Four-Key Text Entry Augmented with Color Blinking Feedback for Print-Handicapped People with Ocular Pathology

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Abstract

The print-handicapped users having ocular pathology may be under constraint of typing when they re-learn to manipulate new text entry technique. In our previous research, the 4-key text entry technique with 3 keystrokes per character was designed adhering to the principle of avoiding lateral hand or/and finger movements. In the present study, the 4-key text entry was augmented with the color blinking feedback provided through a single 2-color light emitting diode coupled with eyeglasses to facilitate learning visually handicapped users to type. The implemented approach resulted in significantly greater text entry rate of about 18 wpm under 2.5 hours of practice vs. 14 wpm and 4 hours of practice without the use of the visual feedback. The color blinking feedback could improve the learning process of text entry techniques if this kind of feedback is still possible to apply.

1. Introduction

Acquiring reasonable typing skills with the aid of a standard 101/104-key Windows keyboard is essential for those partially sighted people who are undertaking the courses of study. It can enable them to write when it may otherwise be difficult or even impossible. Edwards argued that assistive devices have to respond to dramatically varying needs [2]. Therefore, in order to be useful, they should allow adaptation to the personal specific requirements [8]. However, computer access for print-handicapped users is often impeded by the standard keyboard design, which has a layout primarily designed for ten-finger manipulation. That is, current interfaces are well designed to assist an ordinary user in producing fast text entry, but they can be inaccessible for an impaired person. Therefore, it is essential to strictly coordinate technical parameters of the technique to cognitive and sensomotor abilities of the person in order to provide reliable text entry method that would be easy to learn and universally accessible.

There is a substantial body of studies on alternative keyboards that prevent accidental key pressing by severe handicapped people, which are relying on their residual motor control while accessing textual information in electronic form. The largest group of switches used as input devices designed to be activated by the movement of almost any part of the body [1, 3, 4, 5, 7]. Alternative techniques include also Braille keyboards (14 keys), one-hand chord keyboards (5 keys), keyboards and keypad assemblies which can be programmed or customized to provide special functions [6, 8]. The chord keyboard requires one, two or more keystrokes per character to be entered simultaneously unlike the multi-tap technique, which requires all keys to be entered sequentially [6]. Nevertheless, the print-handicapped users having such ocular pathology as diabetic retinopathy, cataract and age-related macular degeneration, still experience the difficulties when they re-learn to manipulate new computer applications, while being healthy person they already acquired typing skills with standard keyboard layout but cannot use it further.

There is a challenge to provide print-handicapped people who have ocular pathology with a textual input method adhering to the principle to avoid lateral hand or/and finger movements. We have previously developed text entry technique based on a simple hierarchical structure, and kinesthetic feedback for physically challenged people [11]. To facilitate the text entry training it has to be augmented with visual feedback.

In many cases of retinopathy diffused color vision is still possible within the paracentral area ($\pm 20^\circ$ deg.). It is also known that impairment in the ability to discriminate between red and green colors is particularly uncommon [8]. Therefore, primary kinesthetic feedback during text entry could be
strengthened with the help of a single two-color (red/green) light emitting diode coupled to eyeglasses. The present study aims to facilitate typing with the implemented techniques by employing the Color Blinking Code [9] that could speed up the learning of print-handicapped people having an ocular pathology to type.

2. Previous research

A four-key text entry technique called UDLR with 3 keystrokes per character was implemented using 2 or 3 fingers to enter text. The implemented technique makes use of four keys (Up, Down, Left and Right arrow keys on the 101-key Windows keyboard) manipulated by 3 fingers: index finger, middle finger and ring finger.

The symmetric hierarchical structure with three levels was applied as the basic layout for symbol input and imaging. The alphabet characters are divided into four functional groups which could be accessible by sequential entering the 1st, 2nd and 3rd keystroke as it is shown below in the examples (Table 1).

Additional operations such as Backspace and Next Line involve 2 fingers when typing these combinations. That is, the length of path from start position to character key-node was equal to 3 keystrokes in average.

