A Flexible On-Screen Keyboard: Dynamically Adapting for Individuals' Needs

Yun-Lung Lin[1], Ming-Chung Chen[2], Ya-Ping Wu[3], Yao-Ming Yeh[1], and Hwa-Pey Wang[3]

[1] Department of Information and Computer Education, National Taiwan Normal University
162 Ho-Ping E. Rd., 1 Sec., Taipei, Taiwan
{harrison,ymyeh}@ice.ntnu.edu.tw
[2] Department of Special Education, National Chiayi University
300 University Road, Chiayi, Taiwan
mtchen@mail.ncyu.edu.tw
[3]Department of Special Education, National Taiwan Normal University
162 Ho-Ping E. Rd., 1 Sec., Taipei, Taiwan
{893090036,e14008}@.ntnu.edu.tw

Abstract. This study was to design an alternative on-screen keyboard and evaluate the efficacy of this innovative layout design for people with severe physical disability. The matrix keyboard layouts was designed based on human computer interaction. A repeated experiment was performed to compare the speed and accuracy of text entry with point-and-click input method between the matrix on-screen keyboard and the Windows XP QWERTY virtual keyboard. Data analysis revealed that the matrix on-screen keyboard provided better performance for the participant. The result also indicates that layout adaptation assessment is a valid tool to confirm proper layout size for users and that alphabetic order is better than QWERTY order for a novice user to learn a new on-screen keyboard. A usability study was undertaken to evaluation the performance of the double click instead of the point-and-click plus Shift key input method. The possible causes of the results and suggestions for further studies are discussed.

Keywords: accessibility, on-screen keyboard, scanning selection.

1 Introduction

Computers allow us to communicate, work, learn, and perform many leisure activities; they also hold great potential for influencing the lifestyles of people with disabilities. Using a standard keyboard might seem quite normal to most people, but using it can be a strenuous task for people with motor disabilities. There are many alternative on-screen keyboards available to people who have difficulty using the standard keyboard. The purpose of this study was to design an alternative on-screen keyboard to improve the entry efficiency of people with motor disabilities. The efficiency of on-screen keyboards depends on the sustainability of the control interface, including proper selection methods and keyboard layouts [1]. Designing for

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diversity was a factor we considered carefully in this study [2]. The keyboard interface design for people with motor disabilities requires the consideration of many factors reflecting the diversity of disability types and disability degree. We have implemented a one handed numeric-based input method for people with mild motor disabilities and automatic scanning for people with severe motor disabilities. To increase the performance of text entry, we also implemented a new approach to the point-and-click input method.

2 On-Screen Keyboards

The keyboard is the most common method of controlling the computer. The drawbacks of the QWERTY keyboard are in its two-handed design and its requirement of the full use of all ten fingers. Thus, people with physical disabilities have difficulties in accessing a standard keyboard. They can interaction with computers by using on-screen keyboards and assisted peripherals. The purpose of assessing physical motor control is to find the most effective input device and selection technique. Lee and Thomas describe the various components of assistive technology access including input device, selection set, selection technique, and application information [3]. Text entry efficiency is dependent on an alternative interface and on the quality of interaction between the user and the access method.

2.1 Selection Technique

Most of the on-screen keyboard support point-and-click, dwell, and scanning input methods. Point-and-click access is suitable for people with limited movement range who cannot reach across the standard keyboard, but can operate a pointing device such as a trackball or touch pad. If the user is unable to press a button or switch, but is able to keep the pointing device steady for a short time, dwell selection is an alternative solution. For users with severe physical limitations who can physically control only one or a small number of muscle movements, scanning is the only viable control option.

Switch-based scanning is typically used by persons with severe physical impairments. These impairments may be due to disorders such as cerebral palsy, acute muscle weakness at advanced stages of muscular dystrophy, or paralysis due to high spinal cord injury. Scanning involves the successive presentation of items in a display from which the user selects a desired item by activating a switch when the item is highlighted. Three types of scanning with a single switch are distinguished: automatic, step, and inverse. Single-switch automatic row-column scanning is the most common scanning approach.

2.2 Selection Technique

Keyboard layout is an important variable in affecting typing speed, typing accuracy, and ease of learning. Typically, on-screen keyboards display the QWERTY keyboard; however, the QWERTY order layout can be confusing for novice users. In addition to QWERTY, layout character sets can be arranged according to alphabetic order or frequency of use. The frequency of use keyboard groups commonly typed characters to reduce physical effort and help increase typing speed. Although the frequency layout is theoretically physically fastest, input on the keyboard layout with alphabetical ordering will initially be easier for novice users.

