Aiding Text Entry of Foreign Alphabets with Visual Keyboard Plus

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Abstract

Computer keyboards are used to input hundreds of different languages using many different alphabets. Despite this diversity, the physical layout of keyboards is fairly uniform, with keyboards generally containing approximately 80 keys spread across six rows (excluding cursor keys and numberpad). In English speaking countries, the QWERTY layout is the de-facto standard binding between the physical location of keys and the corresponding letters of the alphabet.

To aid international and multi-lingual computer use, operating systems allow users to alter bindings between physical keys and resultant characters, but this raises a problem for users as the labels on the physical keys will not match those of the bindings. Software user interfaces such as Microsoft's Visual Keyboard (MVK) help users by providing a visual depiction of the keyboard's new bindings, but users still suffer an overhead in establishing the mapping between the physical and displayed keys.

This paper describes a comparative analysis and empirical evaluation of three alternative techniques for helping users input non-standard alphabets using a standard keyboard. In particular we investigate whether our VKPLUS (Visual Keyboard Plus) user interface, which displays both the physical key labels and the new keybindings, improves text entry rates over Microsoft's Visual Keyboard. The third technique, included for baseline comparison, uses sticky-labels placed over the physical keyboard. Results show that VKPLUS improves performance over Microsoft's system.

Keywords: Text input, keyboard keybindings, visual keyboards, international alphabets

1 Introduction

Since the invention of typewriting by Christophrel Sholes, Carlos Glidden and Samuel Soule in 1867 (Baddeley 1998), the QWERTY keyboard has become the standard method for English text entry, entrenched after the 1915 adoption by training schools of touch-typing (Yamada 1980) which meant users no longer used visual cues in typing, and hence required stability and standardisation of layout to retain proficiency.

The physical layout of keyboards is largely standard throughout the world, but the mapping between physical keys and underlying characters naturally varies dramatically across the different languages and alphabets of the world. Millions of multilingual users, and those who use keyboards with different native mappings than their natural language (as is often the case in Internet Cafes around the world), must alter the keybindings to allow them to work efficiently.

Most operating systems allow users to alter the keybindings so that the alphabets of different languages can be entered efficiently. In addition, software systems such as Microsoft's Visual Keyboard allow users to view the relationship between they physical keys and underlying alphabet—Figure 1(a) shows Microsoft's Visual Keyboard with the Russian language keybindings.

Despite the common use of modified multi-lingual keybindings and associated Visual Keyboard software, there has been little prior research into their effectiveness. In this paper we analyse and evaluate three aids for working with modified keybindings. The three aids are stickers placed over the QWERTY keys showing the new symbols, Microsoft's visual keyboard (MVK), and our modified visual keyboard (VKPLUS), which displays both the new keybinding and the original 'native' labels on the physical keyboard.

In our next section, we examine past methods for facilitating input of non-English alphabets. We then describe our experiment, with a description and justification of each of the three methods of support for modified keybindings that we are testing. A discussion is then given of their performance. Finally, we draw conclusions on the usefulness of each typing aid, and make recommendations for those sectors where facilitating multi-lingual computing is of importance.

2 Background

2.1 Text Entry of non-English Characters

To meet the challenge of entering non-English characters on any system, many methods have been developed. The simplest of these is the use of the 'insert symbol' command available on most word-processing systems. However, this has usually a limited character set, is limited to a specific application, and is very time-consuming to use. It is suited to cases where one or two letters absent from the English alphabet are required. Similarly, short-cut keys exist for symbols not directly provided by the keyboard, typically the accents on vowels needed for other latin languages, such as the é used in typesetting French. This requires a significant memory load on the user when only six extra symbols are required, as is the case for typing in

French; using such a method for a language which has an entire alphabet of non-Latin characters would be extremely demanding for the user. It would also be time-consuming, as for every symbol more than one key would need to be pressed.

To circumvent these problems, several methods of text entry for foreign languages have been developed that avoid the use of the keyboard altogether. One such method is that developed by Henry (1992). This bypasses the need to spend time learning a new keyboard by presenting a pool of text chunks that can be selected to create the sentences the user is trying to enter. This would include syllables, common complete words, as well as individual letters. A more common yet similar method is that of virtual keyboards, where the user is presented with a keyboard on the screen, and uses the mouse or a stylus to select the appropriate key on the screen to make the symbol appear.