<table>
<thead>
<tr>
<th>The 1st stroke</th>
<th>Left</th>
<th>Right</th>
<th>Up</th>
<th>Down</th>
</tr>
</thead>
<tbody>
<tr>
<td>The 2nd stroke</td>
<td>Up</td>
<td>Down</td>
<td>Up</td>
<td>Down</td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td></td>
</tr>
<tr>
<td>The 3rd stroke</td>
<td>A</td>
<td>E</td>
<td>I</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>F</td>
<td>J</td>
<td>N</td>
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<td></td>
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<td></td>
<td>D</td>
<td>H</td>
<td>L</td>
<td>P</td>
</tr>
</tbody>
</table>

Below, the samples of the character selection through a sequential input with UDLR method are presented:

A left – up – left  S up – left – up
J right – up – right Z down – left – right
Space up – down  Backspace right – left

Numerous variations of the UDLR method are possible, such as combinatorial variation of functional groups with three key arrangements according the most frequently used characters and the limited joint mobility of the fingers, which will have an impact on text entry speed. Fingers position of the subject during typing with using UDLR method is shown in Figure 1.

Figure 1. Fingers position of the subject during typing with the UDLR method.

A usability study with eight novices showed that the lowest value of text entry speed was 4.4 wpm and the upper bound for the text entry speed was about of 14 wpm under 4 hours of practice.

In our earlier papers [9, 10], a variant of the light color code for a transformation of textual information into blinking color patterns has been explored. The set of English alphabet characters was displayed through the color patterns consisting of four color units having three gradations of brightness i.e., by means of the diffuse blinks having color of background (gray), red and green. The recognition rate of the color blinking patterns at the exposition time of 480 ms per character was nearly of 95-98% achieved under 3 hrs of training. Therefore, we have used this method to provide the color blinking feedbacks during text entry in the present study.

In Section 3, we give a description of the apparatus used and the procedure of the experiment. Section 4 includes a brief overview of the main results obtained while exploring the efficiency of typing performance with using UDLR technique augmented with the color blinking feedback. In Section 5, we discuss positive effect of the visual feedback provided during 4-key text entry on the typing speed of the impaired subject as well as future prospects for the implemented approach.

3. Methodology

3.1. Participants

Sixteen volunteers took part in the test. There was two-factor within-subjects design. Subjects were divided in two groups with 8 subjects on each to test the two versions of the UDLR text entry technique.
The one group that tested the version of the software non-augmented with visual feedback comprised of 5 males and 3 female users, while another group that tested the version augmented with visual feedback had 6 male and 2 female users. None of the subjects had a prior experience on using blinking coded alphabet, peripheral monitor and UDLR technique before. The ages of the subjects ranged from 22 to 50 years with a mean age of 32. All had low or very low visual acuity.

3.2. Apparatus

The testing was performed using four keys (Up, Down, Left, Right) on the 101-key Windows keyboard. Visual feedback was provided through diffuse imaging of the color patterns. The peripheral display for such a method consists of a single light emitting diode (LED) which is coupled with eyeglasses (Figure 2).

![Figure 2. The peripheral monitor used.](image)

The LED was located close to an eye in a paracentral unfocused position and diffused luminescence was provided [9]. The peripheral display was connected with the experimental software through PC parallel port.

3.3. Procedure

The entire experiment took five days. The second group of the subjects was asked to learn blinking alphabet and repeat the system (1 hour) before they started a testing. Both groups of the participants were also given fifteen minutes to familiarize themselves with 4-key text entry method. They were handed out a paper of the chorded combinations for creating characters as the practice guidance for using 4-key text entry technique. The subjects were told the logic of both methods and advised to memorize the coded combinations. They were allowed to make the one "warm-up" session prior to data collection to get familiarized with the experimental conditions and techniques. The subjects, who wore glasses, were asked to remove them when using peripheral monitor.

Whereas augmenting each key press with visual feedback is possible, this way is unreasonable to be applied. Adding visual feedback into entering process after each keystroke (see Table 1) could be redundant and slow down the learning of the distinctive hand gestures which implemented technique does stimulate to memorize. Therefore, only the last keystroke of the whole key sequence initiated the visual feedback concerning the entered character, that is, color blinking codes displayed through the peripheral monitor.

During the test session, the task of the subject was to listen to the wave file of the test word, remember and enter it. Subjects were instructed to do their best during testing and aim for both speed and accuracy when entering the characters. They could rest as desired between trials. When a wrong character was entered, a corresponding sound was heard to indicate that the subject had to try again until s/he got the right character. The time to input one character was restricted to 10 s.