2.3 Features to Improve Performance

Several commercial on-screen keyboards, such as WiVik, Grids, WinScan and Click-N-Type, provide more sophisticated functions to allow the improved typing performance of people with disabilities. These programs support computer access features like macros, menus, and dialog boxes; some on-screen keyboards support acceleration features. A common approach to enhancing text input rates is to use word prediction. A number of word prediction systems typically offer users a list of suggested completions of the current word. Users can choose a word from the list using a single command. Other acceleration features are abbreviation expansion and smart punctuation. In addition to controlling text entry, many on-screen keyboards have other features to improve ease of use, such as automatic start up, saving and loading user settings, control over applications, and sound actions[4] [5].

3 Design and Method

3.1 Chorded Input Method

We implemented a chorded input method that allows the user to generate a character by pressing two numeric keys. This chorded input method can be operated with a signal hand. As shown in Figure 1, the first key press selects a sub-matrix, and the second key press selects a letter or symbol in that sub-matrix. For example, when using the numeric keypad, the user presses '4' and then '7' to output the corresponding letter 'a' to the application program. Pressing '5'and '5' will generate the space character. The user can use '0' as a cancel button when a typing error occurs. Based on Fitts' law of movement efficiency, punctuation and commands were placed according to their frequency of use to reduce the fingers' travelling distance.

Fig. 1. Keyboard layout design

Fig. 2. Pop-up menu

The goal of universal design is to make objects accessible to everyone. Based on the aim of designing for a diversity of users, our on-screen keyboard supports a wide range of access methods and adjustments. We also added a high contrast layout for visual impaired users. The on-screen keyboard is displayed within a window that can be moved, resized and supports audio feedback to the user. As show in Figure 2, it also includes a pop-up menu to allow for reconfiguration by a right click of the on-screen keyboard.

3.2 Scanning Input Method

Group-row-column scanning is typically more efficient than row-column scanning. The Microsoft Windows XP operating system and some commercial on-screen keyboard applications support group-row-column scanning with the QWERTY layout. We developed a method of group-row-column scanning based on our matrix layout. The major matrix is divided into 9 sub-matrices. During initial input, the user is expected to select the sub-matrix where the target symbol belongs. When the highlight arrives at the desired group, the user presses a switch. The highlight then advance scans each row in the group until the user presses the switch again. Finally, the highlight scans across each item in the selected row until the user presses the switch to select the character. Figure 3 shows 9 groups of the matrix on-screen keyboard and the sequence of group scanning is 4, 5, 6, 7, 8, 9, 1, 2, 3.

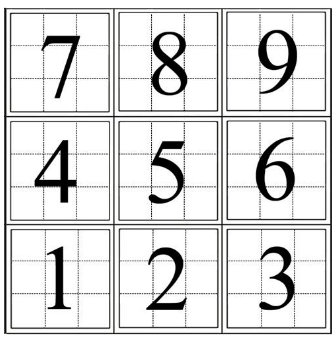

Fig. 3. 9 groups of scanning

The order of the symbols in the scanning keyboard is crucial for the keyboard's performance, since it constrains the access time of each character. We took into consideration letter frequencies in designing our keyboard layout. Figure 4 illustrates the number of scan steps needed to select each item in our matrix. An important principle guiding our design was the notion that different letters occur at different rates in a body of text. Previous research has shown that the letter e occurs about 13% of the time, while the letter z appears at a rate of about 0.2% in a body of English text**[6]**. The letters in the scanning layout are arranged according to frequency of use, which is shown in Figure 5. We also extended the keyboard to special characters such as punctuation, function keys and numeric keys. Since the space character is

6	7	8	7	8	9	8	9	10
7	8	9	8	9	10	9	10	11
8	9	10	9	10	11	10	11	12
3	4	5	4	5	6	5	6	7
4	5	6	5	6	7	6	7	8
5	6	7	6	7	8	7	8	9
9	10	11	10	11	12	11	12	13
10	11	12	11	12	13	12	13	14
11	12	13	12	13	14	13	14	15

Fig. 4. Switch counts in Matrix layout

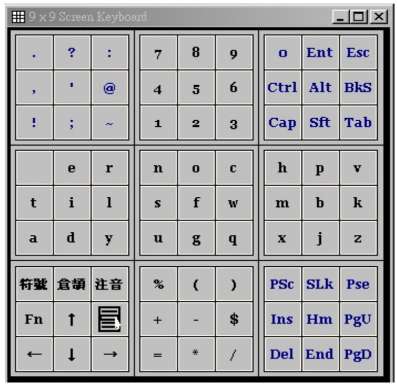

Fig. 5. Scanning layout design

prominent in text entry, it is located on the highest priority position. It was expected that the rearrangement of the keyboard layout according to frequency of use would improve the typing rate by 30-50 % [7].