However, this is, as is any method eschewing the physical keyboard, inherently slow as it requires pointing between different letters, rather than utilising the natural dexterity of humans as does traditional typing. Skilled users of virtual keyboards have hence been proven to be incapable of matching the speeds achieved by experienced typists on normal keyboards, with a maximum input speed of 31.6 wpm attained on virtual keyboards in recent experiments by Shumin Zhai & Accot (2002), who also predicted that with the optimum keyboard layout currently proposed a maximum of 46.6 wpm could be achieved. This means that although virtual keyboards may show some speed advantage initially, it is preferable that the user learn to use a physical keyboard to input the symbols. For expert users who have memorised the location of every symbol, performance would be equitable to that achieved by expert users of the QWERTY interface, with any differences attributable to the movement efficiency of the keyboard layout for the new language. To this end, modifiable keybindings have been developed, taking advantage of the speeds that can be attained from touch typing.

However, for novice users the speed of text input is determined mostly by the time taken to search and find the required key, rather than the time taken to move their finger to press this key (Smith & Zhai 2001). This means that any support offered in finding the appropriate key would be invaluable in assisting novice users come to terms with a new keyboard layout.

2.2 Support for Modifiable Keybindings

A novel way of dealing with learning a new set of keybindings was proposed by Ilinski (2003). This used a haptic keyboard (Cheung 1995), and the user was shown the key that his or her finger was touching before it was actually pressed. The identity of the key is displayed at precisely the point where the text cursor is flashing. If it is deemed that the user needs more help, a picture of the current key and those surrounding it is shown. The speed in typing using the Dvorak keyboard layout was increased by 18%. It was also advantageous that the user need only look at the text they were to type in and the pane in which typed text was appearing.

However, this is not a very practical solution for the majority of users who need to use unfamiliar keyboard layouts, although it could be utilised if it was necessary to quickly train a particular group of users. The technology required is expensive, and not readily available. It also slightly increases the physical effort involved in pressing a key, although the users would soon become familiar with this. Some inexpensive support for typing using modified keybindings is also currently available, such as keyboard stickers, which can be placed over the current keyboard to enable the user to locate the desired symbol. Microsoft Corporation has also produced a visual keyboard(MVK) to aid typing using different keyboard layouts. This shows the keyboard layout on the screen, to use as a map for finding any symbol on the physical keyboard (MSC 2000). When a key is pressed, the corresponding key on the visual keyboard is highlighted. However, there has been no previous evaluation of these more accessible methods.

3 Evaluation

The three support methods to be evaluated are presented below, and the theorised ways in which they may assist typing are described.

3.1 Keyboard stickers

Keyboard stickers aid the user in locating the correct key to press for the desired symbol as they place the new symbols over each key in the keyboard. Typing ability would now be similar to those using a QWERTY keyboard for the first time, as the user must look at the keyboard itself to determine the location of a key. An advantage of this method is that no mapping is required to translate between finding a symbol and knowing which key to press. However, there are concerns both that the fingers themselves could obscure the symbols, making them difficult to locate, and that learning to type in such a way would not encourage the development of touch-typing with the new layout, thus limiting future efficiency.

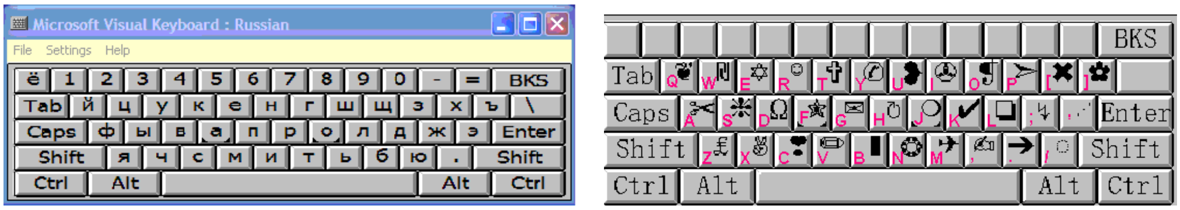
The main keypad of the stickered keyboard used in the evaluation measured 28.5cm across by 9.6cm, with keys measuring 1.2cm across by 1.3cm. Keyboard stickers featured symbols 4-9mm high.