The test words were selected randomly from a sample set of 50 words. Separate words for retyping were used to avoid an additional cognitive load and by taking into account that the test subjects were not native English speakers. The correlation of relative frequency of the characters used during the test with English letter frequency was 0.91. The longest words included 11 characters and the shortest ones were 7 characters in length. The average length of one word was 8 characters. Words were not repeated within blocks but repetitions were allowed from block to block.

One test session consisted of five blocks. Ten words were included in each block. Execution of a condition consisted of a brief practice session followed by three blocks of entry recorded (30 words). Each subject completed five sessions, with no more than one session per day.

4. Results

4.1. Text entry speed

The average performances and standard deviations of the text entry speed for both groups of the participants through 15 blocks achieved at using of UDLR text entry technique alone and augmented with color blinking feedback were compared. The results are presented in Figure 3 and Figure 4.

Since the subjects relied on perception of the color blinking cues which were also unknown for them and learning was still required, an essential effect of
increasing text entry speed was observed only by the 3rd test session. Another two reasons have to be considered for the low entry rates in the beginning. First, tested words included different alphabet letters. This is a good reason because it ensures subjects exploit all color blinking coded combinations during the experiment. However, the appearance of different alphabet letters can essentially impede the learning progress in typing performance. That is, the text entry speed failed to yield a greater text entry rate making use of color blinking feedback during two sessions and reached only of 3.75 wpm by the 1st session. The experiment progress was evident in the 4th session under 2.5 hours of practice. The average text entry rate reached of about 18 wpm by the 5th session.

The data analysis for 8 participants who used the version of software augmented with color blinking feedback over 15 test blocks showed that the lowest average value of text entry speed was about 2.64 wpm with a standard deviation of 0.95, and the upper bound for the text entry speed was 17.67 wpm with a standard deviation of 0.84. In contrast, the use of kinesthetic feedback alone exhibited greater text entry rate already during the 1st session nearly of 4.42 wpm with a standard deviation of 0.75. Color blinking feedback had an impact on the typing performance at the end of testing. The average upper bound for the text entry speed making use of visual and kinesthetic feedback was greater than text entry speed acquired while using kinesthetic feedback alone (17.67 wpm vs. 14 wpm; \( F = 15.0, p < 0.003 \)).

4.2. Error rate

Figure 5 shows the average value of the error rate acquired during the text entry for both groups of the participants through 5 test sessions at using of UDLR text entry technique alone and augmented with color blinking feedback.

An error was recorded when the entered character did differ from the needed character. The data analysis revealed that making use the version of software augmented with visual feedback during text entry exhibited greater error rate of about 20.57 % in the 1st test session than the use of kinesthetic feedback alone which resulted in the error rate of about 18.75 %.

Errors may have occurred because the text entry speed increased over experimental sessions and subjects missed some of the color blinking cues. Becoming accustomed to the typing augmented with
color blinking feedback, the subjects significantly improved the performance and proceeded with quicker and more accurate motor control. Making use the version of the software non-augmented with visual feedback resulted in greater error rate of about 4.75 % to the 5th session than the use of the version augmented with visual feedback, which exhibited error rate of only about 2.25 %.

5. Conclusion

The print-handicapped users having an ocular pathology still experience the difficulties when they re-learn to manipulate new text entry techniques.

In our previous research, 4-key text entry technique with 3 keystrokes per character was designed adhering to the principle of avoiding lateral hand or/and finger movements. In the present study, the technique was augmented with color blinking feedback provided through a single two-color light emitting diode coupled with eyeglasses to facilitate learning handicapped users to type and help them proceed with more accurate motor control.

The use of color blinking feedback drastically improved overall typing performance. The implemented approach resulted in significantly greater text entry rate of about 18 wpm under 2.5 hours of practice vs. text entry rate of about 14 wpm achieved under 4 hours of practice without visual feedback.

The data analysis of the typing learning with visual feedback revealed that making use the version of typing training software augmented with color blinking coded alphabet allowed to decrease as much as twice the error rate during text entry.

The technique employing a residual vision could be useful for development of the wearable assistive devices and educational applications for print-handicapped typists having an ocular pathology.

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7. References


[4] Devices, software, hardware and peripherals that allow and/or utilize Morse Code input for AAC/AT applications. Available at: http://www.uwec.edu/hss-or/Morse2000/equipment.html


