammed when a key was pressed before the previous one had returned. Sholes solved this problem by experimenting with the most common English two-letter sequences and assigning the most frequent couples to opposite sides of the keyboard. This resulted in the QWERTY layout, which was optimal in avoiding key jamming. The Sholes design was present on the first typewriters that entered the business offices and many typists were trained (by the Remington company) for this keyboard. This provided the Sholes' layout a great initial advantage.

## 2.2 Alternative Typewriters & Dvorak

From the start, the Remington machine was challenged by other manufacturers with their own keyboard layout. These alternative layouts were often designed with much more efficiency than Sholes' physics-driven key mapping. An example was Blickensderfer's machine created in 1889, which looked a lot like the (later developed) Dvorak layout. For some reason the Blickensderfer typewriter (and others) failed to seriously endanger the market-leading position of Remington. It could be that Blickensderfer did not have the production capacity that Remington had, or that the early QWERTY market penetration gave Remington a slight (but decisive) advantage. Also, the Remington typewriter won some important typing contests. These competitions were very common those days, though in most historical reviews (e.g. [2] and [8]) we only find mention of the famous Cincinatti contest in 1888, which was won by Remington's star typist Frank McGurrin. The New York Times stated that this victory made clear "once and for all" that the Remington machine (with its QWERTY keyboard) was technically superior. This was the best kind of advertisement that

Remington could wish for and it put many competitors out of business. In reality the performance differences were rather small.

In the 1920s it was the industrial engineer Frank Gilbreth who performed time-and-motion studies on many worker activities. His research on typing showed that the Sholes design resulted in more fatigue and errors than alternative key layouts. He also claimed that the typing speed could be increased with a different layout. Gilbreth addressed the major design obstacles, like "allocating letters among keyboard rows, among fingers, and between the left and right hands" [10].

During the 1930s, August Dvorak and his colleagues at the University of Washington worked on an improved key layout, inspired by Gilbreth's findings. In 1936 he patented his Dvorak Simplified Keyboard. His experiments (that claim the "new" layout to have far superior performance to the "old" layout) were published in [11]. The work reads more like a commercial folder than a scientific publication. Also his scientific accuracy was quite debatable, as was pointed out by Liebowitz and Margolis [17]. Dvorak presented tests taken with totally different test groups and omitted specific details. A second report that favoured the DVORAK layout was a 1944 US Navy document [9] which showed that retraining QWERTY typists to Dvorak typists would repay itself within ten days after the start of the retraining program. This report persuaded the Navy to order thousands of Dvorak typewriters. Unfortunately for Dvorak the Treasury Department blocked the transaction. It seemed like the last opportunity for the Dvorak keyboard to obtain a fair market share. However, Liebowitz reveals that the experimental setup and statistical analysis of this Navy study was unsound. On top of this Arthur Foulke (Sholes' biographer, see [14]) was able to identify the author of this study: no other than Lieutenant Commander August Dvorak, the Navy's top expert in the analysis of time and motion studies during World War II. Liebowitz also shows that Dvorak had considerable financial interest in this study, though Cassingham [6] shows that the Carnegie Foundation for the Advancement of Teaching funding came after the DSK was well established and that the Simplified keyboard was only a small part of Dvorak's work.


Figure 2: The Dvorak layout. The small letters in the corners represent the QWERTY layout.

The US Army decisions to stay with the Sholes keyboard were also based on a state-funded study conducted by Earle Strong, a professor at Pennsylvania State University [26]. This well-documented research showed that the Dvorak keyboards offered no substantial speed gain over the QWERTY layout. It was this report that killed the Dvorak popularity rise. We should note however that Dvorak and Strong had some conflicts in the past and that Strong admitted to have a personal bias against the DSK. Further more, when other researchers requested for Strong's data they found that he had destroyed it all.

# 3 Psychological Aspects

After this overview of the historical context we will now look at the matter from a more ergonomic point of view. This section explains the general psychological (and physical) aspects of typewriting, hoping to get more insight on the human aspects of typewriting. First a general model for typing is presented, followed by a section on Fitts' law.