3.3 Point-and-Click Input Method

Visually based point-and-click interactions are very common for on-screen keyboards. Most on-screen keyboards require use of the Shift key to type the upper case and some punctuation. To minimize the distance of movement, we developed an innovative text entry technique for people with motor disabilities. We designed our method to use the double click instead of the shift key. In our system the user can employ a single-click to output a lowercase letter or number, and a double click to output an uppercase letter, function key, or punctuation.

4 Study Methodology

4.1 Participant

To evaluate the usability of the point-and-click input method, text entry tasks were performed to measure the typing performance of a participant. The participant has a severe physical impairment (Osteogenesis imperfecta). Although she had used computers in the past for three years but she was not familiar with the QWERTY keyboard layout; she had used the point-and-click mode with her left hand. Her performance was poor when using the virtual keyboard embedded in the Windows XP operating system.

4.2 Materials and Apparatus

The evaluation tools in this study included two computer software programs that were designed for this experiment, "Layout Adaptation Assessment" and "Entry Performance Evaluation".

4.2.1 Layout Adaptation Assessment

Layout size is a very important element when considering movement efficiency. A full selection set with large items is obviously easier to access with the point-and-click input method. However, such size requires a considerable amount of space on the screen and increases the travel distance of the pointer. A smaller layout will reduce movement time requirements, but increase the typing error rate. Thus, travel distance and accuracy are the key considerations of when designing for text entry. Our on-screen keyboard supports the re-sizing of the layout and automatically adjusts the size of the individual items correspondingly. Proper layout size is selected for the user by the use of an evaluation tool; our program has seven preset layout sizes. Adjusting the on-screen keyboard to an appropriate layout size and using a double click instead of the shift key should give significant performance improvements for text entry.

The “Layout Adaptation Assessment” program was used to determine the appropriate keyboard layout for the participant. A picture of the program is shown in Figure 6. We applied a binary search tree algorithm to select the appropriate layout for the participant, which is shown in Figure 7. The user selected the proper layout from seven different layout sizes. LAA based on a binary search tree of size 7 and depth 3. A set of three typing tasks was required to be completed for each layout. To counterbalance the effect of learning, the sequences of three tasks were assigned randomly in the assessment procedures.

***Task 1:* x, (, 1, b, (, x, 1, (, b, 1, x, b, x**
***Task 2:* n, o, k, l, o, n, k, o, l, k, n, l, n**
***Task 3:* g, k, 5, 9, k, g, 5, k, 9, 5, g, 9, g**

During the initial assessment of each user the default layout size is type 4 (7.5cm x 7.5cm). A smaller layout is available when the initial assessment result reaches the criterion of 90% accuracy. A larger layout will be allocated when the user cannot reach this criterion. The same procedures will be repeated until the proper layout size for the user is found.

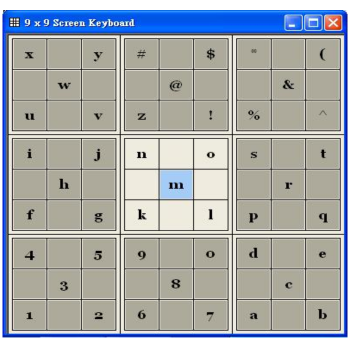

Fig. 6. Layout of adaptation assessment

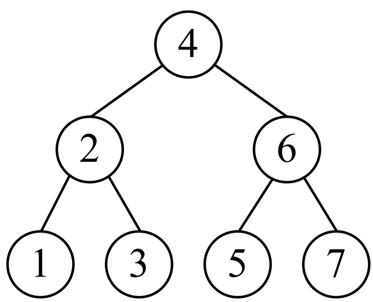

Fig. 7. Layout select algorithm

4.2.2 Entry Performance Evaluation

During our testing, an alphabetical character or punctuation was generated randomly and shown on the upper square of the screen. Some characters required the use of the Shift key in conjunction with other keys. The participant was asked to type the indicated character on our on-screen keyboard and the Windows XP virtual keyboard. A picture of the test application is shown in Figure 8.

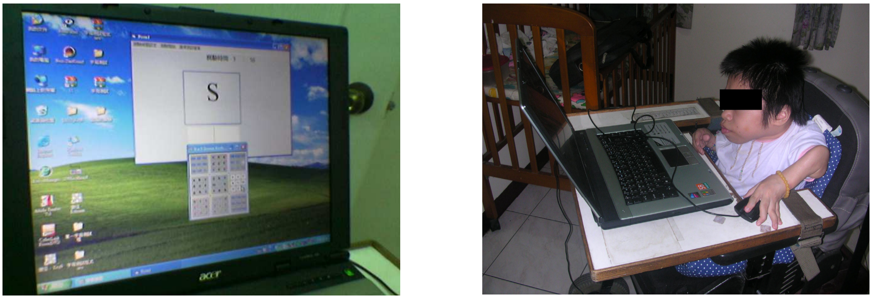

Fig. 8. Typing performance test of Point-and-click Input Method

4.3 Procedure

A repeated experiment was performed to compare the typing speed and accuracy between the two different keyboard layouts. The experiment was conducted with a 15-inch laptop computer in the participant's home. The experiment started with the researcher explaining the task and using the "Layout Adaptation Assessment" program to determine the appropriate keyboard layout for the subject. The result showed that type 2 (6.5cm x 6.5cm) is the proper layout for the participant. After establishing the proper size, the participant took 20 minutes to practice the matrix on-screen keyboard and Windows on-screen QWERTY keyboard.

