# Five-Key Text Input Using Rhythmic Mappings


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## ABSTRACT

Novel key mappings, including chording, character prediction, and multi-tap, allow the use of fewer keys than those on a conventional keyboard to enter text. In this paper, we explore a text input method that makes use of rhythmic mappings of five keys. The keying technique averages 1.5 keystrokes per character for typical English text. In initial testing, the technique shows performance similar to chording and other multi-tap techniques, and our subjects had few problems with basic text entry. Five-key entry techniques may have benefits for text entry in multi-point touch devices, as they eliminate targeting by providing a unique mapping for each finger.



## Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces—*input devices and strategies*

## General Terms

Performance, Human Factors, Experimentation

## Keywords

One-handed text entry, multi-tap, rhythmic tapping, touch


## 1. INTRODUCTION

In recent years, interactive wall and tabletop displays have attracted increasing attention from the HCI research community. Novel interaction techniques have been developed to facilitate activities such as navigation, organization, and collaboration. However, text input is still required for many applications. Separate physical keyboards are inconvenient as they force users' hands away from the display they are interacting with. Projected virtual keyboards solve this problem by allowing input directly on the display, but still require users to attend to the key locations, since they lack the tactile feedback of physical keyboards.



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To retain the benefits of text input directly on the surface of the display and overcome the need for users to attend to and target key locations, each of the users' fingers could be assigned one virtual key. In the one-handed case, which leaves the other hand free to manipulate the display, this gives five keys to work with. As well, the heel of the palm can be mapped to a sixth contact point. Extending a five or six-key mapping to cover the range of characters needed for English text entry requires mapping multiple keypresses to single characters through techniques such as chording, where keys are held simultaneously, and multi-tap, where keys are pressed in sequence [7]. In all of these techniques, as fewer keys are used, more keypresses (either sequential or simultaneous) are required to create an individual character. Rhythms, such as long and short presses, can be added to increase the range of characters that can be generated with a given number of keys. The Morse code alphabet is an example of a single-key multi-tap mapping, in which characters are represented by between one and five long or short keypresses. With five keys available, a rhythmic multi-tap technique can achieve even greater efficiency.

In this paper we study a novel five-key rhythmic multi-tap text input technique using one and two-key sequences of short and long taps. Using a key mapping optimized for English language letter frequencies, it allows for input at an average rate of 1.5 keystrokes per character. We study initial use of the input technique, and demonstrate results similar to those obtained with chording and other multi-tap techniques.

This paper is organized as follows. In the next section, we discuss related work in text input techniques using few keys, particularly techniques using multi-tap mappings. We then describe the input technique and mapping in greater detail. Following this, we present a pilot study in which we show that users can successfully understand the mapping and enter text. Finally, we conclude by describing some improvements that could be made to the technique and its potential application in tabletop displays.

## 2. RELATED WORK

In their work on text entry for mobile computing, MacKenzie and Soukoreff present a series of small keypads used for text entry [7]. These keypads include letter mappings onto the standard telephone keypad via T9 or multi-tap, thumb keypads as on the Blackberry, and chording keypads such as the Half-Qwerty and the Twiddler. For keypads with fewer keys, as on the telephone keypad or the Twiddler, some sequential or chorded keying technique must be used. A useful metric for characterizing the efficiency of these techniques is the required number of keystrokes per character (kspc) [6]. MacKenzie [6] reports keystroke per character rates of about 10 for five-key cursor-based text input methods. For mobile phones, multi-tap techniques average approximately 2 kspc and T9 letter prediction allows a rate of just slightly over 1 kspc. However, all of these techniques require the user to attend to both the keyboard (targeting letters) and the display (verifying words) [7].

Despite disadvantages of keypads with restricted numbers of keys, one advantage of five or fewer-key techniques is that text can be entered without attending to the keypad. Instead, a finger can be left above each key at all times, eliminating the need for key targeting. The keys themselves can even be removed altogether, with the finger taps alone constituting the input. An early system implementing this idea is FingeRing [3]. Using rings mounted on each finger, it detects taps against any surface. Characters are formed using a combination of chorded and sequential taps. A more recent system is Paradiddle [4]. It proposes using finger taps detected with touch-sensitive surfaces or wrist or finger-worn devices. Characters are entered using three-tap sequences with Paradiddle. Given the 200 ms keystroke time of an average skilled typist [2], the speed for three-key sequences would be 600 ms/character, giving a fairly slow maximum likely speed of 20 words per minute for a skilled user.

Sequential-tap five-key techniques such as Paradiddle are based on the ability to create rhythmic tapping actions. Humans master shorter tapping sequences very quickly and, with training, can extend that mastery to longer sequences of keys; for example, two-key planned finger-tap sequences occur at an extremely rapid rate, much faster than sequential planning would permit [1]. By studying interference between these sequential taps, researchers have noted that the sequential two-key tap is planned as a single muscle activation task [1], and that training allows a user to tune this sequential muscle activation for much faster input [10]. Arunachalam et al. note that the inter-tap temporal delay is approximately 100 ms for long sequences of tapping gestures [1]. As well, training further reduces the delay, to about 80 ms for long sequential keying [11]. For individual two-key sequences, tapping times of even shorter duration have been observed, on the order of 20 ms [11, 10].