## 3.1 General model of information flow

In the following sections we only consider typing as a process of *reading* a text and simultaneously copying it with the typewriter. Dictation has the methodological drawback that an external source (ie the voice) influences the behaviour of the typist. While reading, the subject is fully autonomous in his actions and that is why only the activity of copy typing is considered.

We can distinguish five phases in the process of typing [7]. The first stage is **Character Recognition**, when the symbol at the input has to be processed. The human eye reads ahead about 1 second, largely irrespective of typing speed [4]. Fuller [15] found the mean eye-hand span of 100 trained typewriting students to be 0.32 words. If we compare this with the 1.1 words eye-voice span in a reading-aloud task we see that the look-ahead range is much shorter. Also the number of eye movements (ie fixations and regressions) is much greater than in reading, with longer pauses between the eye-shifts. This indicates that "during typewriting the eye does not read at all at its maximum pace or even at the rate which is determined by the requirements of comprehension, but instead reads only rapidly enough to supply the copy to the hand as it is needed" [4].

The second phase concerns the **Storage Buffer**. This is where the information from the eye is stored. Since the eye reads ahead between four and eight letters, these have to be stored in a short-term memory. It appears that eight letters is the maximum look-ahead range, indicating that further look-ahead is blocked by the storage capacity of the short-term memory. Suggestions that advanced typists distinguished themselves by larger reading spans has since long been experimentally refuted by Butsch [4] and Fuller [15]. It seems however that trained typists have the ability to feed their storage buffer at a more steady pace, compared to novice users [24]. Unskilled typists tend to have an irregular input flow, with some pauses when their storage buffer is temporarily depleted. Skilled typists tend to minimise such occurances.

The next phase is the **Motor Program**. It was observed by Shaffer that the interkeystroke intervals (ie the time between successive keystrokes) are very low when the keys are at different hands [24]. The interkeystroke interval occasionally was measured to be under the neural transmission time for a signal to go from the hand to the brain and back again to the (other) hand [21]. This indicates that the brain does not guide the hands in a strictly serial way: while one hand is in the process of depressing a character, the other hand is already preparing for its following task. It has even been shown that the movement of a hand does not only depend on the current character to type, but also on the following letters [16].

The **Keystroke** phase is evident and needs little explanation. We should not however that computer keyboards differ here from typewriters in that the keys need much less effort to be depressed. The mechanical structure of the typewriter demands a greater keystroke interval (time between the first touching the key and finally the release), which can often be neglected with computer keyboards.

The **Sensory Feedback** stage is mainly concerned with error detection. One way this is done is through visual feedback. When a typist is copying a text he is mainly looking at the source text, but also directs his eyes to the keyboard and to the copy. When a skilled typist is not allowed to watch neither the copy nor the keyboard he does reach his normal typing speed, but commits considerably more errors. A possible explanation is that trained touch typists need to consult the keyboard to check the position of their fingers on the home row [7]. Another feedback mechanism is kinesthetic feedback. This can be considered the most important of the two. As typists obtain greater typing skills they progressively depend more and more on kinesthetic signals (from their hands and fingers), as opposed to visual feedback.

### 3.2 Fitts' Law

It is interesting to have a model that predicts the typing speed given the keyboard layout. In order to calculate the typing speed we need the time it takes to perform consecutive key presses (ie the interkeystroke interval). Paul Fitts proposed a formula to predict movement time (MT) in numerous human activities, see [12] and [13]. When we adapt Fitts' Law to typing [19] we get:

$$MT = a + blog_2(\frac{D_{ij}}{W} + 1) \tag{1}$$

Here, $a$ and $b$ are constants, determined by linear regression. $a$ is given in seconds, while $b$ has the unit "seconds/bit". The inverse of $b$ is what Fitts called the index of performance (IP). The log term is the index of difficulty (ID). $D_{ij}$ is the distance between key $i$ and key $j$. $W$ is the width of the key. For example, we take $i =$ '$v'$ and $j =$ '$t'$. The distance (center to center) between these keys is 3.0 cm. The width of the keys is 1.0 cm. Then $ID = log_2(3.0/1.0 + 1) = 2.0$. The unit of the index of difficulty is bits, because of the log factor 2. 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. The addition of 1 guarantees that the ID is always positive – mind that both the distance and width are always positive, resulting in a positive quote $D_{ij}/W$. The constant IP indicates the subject's performance in "bits/second". A trained typist will need little time to press the 'v' and 't' keys after each other, ie he can perform many bits per second; A novice needs more time for this movement. Empirical data suggests that a setting of $b = 1/8.2$ is feasible [19]. The constant $a$ reflects the time that is needed to find the key. For experienced typists this is 0.

Fitts' law can be used to calculate the theoretical interkeystroke interval of a keyboard arrangement. This is done by calculating all digraph (successive letter combinations, including the space bar) distances on the keyboard, as well as the digraph frequency of occurance ($p_{ij}$) in the English language. With this information we can calculate the weighted average time it takes to type a character:

$$t = a + \sum_{i=1}^{27} \sum_{j=1}^{27} p_{ij} b \left( log_2(\frac{D_{ij}}{W} + 1) \right) \tag{2}$$

Mind that the space bar is the 27th character. Because numbers occur with low frequency they are not considered here. Layouts with smaller $t$ values need less hand movement. This movement reduction can lead to speed increases (though we shall see that this is not always the case) and less fatigue.

# 4 Comparison

There have been many comparison studies between the different keyboard layouts. The key mappings can be compared along different dimensions: the typing speed, the required finger movement, and learning rate. We discuss the DVORAK layout, the QWERTY layout and an alphabetic layout.

### 4.1 DVORAK Layout vs QWERTY

Like mentioned in the introduction, QWERTY can be considered the standard keyboard layout in the Western world. Some regions have slightly different key mappings, for example the French AWERTY layout where the 'Q' and 'A' keys are swapped and some accent letters are placed at the top (number) row. But as already stated in Section 2.1, the Sholes keyboard has dominated the market for over a century. The DVORAK layout was "supposed" to be the successor with its optimised key design. Some claim that Dvorak's keyboard was not generally accepted was only caused by economic reasons: "the economics of qwerty". This theory states that people and companies tend to stay with a certain standard, even when there is a superior alternative available

(Dvorak). This prime example might not be so well chosen: We shall see that the DSK keyboard is not so clearly superior to the QWERTY layout.

August Dvorak conducted experiments himself [11], but some crucial aspects of the experimental setup are unaccounted for. For example, Dvorak compared studies with different groups (hi-school students versus college students) and with unknown and probably different class structures and test methods. Also the often cited Navy report should not be regarded as reliable work, because the test groups were probably not equal in initial typing abilities and the statistical analysis was unsound. Lack of independence is also an issue as Dvorak was in charge of the whole experiment.

First let's look at **typing speed**. Throughout history this has been the major quantitative indicator in keyboard comparison. We already discussed typing competitions before in section 2.1. These stayed popular well into the twentieth century. From 1906 to 1932 annual "World Professional and Amateur Typewriting Contests" were organised where typewriter manufacturers could prove the merits of their machine [22]. In 1933 these typing competitions were included in the annual International Commercial Schools Contest (ICSC) and that is when the DSK entered the arena. Dvorak trained students with his keyboard and they were said to "sweep the field". There were reports of 70 words per minute, though this does not revolutionary compared to common QWERTY typists abilities.

Norman did controlled experiments where he compared performance on the QWERTY keyboard, the DVORAK keyboard, the alphabetic keyboard and a random layout [20]. They found that novice users performed better (measured in typing speed, not number of errors) with the QWERTY layout than with the DSK. This is probably caused by prior experience with the universal keyboard – This is a common problem in these experiments. The skilled typists however showed a 5% speed advantage with the DVORAK layout.

