Typing Training System on Touch Screen

with Color Blinking Imaging

Tatiana Evreinova  Grigori Evreinov
TAUCHI Computer-Human Interaction Unit
Department of Computer and Information Sciences
FIN-33014 Tampere, Finland
{e_tg, grse}@cs.uta.fi

Abstract
Acquiring reasonable touch-typing skills is essential for partially sighted students. The goal of our work was to strengthen touchscreen navigation and typing on virtual keyboard using residual visual resources. Visual color patterns displayed with the help of a single two-color light emitting diode coupled to glasses and special layout of tactile markers have been used to design the text entry self-training system. The tactile pointer 110×40 sq. mm provides 15 clearly detectable positions on the touchscreen and minimizes inadvertent selections. Our results show that multisensory approach reduces a period for tutorial. The adequate color stimulation could also promote deceleration of the degeneration of visual nerve.

1 Introduction
Visual impairment reduces an ability to use safely standard consumer products and to gain efficiently access to services or information sources. In the United States, one in every six Americans reports some type of uncorrected vision impairment by the age of 45 (Lighthouse international). Among the elderly, the most common causes of vision loss are age-related macular degeneration, cataract and diabetic retinopathy (Madison & Legge, 1996). Age-related macular degeneration is the leading cause of visual impairment for those, who are 75 years old and older.

Lacking visual feedback, writers who are visually impaired can use alternative means of displaying text, which rely on other senses. Visually impaired persons who cannot be accommodated with available fonts and colors often use screen magnification software, which allow to enlarge the viewing area of a computer monitor display. Such devices also have some disadvantages. The magnifiers are intended to display static text and special visual strategy is supposed for exploitation of this method with hard retinal damage. Both Braille and screen-readers having a speech recognition module cannot be used everywhere.

In the public terminals up to now the pointing devices based on visually feedback are most often exploited. Such terminals exist to provide public access at libraries, banks, presentation halls, Internet and email systems. Commonly, these systems can use touch screens or touchpads. For most users the mouse and touchpads provide the main way of interacting with graphical interfaces. But mice and touchpads both are generally used as relative positioning devices in which the pointer moves relative to its previous position when the device or finger moves. That is not satisfying the requirements of partially sighted persons. For people
who have low vision each position of the screen, each option of interface or each state of input device must have a special attribute or a simple and understandable marker projected on their individual space of imaging [8]. That may be an imaginary plane as well as the skin surface of the user on a palm or fingers. The amount of such markers is limited not only by tactile surface or an overload of sensory canal. Therefore the use of touchpad or touch screen remains as an inefficient method for visually impaired people even at the presence of speech feedback when it is necessary quickly to find or to point a particular item within the keyboard or any layout (Deron, 2001).

There are also alternative keyboards and displays for visually impaired people, which include Braille keyboards, chord keyboards, and keyboards, which can be programmed or customized to provide various functions. A presence of separate keys or software buttons allows the user to have access to a maximal possible amount of the functions. But, if the user has not of particular skills, the keyboard layout makes difficult navigation to select needed position. Others, beyond the current task, displayed elements distract independently what layout has been used - with optimization or conventional.

Age-related diseases, most notably diabetes, can devastate tactile sensitivity. Diabetes could have unfortunate consequences for the aging Braille reader by gravely accelerating the loss of tactile acuity (Nakada & Dellon, 1989). The same applies to other common age-related disorders, notably hand-arm vibration syndrome and so on. The limited customer base for Braille displays also makes them quite expensive.

The goal of our work was to strengthen touchscreen navigation and typing on virtual keyboard using residual visual resources for the persons with low vision who cannot see well. Such means should not only provide access to computers, but also to be equivalent in power and efficiency to those available to sighted users.

2. Background

Acquiring reasonable touch-typing skills is essential for partially sighted students. Since the poor performance has been achieved relative to the mechanical keyboard, touch screens have become the input devices of choice as the sense of touch provides new interaction techniques for visually impaired people. Despite of the versatility of the touch screen is highly desired, empirical studies have found that data entry speed and error rates are often worse with touchscreens than with mechanical key based devices, possibly due to the decreased proprioceptive feedback (Barrett & Krueger, 1994; Wilson, Inderrieden & Liu, 1995). As a result, users in a much degree rely on auditory and visual feedback of the conventional computer applications when self-monitoring input accuracy. It is noteworthy that although visual feedback is not really required for mechanical keyboard use, it provides needed insight at touch screen use.
Visual information gives us a rich, spatially organized representation of a scene. It allows us easy access to both an overview or to specific details (Davies & Cowan). Color is appropriate to find a certain target or to project specific information on the display that is not related to another feature. It is important that only a small number of colors is used to ensure absolute judgment and correct identification and to avoid distraction of the partially sighted user during visual perception of needed information.