3.2 Microsoft's Visual Keyboard - MVK

A visual keyboard may be a useful way of aiding the user to locate the desired symbol on the keyboard. This has the advantage in that it is readily portable, requiring only a small download to implement on any system, and can readily change character sets as desired. Furthermore, it may promote touch-typing habits with the new keybinding as it ensures it is not necessary to look down at the physical keyboard and back up to either the screen or the text being typed in, which degrades typing speed.

There is the concern, however, that typing using a visual keyboard involves an additional step for the user than does using keyboard stickers. First, one locates the desired symbol on the visual keyboard, and then one must transfer this knowledge to finding the correct symbol on the physical keyboard, before finally moving one's finger to the correct key.

For this first step, one can predict that the time taken would be similar to that found in previous research on typing times for novice users of virtual keyboards. This time needed for the user to find the right



(a) Microsoft Visual Keyboard displaying Russian language bindings.

(b) VKPLUS: Both QWERTY characters and the symbols to be typed in are visible on each key.

Figure 1: The two Visual Keyboards examined.

symbol (Soukoreff & MacKenzie 1995) is labelled the visual reaction time(T_{VR}), derived from Hick-Hyman law, and is shown by the equation below (Smith & Zhai 2001):

$$T_{VR} = I_c\,H \tag{1}$$

I_c is a constant between 150 and 200ms (S K Card & Newell 1986) and H is the information entropy of the n number of stimuli, measured in bits as $\sum_i (-plog_2p)$, where p is the probability that item i is the target item. In this case, this would be the probability of the key being that of the desired symbol.

The worst possible case, resulting in the longest visual reaction time, is when all stimuli are equally probable, or, in this context, when the chance of every key containing the desired symbol is equal. This is the case for the first few searches for a particular symbol that the user undertakes, as there are 33 different symbols, which may be in any place on the keyboard. The information entropy would be $\log_2(33)$, and assuming I_c to be 200ms gives a visual reaction time of 1.009 seconds for any sort of visual keyboard.

Having located the symbol here, the second step is to find it on the physical keyboard. The information entropy here is much smaller, as the region of the keyboard in which the key lies is known by the user. The user would move his finger to the physical key that he imagines corresponds to the key in the virtual image, perhaps looking at the physical keyboard to confirm his choice.

Although this search for the correct symbol must be done twice, whereas the use of keyboard stickers sees it occur only once, a search for a symbol on a visual keyboard is thought to be faster than on a physical keyboard, as it looks at a smaller area, can be done with the fingers still resting on the keys, and does not require the vision to shift from the screen. In addition, the second search should be very swift as it uses the information returned from the first search.

This is not necessarily the case however, as it may still prove difficult to map the symbols shown in the visual keyboard to the keys under the user's fingers. MVK does try and help with this by highlighting every key pressed on the keyboard, to give feedback to the user on the position of his or her fingers. Feedback has proved to be of great importance in motor learning, (Keele 1986) but if the keybinding was used infrequently, it is doubtful that much learning would be observed. This feature was retained in the evaluation despite its inability to be replicated with VKPLUS, as it is not this feature which is being evaluated, but rather the best possible performance of the MVK as a whole.

The MVK evaluated measured 16.8cm by 4.8cm, with each key 0.9cm by 0.9cm. This was sufficiently large for the symbols to be seen without effort, but was kept as small as possible to avoid using excess screen real-estate and to allow faster visual scanning of the entire keyboard. Symbols were 3-7mm high. Some undesired distortion was evident in the chosen font's representation of the symbol.

3.3 Modified visual keyboard - VKPLUS

To lessen the difficulty of finding the right key on the physical keyboard after locating it on the visual keyboard, a modified visual keyboard VKPLUS is proposed. This can be seen in Figure 1(b).