## 3. FIVE-KEY TEXT INPUT TECHNIQUE

The time cost associated with three-key sequences in Paradiddle [4], as well as the motor advantages of two-key sequences [1], motivate us to explore decreasing the length of the sequences to one or two taps. In order to use a five-key multi-tap technique with one and two-key sequences to generate all twenty-six letters of the English alphabet, as well as other required characters such as punctuation and numerals, we make use of rhythmic single-key long and two-key short beats to expand the range of input. In Figure 1, we display the alphabet for the method. There are three distinct rhythm or beat patterns in the alphabet: a single long beat (Figure 1a), two short beats (Figure 1b), and optional short-long digram beats (Figure 1c).

The sequence for typing each character is described by its position in the matrices in Figure 1. The column represents the first key, and the row the second, starting from the bottom-left corner. Key 1 maps to the thumb, key 2 to the index finger, key 3 to the middle finger, key 4 to the ring finger, and key 5 to the little finger. (See Figure 2, left.)

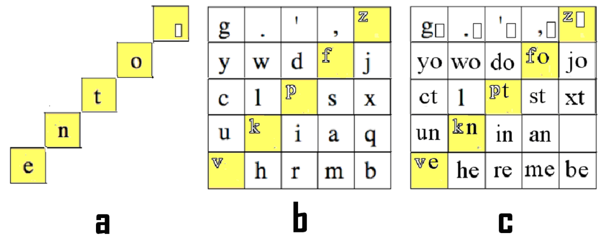


**Figure 1: A mapping of beat-patterns for the five-key input technique.**

Figure 1a depicts the single long-beat characters. By holding down the thumb for more than 200 ms, the letter e is displayed. Likewise, holding the index finger outputs n, the middle finger t, the ring finger o, and the little finger a space. Figure 1b depicts the two short-beat sequences. So, pressing the thumb twice within 200 ms outputs the character v. Pressing the index finger followed by the thumb (column 2 then row 1) yields the letter h. Similarly, pressing the thumb followed by the index finger (column 1, row 2) outputs the letter u. The 200 ms delay, used for the length of single-key characters and the maximum time between keypresses for two-key sequences, is set based on the 100 ms inter-tap delay identified by Arunachalam et al. [1], and can be adjusted by the user.

In addition to the five basic keys, an extra modifier key can be used to extend the range of possible input. It is used to switch the mode to uppercase letters, numbers and punctuation, or accented letters, which are then selected using the basic keys, as well as to enter additional punctuation such as line breaks and backspaces. (The mappings for the modifier key can be seen in the top matrix in Figure 3.) In a keypad-based implementation, the modifier key can be assigned to an extra key near key 2, to be pressed with the index finger, as it is never used in sequences with key 2. In a buttonless tabletop implementation an alternative solution is required. One possible mapping is to activate the modifier key by tapping the display with the heel of the palm. Figure 2 shows mappings for both possibilities.


**Figure 2: Five-key text entry using fingers and palm on a touch surface or using a numeric keypad.**

### 3.1 Keystrokes Per Character

In common English usage, approximately 36% of all characters written are represented by the letters e, n, t, and o. As well, the average word length is five characters, followed by a space. As a result, approximately 45% of all typed characters are represented by single keypresses in this alphabet. For common English typing the alphabet requires on average 1.55 keystrokes per character.

To further reduce the keystrokes per character, Figure 1c depicts a mapping of short-long rhythms that define a set of common digrams on the English language. It covers four of the ten most frequent English digrams [9]. These four digrams—“he”, “in”, “an”, and “re”—allow 10% of common English to be entered using one keystroke per character, including common words such as “the”, “here”, and “there”. While a full analysis of typical keystrokes per character must be performed at the full word level and will fluctuate based on the writer’s vocabulary, in practice we observe keystrokes per character rates of approximately 1.4 for expert users.

## 4. TESTING

To validate the text entry method, we performed a short study of its effectiveness for basic text entry. The purposes of this study were two-fold. The first goal was to evaluate whether or not users could understand the input technique after a short introduction. The second was to measure baseline usability of the technique over a short typing session. The rationale for these baseline studies was the observation, by MacKenzie and Soukoreff, that “the novice experience is paramount for the success of new text input methods” [7].

Ideally, testing of this technique would be performed using a dedicated input device with just the required keys, in an optimal arrangement, or a touch-sensitive surface, as proposed earlier. However, to do our initial pilot testing, we adapted a USB numeric keypad to support text entry, as shown on the right in Figure 2. The keys were assigned as labeled, with E indicating the extra modifier key.

There were six participants in our initial study, all graduate students at our institution. Of these participants, five were male and one was female. One participant (Participant 4) was left-handed but chose to use his or her right hand during the study.