Macular degeneration and similar diseases of the retina may lead to central vision loss. The following visual field photos (Figure 1) were created from information submitted by the members of MDList (Through our eyes. A Gallery of Personal Visual Perceptions). In many cases of retinopathy diffused color vision is still possible within paracentral area ($\pm 20^\circ$) and could be used during the text-input process through conventional keyboard to provide visual feedback for partially sighted user. It is well known that impairment in the ability to discriminate between red and green colors is particularly uncommon, and it is estimated that about only 8% of all males have some deficiency in this area, though it is much rarely for the females (Fisher & Petrie, 2002).

A color is one of the visual attributes that we are able to process pre-attentively. Color tagging is a causality-detection strategy, which takes advantage of the human capacity for pre-attentive processing. Pre-attentive processing is that portion of visual processing that we are able to do in parallel processing that takes a constant time to perform, independent of scene complexity (Davies & Cowan).

To facilitate typing tutorial on keyboard or touch screen we see a need in strengthening of primary feedback with the help of a single two-color light emitting diode coupled to glasses and special layout of tactile markers. Such system would allow multi-sensory approach at typing on virtual keyboard by combining both tactile and visual modalities. But it is necessary that this system...
could require minimum resources of the visual perception and use habitual position of the fingers on the board.

In preliminary research two types of tactile pointer and a special program were implemented for exploration the structure of feedback cues and strategy of the input during manipulations of a partially sighted novice user (Figure 2).

![Figure 2: Tactile Pointer layout for 25 keys of the virtual keyboard.](image)

Tactile pointer was implemented with using transparency film and copper wire (diameter is 0.2 mm). It does not disturb the normal use of the touch screen. The textured pattern has well recognized tactile markers: angles and lines. It presents the coordinate system concerning which sensory fields (software buttons) are oriented and may be easily detected. The partially sighted people can navigate with the help of these markers, recognizing a key position on the touch screen. Touch buttons were arranged in groups, based on similarity of function and frequency of use. These groupings exploit natural anatomical position of the fingers. Since there were only 25 positions of virtual keys, we grouped them and several positions were destined to switch a state of functional groups (Figure 3).

Pilot experiments of the use of Tactile Pointer have shown that during blind manipulations tactile feedback based on a special textured pattern allows facilitating detection of different positions of touch screen (Evreinov & Raisamo, 2002).

![Figure 3: Snapshots of the program for 19” monitor of ELO Touchsystem inc.](image)
In earlier papers [Evreinova & Raisamo, May 22-25, June 13-14, October 19-23, 2002] we have explored a variant of the light code for transformation efficiency of textual information into visual color patterns. Two-color blinking spot on the screen of monitor provided visual feedback regarding characters entered in textual box with the visible size of the spot was about 4 degrees. The color pattern consisting of light units having three gradations of brightness: 0.0, 0.5 and 1.0. The light units within the sign pattern should not be separated.

The comparative analysis of an amount of recognized test symbols among distractors (noise symbols switching attention) obtained under the investigation of pairs at exposition times 320, 400, 480, 560 and 640 ms was made.

Primary task of subjects consisted in temporal remembering the single color combination and counting the amount of these color patterns appearing within the presented sequence. After getting of a basic level of subjects familiarity with the whole blinking alphabet it was found that, some symbols were hard to remember during of the learning process. They were incorrectly distinguished in the pattern of the word when peripheral monitor was used. Therefore, we modified some of the letters in the blinking coded alphabet [Evreinova & Raisamo, June 13-14, 2002]. Both versions of letters before and after modification are shown in the Table 1. The modified version of the English blinking coded alphabet is shown in the Table 2.

<table>
<thead>
<tr>
<th>English alphabet</th>
<th>1st color unit</th>
<th>2nd color unit</th>
<th>3rd color unit</th>
<th>4th color unit</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
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Table 1: Two versions of letters – before and after modification

Brightness level and color:
1 - B = 0.5 / green; 2 - B = 1.0 / green; 3 - B = 0.5 / red; 4 - B = 1.0 / red;
5 - B = 0, the LED switch off

Based on preliminary results, we implemented the special self-training system for partially sighted people that reduce a period for touch-typing tutorial on the virtual keyboard by combining tactile feedback and residual visual resources.
3. Methodology
A usability study was undertaken to evaluate the new version of Tactile Pointer layout for 15 keys of the virtual keyboard. The goal of our research was to explore an efficiency of typing performance and the learning trend over whole experiment.