It is necessary for swift typing using a visual keyboard that the information entropy of the second search, that of finding the correct key to press on the physical keyboard, is as low as possible. To do this, VKPLUS takes advantage of the familiarity with the native mapping.

VKPLUS would show not only each new symbol for each key, but also the former QWERTY symbol. This would mean once the new symbol was found on the visual keyboard, the QWERTY symbol present would give a precise location of the key on the physical keyboard. This would reduce the information entropy towards a limit of zero, depending on the user's familiarity with the QWERTY keyboard. However, this interface may impinge the performance of novices, as the QWERTY symbols may be distracting. VKPLUS would also be expected to be more useful for tasks involving symbols located on keys corresponding to commonly typed symbols in English text.

VKPLUS, as used in the evaluation, was based in appearance on the MVK, with the same dimensions. Each key contained a symbol 3-6mm high in black, and a pink character 3mm high in the bottom left corner corresponding to the QWERTY keyboard character for the particular key.

3.4 Method details

The aim of the experiment is to evaluate the differences in accuracy and speed when typing symbols, or non-Latin alphabet characters, on a stickered keyboard, MVK, and VKPLUS. The effect of the typing proficiency of the user will also be examined to see how this affects results. The experimental design is a 2x2x3 mixed factorial analysis of variance (ANOVA). The between-subjects factor 'typing proficiency', has two levels: expert and novice. The within-subjects factor 'symbol location' likewise has two levels: commonly-used keys in English typing, and infrequently-used keys. It is hypothesised that, for novice users, tasks with symbols on commonly used keys would be performed faster when using VKPLUS as the user would better know the location of the corresponding QWERTY keys. The final factor is within-subjects and refers to the type of support offered, with three levels: keyboard stickers, MVK and VKPLUS.

There was no haptic support offered on any of the keys of the physical keyboard. The display resolution for the duration of the experiment was 1280x1024.

3.5 Experimental system

A program was written to measure the speed and error rate when typing in symbols. The interface can be seen in Figure 2.

This first tested the participant's natural typing speed and accuracy to classify them as either a novice or experienced typist, through counting errors made and measuring the length of time taken to type an introductory text extracted from Mark Twain's "Huckleberry Finn". Eight of the 16 volunteer participants were classified as experienced typists, typing at over 40wpm with 75% accuracy, with an average of 53.32wpm. The novice typists attained an average of 26.79wpm on the sample text.

Following this, the participant was introduced to the first of the three methods of support for typing symbols evaluated. The order in which interfaces were evaluated was balanced using a Latin square method. 33 Unicode symbols, which were readily recognisable by the participant but not part of the standard character set typically represented by the QWERTY keyboard, were used to represent the characters of a non-Latin alphabet. It was decided to maintain the same symbol 'alphabet' for each interface, as some symbol sets may have been easier to recognise than others, and hence affect the visual reaction time.

Each task required the participant to type in a string of symbols with the aid of a particular method of support by pressing the keys assigned to the appropriate symbol. Strings to be typed in were on pieces of paper, to avoid confusion between them and text already typed. These were attached to the monitor. Each participant was first given three training tasks for each new interface, each 6 characters long including one space, and then had to complete eight timed tasks of twelve characters long (including one space).

No symbol was repeated twice in a row, and the distribution of each symbol for a particular layout was relatively even. Four of the tasks used only symbols that required typing keys commonly used in typing English text, such as 'e', 'a', and 't', based on the frequency distribution of letters in English text (Beker & Piper 1982). The other four tasks consisted only of symbols located on keys rarely used by typists, such as 'z', '/' and '['. The time taken and errors made in typing each task was recorded. Total accuracy was required for a task to be considered complete, allowing the number of times the backspace key was pressed to be used as a simple measure of accuracy. Furthermore, the experimental interface did not permit any further typing upon making an error. This ensured that the time taken for a particular task was not confounded by a user taking time to find any errors. If a wrong character was entered, it was highlighted to help the user recognise the error.