Recent experiments by West indicate the same figures [27]. According to West's findings the QWERTY users reached a typing speed of 81.95 wpm and the DVORAK trained users achieved 84.90 wpm. This is a 4% superiority for Dvorak's keyboard. This does not sound like "sweeping the field" and it is questionable whether QWERTY users will be persuaded by this small gain to switch over to DSK.

When we examine the required **hand movement** of both keyboards we see that the DVORAK keyboard has a clear advantage. In fact it was designed to reduce finger movements. 70% of typing is done at the home row, 22% is done at the top row and only 8% requires the bottom row. In the QWERTY layout these respectively values are 32%, 52% and 16%. On QWERTY,there are only 300 English words that can be typed by the home keys (without any finger movement), on the DSK it is around 5,000. Also a comparison with Fitt's law is in favour of DVORAK layout: like described in Section 3.2, the average "Fitt's energy" that is needed for typing consecutive letters can be calculated and this is much lower for Dvorak than for QWERTY[1]. This clearly indicates that less hand movement is needed on a DSK layout. One would assume that this reduction in hand movement would create an increase in typing speed, but this is not the case. Norman and Rumelhart [21] give a plausible explanation. According to them, there are three factors that play a role in speed optimisation:

A The loads on the right and left hands are equalised

B The load on the home row is maximised

C The frequency of alternating hand sequences is maximised and the frequency of same-finger typing is minimised.

The DSK fulfills the first two constraints, but the QWERTY layout is better at constraint C. Indeed, Sholes designed his keyboard mapping specificly to avoid the key jamming. He did this by placing frequently used letter-pairs (digraphs) far apart. It seems that this mechanical rationale accidentally resulted in a fast keyboard.

[1]Though the actual values depend on the chosen lexicon and parameter settings.

Finally the **learning speed** should be considered. We have found numerous sources that tell of great learnability for the DVORAK layout. The Navy report states that it took 52 hours of training for typists to regain their old QWERTY scores. After 86 hours of training the typists had showed speed increase of 74%. Both Strong and West trained their subjects for roughly 100 hours and obtained a small increase in typing speed. As these last two research studies seem more sound we shall give more credibility to them. It is hard to compare these learning times with those required for QWERTY, because you have to train users that have never had any contact with the universal keyboard. An anecdote tells us that in the 1930s at US Tacoma schools, thousands of children took part in a comparative experiment showing that children can learn DVORAK in one third the time it takes to learn QWERTY. This seems not very likely and such training results have not been confirmed in any scientific source.

## 4.2 Alphabetic Layout

For novice users the QWERTY and DVORAK keyboards both look like random configurations. Even customed typers find it sometimes tricky to find a specific key. This raises the question whether an alphabetic ordering can reduce the search time that unexperienced typists need to find the right key.

However, Norman compared different alphabetic designs with random keyboards and found that typists displayed no difference in **typing speed**. So the alphabetic line-up does not give much help for novice typists. This is probably due to the high mental effort that is required for the alphabetic arrangement; simply memorising the keys seems to be a better strategy than relying on the alphabetical knowledge. When Norman compared the alphabetical layout with the QWERTY keys he found a minimal advantage for Sholes' configuration. This is probably due to prior contact with the universal keyboard. Apparently, searching the keyboard is not helped when the keys have an alphabetic ordering; Consulting the alphabetic knowledge takes a lot of time compared to scanning the keyboard. Norman also tested expert typists on both keyboards and found a typing rate advantage ranging between 2% and 9% for the QWERTY layout. This is for the most part caused by the subjects' greater experience with the QWERTY keyboard. Secondly, the QWERTY layout makes sense because frequently used letter combinations are placed at greater distances; the alphabetic layout does not have any rationale in that respect.