3.1 Participants
In longitudinal studies, fewer participants are usually engaged but they are tested over a prolonged period of time. In this study, we used 8 volunteers from staff and students at the University of Tampere. The ages of the subjects ranged from 21 to 47 years, and all had a normal color sight but low visual acuity. There were four male and four female. All used computers on a daily basis. The average computer experience of all participants was 4.2 years. All had regular experience with the blinking coded alphabet and used both the peripheral monitor and Tactile Pointer for 25 keys of the virtual keyboard before. They were recruited from these subjects who participated in other related experiments earlier. Since a virtual keyboard for tactile layout was specifically designed for English, we picked only participants who have fluent knowledge of English. All were well informed on the time commitment required for the experiment.

3.2 Apparatus
The experiment software Blinking Pointer was developed in Microsoft Visual Basic 6.0. Speech feedback cues were wave files formed via AT&T text-to-speech engine for each character within test sentences and for whole sentences or commands. Visual color patterns were presented through the blinking spot, which was projected into paracentral field of the sight on the screen of 30 mm in diameter. The peripheral display for such method consists of only the single light emitting diode (LED), which was coupled with glasses (Figure 4). The LED is located close to an eye (paracentral unfocused position and diffused luminescence), it would not require to recognize a precise form of characters from segments, and thus would not create essential inconveniences in a direct viewing. The peripheral display was connected with the experiment software through PC parallel port.

![Figure 4: Peripheral monitor in working condition](image)
3.3 Design implementation

The tactile pointer 110×40 sq. mm was implemented with transparency film and copper wire (diameter 0.2 mm). Special layout of tactile markers provides 15 clearly detectable positions on the touchscreen, which correspond to keys of the virtual keyboard (Figure 5). To formalize the typing task we decided to use only alphabet characters excluding numerals and special signs, in total 26 symbols. Since there were only 15 positions of virtual keys, we grouped them specifically. Ten positions of touch keys were intended for input of the letters, one key was destined to switch a letter case (lower/upper) and two keys provided the space character. The position “space” was not used in this series of experiments. The virtual keyboard for special layout of tactile markers is shown in Figure 6. In the following section we describe the experimental methodology of the touch-typing training on virtual keyboard using residual visual resources. Visual feedback was provided through color patterns imaging with the help of the peripheral monitor. Our goal was to capture a snapshot of subject performance at the onset of typing learning with color-blinking imaging and after some practice on a virtual keyboard in the same mode.

Figure 5: Tactile Pointer layout for 15 keys of the virtual keyboard

Figure 6: Virtual keyboard for tactile layout
3.4 Procedure

The experiment was conducted in special usability laboratory. To minimize interference from any other source the lab was completely booked for the experiment. The entire experiment took about two weeks.

The main goal of this research was to form typing skills on virtual keyboard at using diffuse color (visual) and audible cues. Each participant was given written instructions explaining the task and the goal of the experiment. Participants were then given the touchscreen. The 19” monitor of ELO Touchsystem inc. and loudspeakers were positioned on the separate desktop. The height of the desktop was 26 inches, a standard height for typing. The desktop could be adjusted by about two inches to allow for different body sizes. The experimental setup is shown in Figure 7.

![Figure 7: Monitoring of the testing program on the examiner side](image)

Since all tested subjects had regular experience with the blinking coded alphabet and used Tactile Pointer for 25 keys of the virtual keyboard before, they were not given practice session prior to data collection.

During the test session, the task of test person was to hear, remember and enter brief words, which were provided by the software. The words were selected randomly from a source file of 70 words. Subjects were instructed to aim for both speed and accuracy when entering the characters. As well, they were told to ignore mistakes and continue with the rest of the sequence when a mistake was made. When an error occurred, the brief earcon was heard. Each session lasted about 55 minutes and was divided into two 25-minute periods. Each half-session contained four blocks of a recorded entry. A five-minute break was allowed between the two half-sessions. Each block contained 10 words of about 12 characters each. Words were not repeated within blocks but repeats were allowed from block to block. The words were chosen to be representative of English and easy to remember. Subjects had the opportunity to playback the word before entering the text as many times as needed for the better remembering. Each
subject completed 14 sessions, with no more than one session per day. The formal experiment has taken two weeks, that is, 56 experimental blocks were registered for each participant. Sessions were scheduled Mondays through Sundays. This was to simulate "regular use" of the virtual keyboard (new/specific tactile layout) while trying to avoid fatigue and accommodating participants' daily schedules.

It was a longitudinal study attempting to practice participants toward expert performance. Therefore, to help motivate subjects, the results of each user's performance: exercise time, errors and the mean of typing speed, were displayed at the end of each block. Performance expectations were not explained, however. Instead, participants were constantly reminded to do their best on tested layout. The measuring procedure was started from the first touch of the tactile marker. Audible and visual cues accompanied the entering of each character. According to our previous research the better exposition time for recognition of color patterns was 480 ms. Therefore we used this exposition time for color blinking imaging. Snapshot of the testing program during of the testing is shown in Figure 8.