After completing their tasks for a particular interface, the participants signalled their level of agreement with three statements on a 5-point Likert scale: Q1 "I found this support interface made my task of typing different symbols on a QWERTY keyboard easy", Q2 "I thought this method of typing different symbols on a QWERTY keyboard was fast" and Q3 "I liked this way of typing different symbols on a QWERTY keyboard" (disagree 1, agree 5). This also provided a break from the experiment for the participants, to reduce the fatigue that can be experienced in within-factor studies.

Each method of keybinding support was associated with a different keyboard layout, to ensure the positions of symbols were not learned by the time the participant used later interfaces. However, to ensure that the results were not affected by differences for different layouts in the total physical distance to be travelled by one's finger to type in a particular string, the strings to be typed for each layout used the same physical keys on the keyboard. This did mean, however, that the symbols for a particular task would change between layouts. Tasks were presented in a random order.

The participants finished by specifying which method of keybinding support they preferred, which they thought enabled them to type the fastest, which was the easiest to use, and which of the two visual keyboards they preferred.

4 Results

A mean time of 35.8s (σ12.9) was observed for the 384 tasks completed across all interfaces with an average error rate of 1.6 characters per task (σ2.1). The time taken by many subjects was thus longer than had been anticipated, despite testing the tasks prior to recording the experiment. Participants had a variety of reactions to the tasks and interfaces, and in many cases frustration was experienced, with one participant commenting that the MVK could be used as "an effective form of psychological torture".

The more experienced typists attempted to use all fingers to type using both visual keyboards, and often did not look at the physical keyboard to type a key after locating it in the visual keyboard. However, some reverted to one-handed typing when faced with the stickered keyboard. Novice typists tended to be more likely to look at the physical keyboard every time a key needed to be pressed.

4.1 Quantitative Analysis

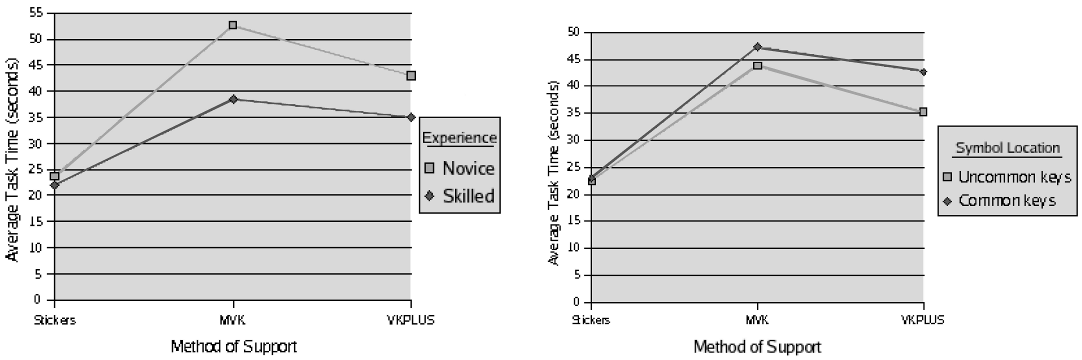
Tasks were completed for the stickered keyboard in a mean time of 22.8s (σ5.4), 39.0s (σ8.7) for VKPLUS, and 45.6s (σ10.9) for MVK. This was a significant difference ($F_{2,28} = 148.2, p < 0.001$) and post-hoc analysis using paired t-tests with a Bonferroni correction of 0.017 [1] showed the difference to be significant between all pairs of interfaces.

There was also a significant difference in speed between the novice and experienced users, with mean times of 39.8s (σ14.5) and 31.8s (σ9.7) respectively: $F_{1,14} = 8.8, p < 0.05$.

There was significant interaction between these two factors, which can be seen in the graph in Figure 3(a), which shows that the expert users had less

[1] At the 5% level the Bonferroni value is calculated as 0.05/number of tests, which is 3 in this case

Figure 2: The MVK interface. In this case, the user has just made an error, indicated by the highlighting of the heart symbol.



(a) Mean task time plotted against interface type, for novice and skilled users.

(b) Mean task time plotted against interface type, for common and uncommon keys.

Figure 3: Mean task times by interface across experience levels (left) and key type (right).

trouble adjusting performance for the visual keyboard methods than did novice users, especially in the use of MVK: $F_{2,28} = 10.3, p < 0.001$.

