A Wearable Input Mechanism for Blind users of Computers based on Mental Mapping of Thumb-To-Phalanx Distances

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ABSTRACT

As computers become common in different work environments, more accessible forms of interaction are required so that blind people may cost-effectively perform computer-based tasks requiring precise input. The human hand has 14 digital bones called phalanges. We propose an affordable mechanism for entering input into a computer which maps individual keys to the phalanges of each finger but the thumb. Our study shows that this mechanism can be used as a plausible input method in workspaces. We show that participants can achieve entry rates of up to 6.0 Words Per Minute (WPM) and have an average Character Error Rate of 3.58% with up to 100 minutes of practice.

Author Keywords

Blind; Finger-to-Finger; distance, segments

ACM Classification Keywords

CCS → Human-centered computing → Accessibility → Accessibility technologies

INTRODUCTION

As the use of computers in workspaces has increased, there is a need to provide blind employees and online examinees for jobs with accessible interaction mechanisms to minimize typing inaccuracies and increase work efficiency. Many solutions have been proposed. Gaines [1] explains a system which uses gestures on a mobile screen and determines the location of the tap based on the QWERTY system. BraileSketch [2] is based on a swipe-based mechanism on a touch screen to track points corresponding to braille symbols of characters. Perkinput [3] uses taps to recreate typing on a Perkins Brailler on a phone. BrailleTouch [4] and BrailleType [5] allow users to tap on six points on the screen to represent the braille cells. However, these systems rely on a touch panel and are battery operated, which can become inconvenient in the work environment.

Blind people also use normal QWERTY keyboards along with Refreshable Braille Displays [6] for verification of input. Braille displays provide feedback via tactile responses and have been modified for usage in tablets [7] as well, but they are expensive as prices vary from $500 to $13,500 [8].

Speech-to-Text systems using deep neural networks such as DeepVoice [9] are reducing error rates and are popular but give irregular results depending on surrounding noise and microphone quality.

Glove based systems such as The Chording Glove [10] require the user to memorize combination of keys to press together to represent characters, while function and sticky keys increase the number of possible characters. Choudhary [11] relies on Braille literacy, using 6 capacitive sensors to represent braille cells to be tapped to represent a character.

SYSTEM DESCRIPTION

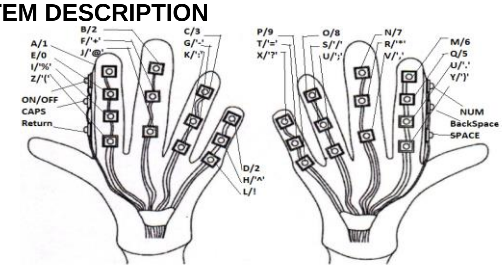

Figure 1. Mechanism showing layout of buttons on glove. Each button is assigned an 'Alphabet mode' and a 'Number Mode' character, indicated after '/'. Number Mode starts after pressing 'NUM' key.

Our 'Mentalitype' keyboard mechanism is composed of 32 push-buttons which give tactile responses. 26 of these buttons map to the alphabet (arranged in order from index to little finger in each hand, in our implementation), numbers and punctuation (based on the mode currently set on the device). The remaining 6 are for: POWER, NUM/Alphabet, Spacebar, Enter, CAPS LOCK and CTRL keys.

Each phalanx of each finger (except the thumb finger) in both hands is mapped to a character as shown in Figure 1. In our implementation, we have mapped all 24 phalanges to 24 letters of the English alphabet. 2 extra buttons were added (one on each hand) below the proximal phalanges of the index finger of each hand to accommodate all 26 letters.

Furthermore, 3 buttons are added on the sides of the index fingers facing the thumbs, which are mapped to modifier keys such as Caps Lock, Space Bar, Return, Backspace etc.

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The user will provide an input by touching the key with their thumb and pushing it down. Each push button switch is connected to a port in the Microcontroller board used for this mechanism. The Arduino Due was chosen as it functions on an Atmel AT91SAM3X8E microcontroller chip which can handle the strict timing requirements for USB interfacing and provides a library for the same [12]. Each button can be reconfigured to map to certain characters as per the personal needs of the user. Audio feedback of each letter is provided with the NVDA [13] screen reader software. This design was proposed assuming users understand the relative positions of body parts better than off-body systems (touch screens, keyboards, etc) but we will work with users to explore alternative arrangements of keys, using participatory design methodologies as suggested by Spinuzzi [14].

