Effects of common keyboard layouts on physical effort: Implications for kiosks and Internet banking

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Abstract: This study investigates the effect common keyboard layouts have physical effort. First, alphabetic keyboard layouts are experimentally compared to the QWERTY layout. Second, the number row often found on QWERTY keyboards are experimentally compared to numeric keypad layout. Our study shows that users operate more effectively using a QWERTY layout than an alphabetical layout. Moreover, users operate more effectively using a numeric keypad compared to a row of number keys. Implications for two important application areas in society, namely touch-based self-service kiosks and numeric input in context of Internet banking are discussed.

1. Introduction

This study target two application domains that affect most users in society, namely self-service kiosks and internet banking. Citizens are increasingly reliant on self-service kiosks to access public services irrespective of physical or cognitive ability (Hagen, 2010). Moreover, banking is increasingly carried out via the Internet and many banks have imposed fee policies that penalize personal banking.

Current computer technology is mostly controlled using keyboard and mouse input. Other technologies are available for users who are unable to use these input techniques. Keyboard and mouse metaphors are also used with alternative input technologies such as gaze-based input (Isokoski, 2000). A myriad of optimized keyboard layouts have also been proposed. However, this study will focus on the accessibility of commonly used keyboard layouts as this is highly relevant for a major segment of society, including the aging population who may be particularly struggling with inappropriate designs because of reduced vision, mobility and/or cognition.

Two of the seven well-known universal design principles are especially relevant to keyboard input, namely design principle 3 which states that a design should be simple and intuitive, and design principle 6 which states that a design should result in low physical effort (Connell, 1997). An intuitive design is related to knowledge. In context of keyboards knowledge is referring to familiarity with keyboard layouts. Currently, the de-facto standard textual keyboard layout is Sholes QWERTY-layout. Consequently, most computers sold today come equipped with QWERTY keyboards. Users with some basic knowledge of computer use are often familiar with the QWERTY layout. This familiarity can be basic where the user employs a so called hunt-and-peck strategy where one or two fingers are used to input text, or touch typing in which all fingers are used to achieve higher text input speeds. Research has shown that knowledge of QWERTY can be exploited to achieve alternative non-keyboard forms of text input (Sandnes, 2007). Despite this knowledge it is not uncommon to find non-QWERTY keyboard layouts – especially alphabetically ordered layouts. This is particularly relevant when the keyboard is implemented in software and deployed on touch sensitive displays, for example for textually specifying destinations (Sandnes, 2010). For instance, in Norway alphabetical layouts can be found on the ticket vending machines of the main train operator, and in the ticket collection self service machines in the Oslo Cinemas. One rationale may be that the designers assume that more users are familiar with the alphabet than QWERTY layout, and that users familiar with QWERTY also are familiar with the alphabet. However, the standing in this study is that this is not true as alphabetical layouts are more disturbing than helpful for users that are familiar with QWERTY. Especially, when using self-service kiosks in a public setting it is ever more important that aspects of the operation are familiar to the user. The research on virtual keyboards has mostly focused on new keyboard layouts for improved performance (Zhai, 2002) and not focused on the effects of alphabetical layouts. The observations made herein give rise to the following hypothesis:

- Hypothesis 1: Users with some computer experience will perform better using a QWERTY layout than an alphabetical layout.

Moreover, for numerical input, that is, the input of digits, there are currently three de-facto standards. First, the common numeric keypad comes in two flavors, the ones with the 1-digit at the top left corner, and the inverse numeric keypad where the 7-digit occupies the top left corner. The latter can be found on most full-desktop keyboards and calculators, while the former can be found on most mobile phones, door-lock keypads, many cash-point machines and payment-terminals. The third type is found on most desktop keyboards and on typewriters, namely the top row of digit keys which originally was designed for touch typists. It is natural to expect that the two flavors of keypad input will require less physical effort than the touch-based typewriter-style top-line of digit-keys since the fingers have to move smaller distances. According to the 6th universal design principle, numeric keypad input should therefore be preferable. Still, many users nowadays purchase small laptop or netbook computers that are not equipped with numeric keypads due to their small form factor. In practice, only larger laptop computers with 16 inches displays or larger as well as desktop computers are equipped with numeric keypads. One consequence of this is that numeric input is more strenuous and difficult. This is especially relevant in context of Internet banking where digit input is common. For example, in Norway users typically need to input an 11 digit bank-account number, the amount and a transaction identification code (KID) that can be up to 30 digits long. The current practice for internet banking in Norway has been criticized for being error prone especially due to the reliance on digit input (Olsen, 2008a; Olsen, 2008b). Therefore, one key question in this study is whether the emergence of keypad-stripped computers is a threat to the usability of Internet bankers? This is captured in the following hypothesis:

- Hypothesis 2: Users are more productive using a numeric keypad compared to the top row of digit-keys found on QWERTY-keyboards.

This study omits the issue of numeric keypad orientation and focuses on the configuration found on most desktop keyboards, that is, numeric keypads with the 7-digit in the top left corner.

2. Method

The experiments in this study were carried out as a large set of mini-studies. Each mini study was carried out by a student group on a small set of users performing a small scale test. The tests were performed by second year undergraduate students as part of coursework for an introductory course in human computer interaction. The text entry experiment was conducted by the enrolled students during the autumn of 2009, while the numeric input was conducted by class enrolled during the autumn of 2008. Each student group designed their own test and the methodology therefore varies. The results presented herein are based on the overall results obtained. These overall results should be robust as it is not dependent on a single experimental design and set of users.

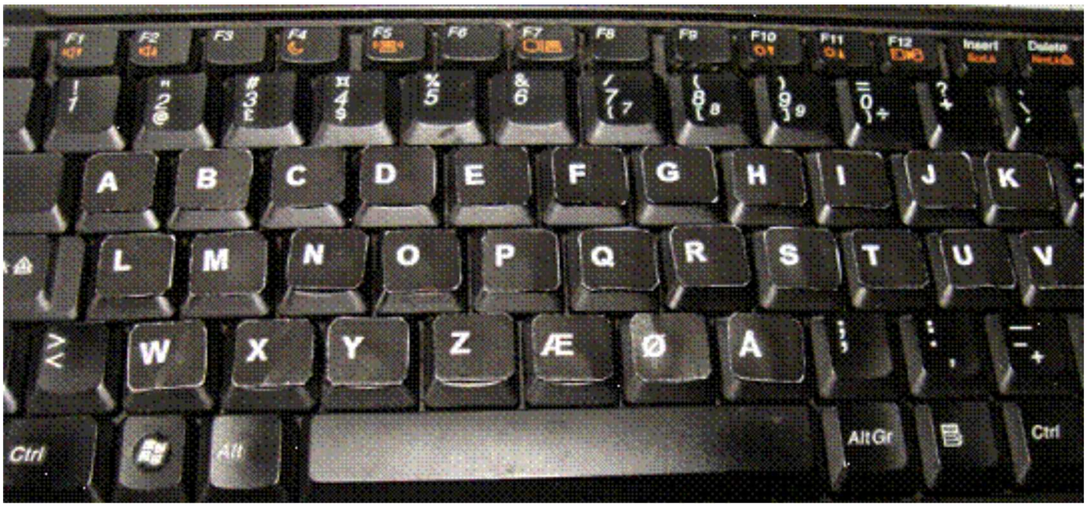

Figure 1. Example of an alphabetic keyboard layout (photograph by Butt & Lindseth).

3. Textual input

3.1 Participants

A total of 14 successfully completed projects are included. Details are listed in Table 1. The number of participants varied from 8 to 42 with a total of 257 participants. The participants were predominantly computer literate individuals and students at Oslo University College. However, a handful of the participants were older individuals and individuals with minimal computer experience. The participants were both male and female.

3.2 Apparatus

Four strategies were employed, namely modified keyboard, touch screen, mouse point and paper. The projects that involved modified keyboards executed the experiment with two physical keyboards – one with an ordinary QWERTY keyboard and one where the keys were physically swapped from QWERTY to alphabetic layout or by means of letter-stickers on the keys (see Fig. 1). For the alphanumeric keyboard layout key-mapping software was used together with either custom made or third party keystroke logging software.
One of the touch based experiments used a GPS-device with a configurable keyboard (QWERTY or alphabetic) while the other project employed a notebook computer with a touch sensitive display. One project employed a virtual keyboard where the users had to use the mouse to click on the letters. Finally three of the studies employed paper-based evaluation where the users were asked to type directly on paper.