There was also a significant difference with regards to the location of symbols. However, this proved surprising as the tasks that used keys that are not commonly used in English text were actually performed faster, with a mean task time of 33.9s (σ12.6), than those using commonly used keys (37.7s,σ13.1): $F_{1,14} = 12.6, p < 0.01$. There was some interaction between this and the interface used, shown in Figure 3(b): $F_{1,14} = 4.4, p < 0.05$. Although there was almost no difference between performance time for tasks using symbols on either frequently or rarely used keys when the stickered keyboard was used, this was not the case when using MVK or VKPLUS. No interaction was observed however between the experience level of participants and the location of symbols:$F_{1,14} = 0.21, p = 0.651$.

When looking at typing accuracy while completing tasks, there was a significant difference in the mean number of errors per task across the different interfaces: $F_{2,30} = 57.471, p < 0.001$. This seems likely to be caused mainly by the comparatively high error rate achieved by MVK, with 3.8 wrong characters (σ2.2) per task, whereas the stickered keyboard had only 0.24 errors (σ0.31) and VKPLUS 0.7 (σ0.6). Paired t-tests using a Bonferroni correction confirm this, with MVK significantly less accurate than either the VKPLUS or the stickered keyboard ($t_{15} = 6.9, p < 0.001$ and $t_{15} = 7.2, p < 0.001$). This demonstrates the high level of difficulty of matching a key from a visual keyboard to the physical keyboard when one can use only keyboard shape as a guide. The small difference between error rate for the stickered keyboard and VKPLUS was also significant ($t_{15} = 3.5, p < 0.017$).

There was only marginal difference between users of different levels of experience ($F_{1,14} = 3.79, p = 0.07$) and no significant difference between symbols located on commonly used and rarely used keys ($F_{1,14} = 0.01, p = 0.938$) with regards to accuracy.

4.2 Subjective measures

A Friedman test was performed on the results of the Likert evaluation, which produced similar results to the performance measures. In assessing how easy a particular interface made symbol input, there was a significant difference between the ratings for each interface, with the stickered keyboard attaining a mean of 3.9 (σ0.96), VKPLUS a mean of 3.1(σ1.4) and MVK a mean of 2.1(σ0.85): $\chi^2_r = 14.46, p < 0.01$. In assessing how fast an interface enabled them to type, there was again a significant difference between the interfaces ($\chi^2_r = 9.59, p < 0.01$), with the mean for the stickered keyboard 3.25(σ1.1) and 2.6 (σ1.3) for VKPLUS. MVK had a mean rating of 1.75(σ1.0). Participants' preferences rankings show the stickered keyboard again ranked significantly higher, with a mean of 3.5(σ1.3) compared to 2.6(σ1.3) for VKPLUS and 1.9(σ1.0) for MVK: $\chi^2_r = 8.0, p < 0.05$.

Two-way χ^2 analysis was then applied to the participants' votes for their preferred interface, showing there to be marginally significant results, with experienced users slightly preferring VKPLUS (5 votes) to the stickered keyboard (3 votes) and MVK (1 vote), whereas all but one novice user preferred the stickered keyboard, with the other voting for VKPLUS: $\chi^2 = 4.4, p = 0.1$.

When asked to vote their preference between the two visual keyboards, MVK and VKPLUS, there was a marginally significant difference with Yates' correction for continuity applied, with 12 votes for VKPLUS and only 4 for MVK: $\chi^2 = 3.1, p = 0.08$. There was no interaction between the level of experience of the users and their preference, as two of the eight users of each category preferred MVK.

5 Discussion and Further Work

As can be seen from the above results, the stickered keyboard outperforms VKPLUS and MVK in all regards. However, it is not a practical solution in many cases, as the stickers would adversely affect normal typing, it would be hard to change alphabets, and it is not very portable. It also does not promote touch-typing, as seen by the number of participants who used either only one hand or two fingers to type with, resulting in an inherent performance limit. Experienced users complained that it made them feel awkward, and that their fingers obscured symbols.