4. Results and Discussion

4.1 Text Entry Speed - The Learning Curves

The average performance of the text entry for one of participants through 56 blocks at using of peripheral monitor and audible cues during the touch typing learning (training) on virtual keyboard is shown in Figure 9. Text entry speed was converted to “words per minute” by using of the typists’ definition of a word – five characters including spaces.

The virtual keyboard faired poorly initially (2.52 wpm) despite of all had regular experience with the using both the blinking coded alphabet and peripheral monitor before. We have considered several reasons for the low entry rates. First, our tested words included many different letter of the alphabet. On the one hand,
this is good because it ensures subjects touch every key during the task. On the other hand, the appearance of different letters of the alphabet can essentially aggravate the progress in touch-typing performance.

A significant effect of increasing user text entry speed has been observed only at the 5th session. This is under five hours of practice. The experiment progressed performance continued to improve at the 11th session. This is likely due to subjects getting accustomed to the software and the feel of the tactile layout. The average text entry rate reached nearly 15 wpm by the 14th session.

The full data analysis of the touch-typing learning at using of color blinking imaging for 8 participants over 56 test blocks showed that the lower average value of text entry speed was 2.57 wpm (Figure 10), and an upper bound for the text entry speed was 14.84 wpm (Figure 11). The average value of text entry speed was faster (2.62 wpm and 14.98 wpm were lower and upper bound accordingly) at using of the speech feedback. However, speech feedback signals had less influence on the test performance in both beginning and in the end of experimental session when color cues were used (F < 0.053).

![Graph showing learning curves to 14th sessions by one of subjects](image-url)

Figure 9: Extended testing: learning curves to 14th sessions by one of subjects
Figure 10: The average performance of the entry speed by subject without training, first session

Figure 11: The average performance of the entry speed by subject, fourteenth session
4.2 Error rate

An error was recorded when the user-entered character differed from the given character. As it was expected, there was significant difference between the average value of the error rates at the beginning of the experimental session (25.67 %) and in the end of the testing (1.17 %) (Figure 12). The higher error rate in the first sessions was likely due to participants’ constant need to recognize color patterns immediately after touch-typing.

During of the experiment we have explored what kind of errors occurred and why they have taken place. Some typical error was adding an extra character or tangling neighboring keys due to low familiarity degree with keyboard layout during blind typing. The confidence in being familiar with the virtual keyboard layout allowed participants to proceed with quicker and more automatic motor control. Errors may have also occurred because the text entry speed increased over sessions and subjects missed visual and audible feedback cues.

It is noteworthy that although participants were not instructed to anchor any body part, they tended to anchor their elbow on the desk and hold their wrist in the air when using the tactile pointer. The moderate text entry speed achieved with the tactile pointer in the present experiment, therefore, may simply have been a function of "wrist ceiling effects" for this device.
4.3 Dynamics of the typing training

Figure 13 demonstrates that the time of the test blocks completion was essentially followed, from 280 s at the beginning to 95 s in the end of experiment, due to increasing of the touch-typing skills on the virtual keyboard.

In general, our experiments showed that the subjects could gain familiarity with tactile pointer fast as well as to achieve significant increasing of typing accuracy using suitable position of the fingers on the virtual keyboard. The high error rate during the first and second experimental session was probably related to the deficient knowledge of the feedback signals requiring recognition efforts. Some users had less difficulty with text entry at using of the speech feedback cues, because brief words could incorrectly be distinguished.

![Figure 13: The total times of the test completion for 14 experimental sessions (s)](image)

5 Conclusion

The text entry self-training system was designed using visual color patterns displayed with the help of a single two-color light emitting diode coupled to glasses, special layout of tactile markers and speech feedback cues. The tactile pointer 110×40 sq. mm provides 15 clearly detectable positions on the touchscreen and minimizes inadvertent selections.

The majority of people who cannot see well are unable to use the small dots of the Braille system due to low tactile sensitivity. The experimental results showed that during blind manipulations tactile feedback based on a special textured pattern allows to strengthen touchscreen navigation and typing on virtual keyboard using residual visual resources reduces a period for tutorial. Speech feedback had less influence on the performance of the test. The using of color
blinking imaging improves an access to the textual information for the partially sighted people. We suggest that the proposed method could be useful for development of wearable assistive devices and educational applications for visually impaired typists. In subsequent experiments we investigate vibration patterns as feedback cues as well as user input. An adequate color stimulation of the visual analyzer could also promote deceleration of the degeneration of visual nerve.

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