3.3 Procedure

For each test the participants were asked to enter text with both the QWERTY and the alphabetic layout. Half the participant started with QWERTY and the other half started with the alphanumeric layout. All subjects have to perform some copy tasks, comprising of everything from a single phrase to a paragraph of text.

Two strategies for measuring the performance were employed. Either participants were asked to copy a passage of text and the total time was measured, or the number of entered symbols within a given time was measured. The measurements were done either manually and by the means of software.

There were no practice sessions in any of the experiments.

3.4 Analysis

The data was analyzed in Microsoft excel using the Analysis toolpack. Significance tests were performed with two-sided paired t-tests with a significance level of 0.05. It was therefore assumed that all the measurements were normally distributed.

Table 1. Results of the QWERTY versus alphabetic layout experiments

Type	Participants	Productivity	Error
keyboard	26	sig.	sig.
keyboard	9	sig.	non- sig.
keyboard	15	sig.	sig.
keyboard	41	sig.	sig.
keyboard	20	sig.	non- sig.
keyboard	8	sig.	sig.
keyboard	11	sig.	
keyboard	8	sig.	non- sig.
touch	10	sig.	sig.
touch	15	sig.	
mouse point	10	sig.	
paper	12	sig.	
paper	42	sig.	
paper	30	sig.	

3.5 Results

Table 1 lists the results of the experiments including the method applied, number of participants whether there is a significant difference between the alphabetic and QWERTY layouts in terms of both productivity and error. Note that the actual productivity data are listed since different types of data were collected in the projects. Note that not all the project groups analyzed the error rate.

The results show that in all instances there were statistically significant differences between the QWERTY and alphabetic keyboard layouts where QWERTY were the most effective in all instances. It is therefore safe to conclude that there is a difference in productivity with the two keyboard layouts. Moreover, for the eight experiments where error was measured only 62.5% resulted in a significant difference in errors. This is not enough to conclude that there is a difference in error between the two keyboard layouts.

As a specific example relevant to a touch sensitive kiosk the experiment involving a touch sensitive GPS resulted in 16.0 WPM (words per minute) for the QWERTY-layout (SD=6.8) and 9.7 WPM (SD=6.1) for the alphabetic layout ($t=9.2$; $p<0.01$; $df=14$).

Figure 2. QWERTY-digit versus numeric keypad.

2. Numeric input

4.1 Participants

A total of 12 successfully completed projects are included. Details are listed in Table 2. The number of participants varied from 8 to 30 with a total of 179 participants. The subjects were predominantly computer literate individuals and students at Oslo University College. However, a handful of the participants were older individuals and individuals with minimal computer experience. The participants were both male and female.

4.2 Apparatus

The experiments were conducted using either desktop computers or laptop computers with either full keyboards including a numeric keypad (see Fig. 2), full USB-keyboard attached or numeric USB-keypad attached. Data was collected either manually using a stopwatch, custom made software or third party software including Data Entry Test 2004, Internet typing game, Type Inspector Pro and Maxtype pro.

4.3 Procedure

For each test the participants were asked to enter digits with both the QWERTY and the numeric keypad layouts. Half the participant started with QWERTY and the other half started with the numeric keypad layout. All subjects have to perform some copy tasks, comprising various lengths of chunked digit strings.

There were no practice sessions in any of the experiments.

4.4 Analysis

The data was analyzed in Microsoft excel using the Analysis toolpack. A significance tests were performed with a two-sided paired t-test with a significance level of 0.05. It was therefore assumed that all the measurements were normally distributed.