USER STUDY:

In our study, we worked with 5 blind participants and conducted 5 sessions of testing per participant, each lasting up to 20 minutes and involving typing tasks. Words chosen for the study are from the Oxford 3000 list [15], which is curated considering frequency, familiarity and range in English language. A pool of 15 words were chosen for each participant such that they covered all letters. We calculated the following to test accuracy and speed of typing:

1. Entry Rate: The typing speed in Words per minute, assuming 5 characters (including spaces) is a word. This allows us to compare the speed of typing.

2. Backspaces Per Tap (BPT): The total number of taps deleted divided by the total number of taps entered by the participant [1]. This helps determine the accuracy of typing. It gives a large value if the number of initial taps being deleted is large, which would indicate that the system does not help increase accuracy.

3. Character Error Rate (CER%): The minimum number of additions, deletions and substitutions to obtain the reference text, divided by the total number of characters entered and multiplied by 100 [1]. This indicates the number of errors during typing which remain unknown to the user.

In the first session, the participants were asked to test each button on the device and form their own words to increase their familiarity with the system. They were then asked to type the alphabet and all parameters were calculated.

In the second session, 4 two-letter words were chosen from the word list and the participant had to type them with spaces. This was repeated twice per session per participant, with different ordering of words. In the consequent 4 sessions, the number of characters in words used were increased by 1, while the number of words typed remained the same. In session 5, each participant had to write sentences of up to 25 characters. The sentences were such that they contained at least two words from the Oxford 3000 list irrespective of whether they had been encountered in the participants' previous sessions or not. Table 1 shows an example of text a participant would write over the 5 sessions.

Session	Reference Text
1	abcdefghijklmnopqrstuvwxyz
2	my as it is
3	cat dog try all
4	baby quite hole zone
5	that is a brown fox

Figure 2. Image of the Mentalitype Keyboard mechanism. Table 1. Sample text used in all sessions.

Results:

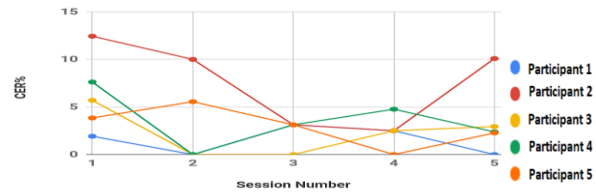

Figure 3. Participants' CER% by session.

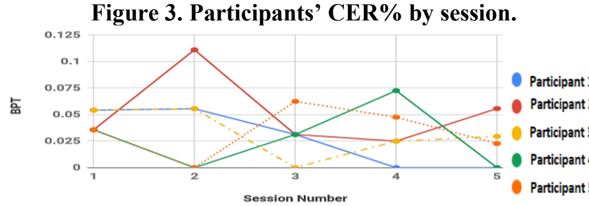

Figure 4. Participants' BPT by session.

The participants averaged an entry rate of 3.57 WPM which betters the BrailleType's initial 1.45 WPM. There was an observed increase in speed with every session. Two participants reached 6.0 WPM in the last session, which indicates that with longer sessions the speeds could eventually compete with the Chording Glove's initial 8.9 WPM. The average CER% was 3.58% and the average BPT was 0.03, both of which are very competitive with Gaines' (2.08% and 0.068), BrailleType's (8.91%) and BrailleSketch's (10.6%). The average BPT and CER% decreased after each session except one, which suggests that accuracy could improve with longer sessions per participant.

CONCLUSIONS:

The Mentalitype keyboard is feasible for use as a high accuracy keyboard for blind users. With continued practice, users can improve typing speed, which can make our mechanism useful for daily use. We will perform more sessions with participants to verify this. For future studies, we are working with a school to introduce the device to autistic children, since our mechanism requires a maximum of 2 Gestures Per Character (GPC), which could benefit slow learners. As per participants' suggestions, we aim to enable them to customize the character-key mappings through software as per personal needs. This could also enable people with Symbrachydactyly to personalize the mechanism to improve their ease of typing. We are also looking into different materials and button dimensions to accommodate more people having different hand sizes. We will also explore security aspects of the system to study the protection of user privacy while inputting sensitive information.

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