It is with this in mind that the two visual keyboards are compared. VKPLUS was faster and more accurate than MVK, and preferred by most users. The hypothesised reasons for its superiority seem to have been borne out in that there was a greater difference in performance between experienced typists and novices here than with MVK, seeming to reinforce observations that the experienced typists were able to take advantage of the QWERTY character corresponding to each symbol to often find the appropriate key without looking at the physical keyboard.

Although MVK saw more errors occur, particularly with hard-to-reach keys, some haptic support such as raised bumps on certain keys on the keyboard may have significantly helped both speed and accuracy. It also must be kept in mind that following one error with MVK, it was usually quickly corrected. The user could see the results of their last key-press on the MVK and use this to move their finger to the correct place. On the other hand, MVK also saw compounding errors as, having made one error, the user quickly typed keys nearby until the right one was pressed.

Our hypothesis that tasks involving more commonly used keys would be performed more quickly using the VKPLUS keyboard than tasks with symbols located on rarely used keys was proved incorrect. This may be a result of the difference in memorability or recognisability of the symbols used on these keys. In addition, there were only 13 keys classed as rare, and 20 as common, meaning the tasks with rarely-used keys would have had slightly more repetitions of symbols, so their location could be learned. There was initially two more tasks using common symbols which would have alleviated this imbalance, but due to time constraints on the experiment these were dropped. There could also be some bias in the proximity of keys to be typed for each of the two kinds of task.

There was also concern over performance degradation during the experiment, due in part to the time taken for the experiment, as well as because the change in keyboard layouts confused participants who remembered previous locations of symbols. Shorter tasks may hence have been preferable, and a complete new set of symbols for each new interface would have helped, but this would have introduced the potentially confounding factor of the recognisability of different symbol sets. A graph of the average task time as the experiment proceeded showed a slight upward trend, the effects of which were hopefully minimised by the Latin square arrangement of the order in which interfaces were evaluated.

There were also some concerns that the visual reaction time when using the visual keyboards was adversely affected by some inevitable distortions and dissimilarities of the printed symbols with those on the visual keyboard.

The QWERTY letters on VKPLUS could also have been improved to avoid clutter and interference with symbol recognition, although this was rarely complained of. The visual keyboards also did not have the values of the number keys displayed, and one user commented that displaying these might have helped him find the right key to type.

Future work would investigate improvements to VKPLUS to help symbol recognition, looking at the size, position and even colour of both VKPLUS itself and the symbols and QWERTY characters on each key. A more detailed examination of the visual reaction time with respect to these factors would be useful.

Further research into the rate of learning a new keybinding using different methods of support would also be worthwhile, as would an examination of the typing style violations common for each method. An investigation into the performance of interfaces when meaningful strings of text in a non-Latin alphabet were to be typed by users familiar with that alphabet would also be valuable. In this case, the string to be typed in would not have to be continuously referred to, and there would be no problems with recognition of symbols. However, if users were very familiar with another alphabet they would be less likely to be familiar with the QWERTY layout. Hence the VKPLUS method may not be as helpful for them as it would be for those who are familiar with the QWERTY layout but still want to type in other alphabets, such as foreign language students.

6 Conclusions

In today's increasingly internationalised and technological society, the ability to be able to use a standard keyboard to input foreign text is important for a significant number of users. The modified keybinding support provided with many operating systems offer a way to do this by taking advantage of inherent human dexterity and allowing the symbols to be naturally typed in. To support these and show users where their desired symbol is located, this evaluation showed stickers on the keyboard enables the fastest and most accurate typing. However, it is more valuable, in light of the non-portability of such stickers, the inability to change languages rapidly and the bad typing habits it encourages, to look at visual keyboards and the level of support they offer. VKPLUS significantly outperforms MVK in both speed and accuracy, and in terms of user preference. For experienced typists, VKPLUS proved to be even more beneficial than for novice users.

Hence for users needing to type in foreign alphabets the modified visual keyboard VKPLUS is recommended, as it will ensure high accuracy and better speed than MVK. The performance of VKPLUS could be improved in future work, possibly by the addition of MVK's feature of highlighting of keys when pressed.

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