Table 2. Results of digit entry experiments with QWERTY versus numeric keypad

participants	productivity	error	numpad	qwerty
10	sig.	non-sig.	112,3	67,7
19	sig.	non-sig.	102,9	75,6
18	sig.	sig.		
9	sig.	sig.	124,9	93,4
8	non-sig.	non-sig.	50,4	44,5
30	sig.	sig.	103,4	75,8
30	sig.		160,0	117,6
11	sig.	non-sig.	106,5	78,1
15	sig.	sig.	101,2	64,8
9	sig.	non-sig.	88,6	64,3
10	sig.	non-sig.	96,9	75,8
10	sig.	sig.	83,1	69,5

4.5 Results

Table 2 lists the results of the experiments. The results show that 11 of the 12 trials showed a significant difference between the numeric keypad and the qwerty based layout in terms of productivity. Based on this evidence it can be concluded that there is a significant difference between the two layouts and that the numeric keypad yields higher productivity than the QWERTY layout. However, only 5 of the 11 trials which recorded errors found the errors to be significantly different. In these cases the numeric keypad resulted in more errors than the QWERTY layout. However, this is not sufficient evidence to conclude that there is a difference in error rate between the two layouts.

In terms of performance the mean number of digits per minute with the numeric keypad was 102.7 (SD=26.9) while the number of digits per minute with the QWERTY layout was 75.5 (SD=18.4). This means that the numeric keypad leads to a 25% performance increase over the QWERTY row of digits.

5. Discussion and implications

The results presented in Table 1 support hypothesis 1, namely that there is a difference in terms of productivity between an alphabetic and QWERTY keyboard layout. One implication of this is that designers of software keyboards such as those found on self-service kiosks, mobile handsets, and such, should avoid alphabetic layouts and instead use QWERTY layouts where the user can clearly identify the QWERTY layout and reuse their knowledge and skills. Most users nowadays use computers in some form. Only a small minority of users may not have any experience with computers and hence may find the alphabetical layout more beneficial.

Overall, text-input free interfaces are preferable on self-service kiosks or mobile handset applications. This is also connected to the principle of recognition versus recall, that is, text input is strongly connected to recall from memory which is harder than input based on recognition.

Next, the results presented in Table 2 support hypothesis 2, namely that there is a difference in terms of productivity between using a numeric keypad and the row of digits on top of QWERTY keyboards. This has implications for internet banking. Most people, for instance in Norway, are strongly encouraged to use Internet banking. A majority of users do not view themselves as computer experts and may not wish to invest too much in computer equipment, especially older users. These users may often opt for cheaper models of computers, often small notebooks or netbooks. The low cost of netbooks have lowered the bar for everyone to own a computer. However, these cheap small form factor devices do not have numeric keypads and these users may therefore experience digit-entry intensive Internet banking tasks as troublesome and laborious. A result would be to inform these users of low cost solutions that may greatly enhance their online experience. One simple solution is to connect inexpensive full-sized keyboard or separate numeric keypads (Sandnes, 2006). The USB-interface means that most users can perform such hardware installations themselves without any need to install software drivers.

6. Limitations of this study

This study has focused on text input in terms of touch displays. Touch-based virtual keyboards are problematic from a universal design perspective. Current touch technology is not easy to use for blind users or users with motor problems such as users with Parkinsons. Moreover, virtual keyboards can also be problematic for users without motor problems or who are not visually impaired. One reason is the lack of haptic feedback and the fact that the hand is obstructing the visual representation of the keyboard.

The experiments described herein predominantly involved users without reduced vision, motor or cognitive difficulties. However, it is likely to expect that the results generalize to users with reduced vision, motor and cognitive abilities.

7. Conclusions

This study addressed keyboard layouts for text input and numeric input. The results confirm that the QWERTY layout in general is superior to alphabetic layouts in terms of productivity. There is no evidence that there is a difference in terms of error. A consequence of this finding is that especially self-service kiosk designers should avoid software keyboards with alphabetic layout and by convention employ a QWERTY layout with a visual appearance of a physical QWERTY keyboard. Moreover, the study showed that numeric input using the numeric keypad is superior to using the row of digit keys on the top of QWERTY keyboards in terms of productivity, but not in terms of error. A consequence of this finding is that users should be made aware of the consequences of using small notebook or netbook computers without numeric keypads when performing internet banking and that simply attaching an inexpensive numeric keypad can greatly enhance the internet banking experience.

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