Unfortunately, Norman does not report of a **hand movement** analysis. It is interesting to note that Smith and Zhai proposed a virtual keyboard that incorporated both an optimised layout (in terms of reducing the total Fitts' energy) and an alphabetic bias [28, 25]. A virtual keyboard is displayed on a PDA and a stylus pen is used to tap the keys. Though the use of one hand instead of two influences the typing behaviour, we can still use Fitts' law to analyse the total finger movement. The advantage of a virtual keypad is that novice users are not familiar with them. This allows us to compare optimised keyboards with alphabetic keyboards in a clean way.

First Zhai and Smith developed an optimal layout which provides a 50% speed increase over a virtual QWERTY layout. This is due to the fact that frequent digraphs are arranged on opposite sides of the QWERTY keyboard. With two hands, this is an advantage; with one hand however this breaks down typing performance considerably. That is why the optimal virtual layout is so much different from the DVORAK layout.

Zhai and Smith compared an optimal virtual keyboard with a keyboard that had a slight alphabetic bias, but had 1.9% less movement efficiency, according to Fitts' law. The researchers found that subjects faced with the optimised keyboard produced a mean typing speed of 8.9 wpm after 15 minutes of training. The alphabetically ordered keypad produced an average performance of 9.7 wpm. This 9% difference indicates that an alphabetic bias does help novice users to type faster. Expert users should be better of with the optimised keyboard because the searching time is minimal for them (they have memorised the key positions), though this has not been tested.

MacKenzie also conducted a comparison between different virtual keypads [18]. Among other configurations, he let novice users (unexperienced with virtual keyboards on PDAs) type a 45-character sentence on an alphabetic keypad and on the so-called Fitaly keyboard, which is optimised for stylus keypads. The sentence was: "the quick brown fox jumped over the lazy dogs".

Although this sentence contains all letters of the alphabet, we should criticize his neglection of digraph frequencies: some letters are more used in common language than others. Secondly, 45 characters seems a rather short test. Nevertheless, MacKenzie found that the alphabetic keyboard produced slightly larger typing speeds than on the optimised Fitaly keyboard: 10.6 wpm versus 8.2 wpm. This complements Norman's results, who compared alphabetic layout with the QWERTY keyboard. There he found an advantage for the QWERTY keyboard, which could be contributed to the users prior experience with the universal keyboard. MacKenzie's results now say that without this prior knowledge (all subjects were unknown with the optimised key layout) the unskilled typists perform better with the alphabetic arrangement. We also should note there there were some methodological differences between these studies, which strengthen this conclusion. The major difference between the two studies is that MacKenzie did not allow any training before the test. In this way, he wanted to capture the pure novice performance. And indeed, his results indicate that the alphabetic layout can support truly unexperienced users.

Apparently there are two processes involved when (novice) typists are trying to find the right key. With the alphabetic arrangement there is the consultation of the alphabet. Secondly users depend on their memory of key locations. Truly unexperienced typists mostly rely the first process, because they have no knowledge of the key positions. But Norman's tests with subjects who did have some (though minimal) QWERTY experience showed that the alphabetic process was already slower than the memory process. This indicates that even after short training, the alphabetic arrangement loses its advantage.

# 5 Conclusion

We have seen that the DVORAK layout does produce better typing speed performance than the QWERTY keyboard, but that this difference is just 4 or 5%. When we look at the history of the typewriter we can assume that people are not willing to switch to this superior design: the gain is too small compared to the costs of retraining.

The major feature of Dvorak's DSK, however, is its optimised key placement. The DSK is designed for touch typing and significantly reduces finger movement and thus typists' fatigue. Though this ergonomic feature has been pointed out in many different studies –and in fact is quite evident– this has not convinced the general public that they are better of with the DVORAK layout.

The alphabetic design does seem to have a positive effect on the typing performance of unexperienced typists, at least with virtual keyboards. But we also see that when novice users are not true novices (ie they had earlier contact with a specific keyboard) this performance gain disappears. Apparently even after short training the mental effort of consulting the alphabet knowledge takes more time than the finding process (ie scanning, recognising and memorising the keys). This tells us that it might not be worthwhile to implement an alphabetic keyboard because only the most unexperienced users, which are very few in today's information society, will benefit from it.

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