A picture of the evaluation situation is shown in Figure. 8. A character was displayed on screen and the participant was asked to type the characters as accurately as possible, without performing any error correction. Keyboard trials were conducted twice a day over a period of five days.

Each session was administered in the same way by the researcher. This involved adjusting the table height and positioning the monitor and mouse appropriately. Each session had a dissimilar sequence of two different keyboard layouts to counterbalance the effect of learning. This process was repeated until the subject finished all the test session of the two different keyboard layouts.

5 Result and Discussion

Text entry speed and accuracy are often used as performance measures for evaluating input systems. As shown in Figure 9, we obtained fifteen measurements of text entry speed. Using the matrix on-screen keyboard, the participant could type only 28 correct characters in the first session, but was eventually up to 103 characters in the last session; whereas the results of the QWERTY layout of the Windows XP on-screen keyboard started at 24 characters and ended at 94 characters. The result indicates that the participant performed better while using the matrix on-screen keyboard than the using Windows XP on-screen keyboard.

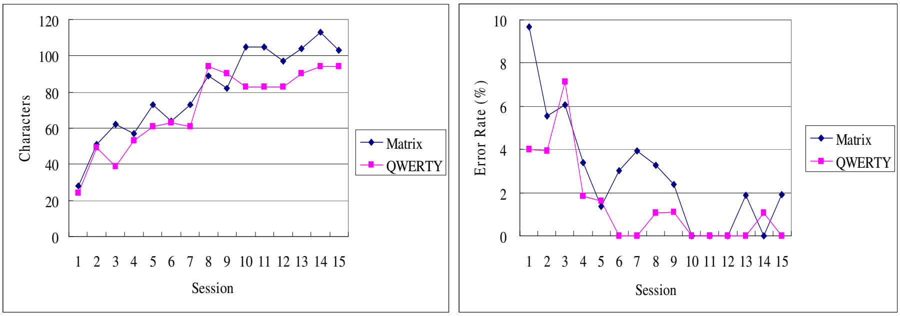

Fig. 9. Entry speed and error rates by variant and session

The participant occasionally made errors, there was no significant difference between the error rates on each keyboard layouts. We also wanted to know how the participant felt about the new approach. An interview was conducted with the participant after the final session. The participant indicated that "Layout Adaptation Assessment" is a valid tool to confirm the proper layout size for users. She also stated that the alphabetic order is better than QWERTY order for a novice user.

6 Conclusions

The need for participation in an information society has let to several research efforts for designing accessibility solutions for people with disabilities. People with motor disabilities do not have the ability to efficiently use standard input devices. This paper has introduced a new on-screen keyboard for use in combination with selected layout sizes. The experiments demonstrate the effects of our on-screen keyboard in comparison to the Windows XP virtual keyboard. The result reveals that the matrix on-screen keyboard worked more effectively than the QWERTY keyboard in the usability evaluation. However, during the evaluation, each input method session only lasted 5 minutes. User fatigue may be a potentially problematic variable that must be evaluated in future studies.

A usability study was undertaken to evaluate the performance of the double click in comparison to the point-and-click plus Shift key input method. Future research that validates the effectiveness of other access methods for people with motor disabilities is needed.

Speed of entry is not the only criterion for an efficient input system. We should take into account other issues such as ease of learning, low error rates, and simple error correction. The time spent on correcting typing errors has a major impact on text entry efficiency. A potential limitation of this study is its reliance on only one participant, which may limit the research results to the people with motor disabilities.

To confirm with the concept of dynamic diversity, on-screen keyboards need to be suited to the changing requirements of the user. Successful computer access often requires a combined approach, an on-screen keyboard will rarely provide a complete solution. If alternative computer input devices are necessary, it is likely that the hardware settings will need customizing. People with motor disabilities may need to adjust the configuration of their input system, but often find it is an obscure and difficult process. By means of a number of the evaluation sessions, the system ideally could, according to the user's preferences and abilities, automatically be self-customizing.

The success of input systems depends on numerous physical and psychological factors. As for future work, we will advance our system by making it compatible with output adaptive tools, to provide better solutions for people with motor disabilities.

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