The evaluations were conducted using a numeric keypad attached to a computer running our test application. The application displayed the target and input text, as well as the reference matrix showing the key mappings for each character, as shown in Figure 3.

At the beginning of each session, participants were given a brief demonstration of the method, shown the proper finger placements on the keypad, and given an explanation of the rhythm patterns and the mappings used in the reference diagram. They then proceeded on their own through five minutes of training exercises that introduced sets of characters in related groups, beginning with the long beats, then the short two-key sequences, and finally the short-long digrams. This training was followed by transcribing five practice phrases and then ten test phrases. The phrases were chosen randomly from MacKenzie and Soukoreff’s representative 500-phrase set [8], modified to contain only lowercase letters.

To analyze the results of the tests, the participants’ entire input streams were recorded, including text and backspaces.

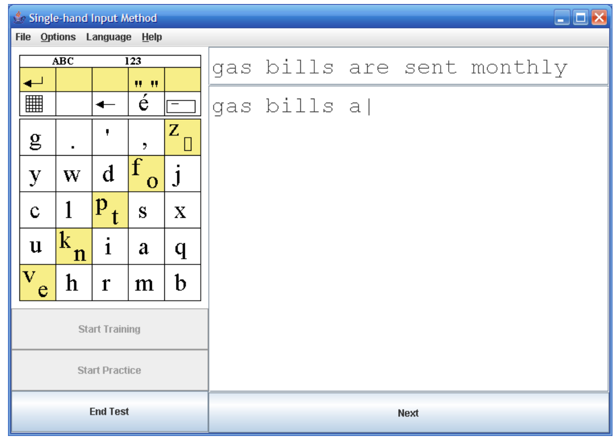


**Figure 3: The test application.**

Participants were instructed to transcribe the phrases as quickly and accurately as possible. They were shown how to perform a backspace, but were not told whether or not to correct their errors. This unconstrained text input allowed the calculation of uncorrected and corrected error rates using Wobbrock and Myers’ character-level techniques [12].

## 5. RESULTS

We analyzed the input data gathered in the study using Wobbrock and Myers’ StreamAnalyzer program, which calculates various text entry performance measures described in their’s and others’ work [12].

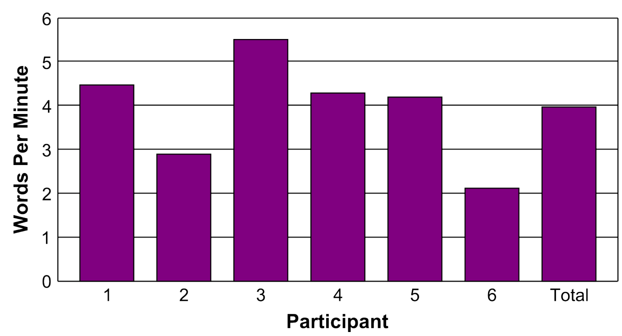


**Figure 4: Mean text entry rates.**

The mean text entry rate over all trials was 3.98 words per minute (SD = 1.24). The speeds for individual participants are shown in Figure 4. We have not shown adjusted words per minute since the participants corrected almost all of their errors (in all of the trials only one character of erroneous input was left uncorrected), making the values essentially identical.

| Participant | 1 | 2 | 3 | 4 | 5 | 6 | Total |
|---|---|---|---|---|---|---|---|
| Total Error Rate (%) | 6.90 | 12.95 | 13.60 | 4.64 | 9.00 | 29.44 | 11.89 |
| SD | 5.08 | 6.87 | 6.42 | 3.68 | 3.46 | 7.16 | 9.52 |

**Table 1: Mean error rates.**

The mean total error rate across all trials was 11.89% (SD = 9.52%). The error rates for individual participants are shown in Table 1.

## 6. DISCUSSION

Text entry techniques are often compared on the basis of speed, measured in words per minute. While other sequential and chorded keying techniques such as Paradiddle [4] and the Twiddler [5] have benefited from longitudinal studies of text input, we have just begun our exploration of rhythmic sequential tap techniques. However, one thing our study shows is that, during their initial twenty-minute typing session, our words per minute entry rate and total error rate are similar to those of new Twiddler users (4.0 wpm with total error rate of 0.119 for rhythmic multi-tap versus approximately 4.3 wpm with total error rate of 0.123 for Twiddler).

It should also be noted that one of our participants, Participant 6, had difficulty mastering the multi-tap technique, and may be an outlier in both entry speed and error rate. Considering the first five participants, Partcipant 6 is more than 2.5 standard deviations below their mean typing speed, with total error rate more than 5 standard deviations above their mean total error rate. Without this participant, average typing speed is slightly above and total error rate significantly below Twiddler adopters.

### 6.1 Improvements to the Technique

Our pilot study suggested one area of the technique, the method of presenting it to new users, that could particularly benefit from refinement. Several participants found the matrix diagram hard to understand and spent a great deal of time searching the grid for the character they needed to type. We believe that by presenting the mappings in another layout, such as the alphabetical grids used with the Twiddler and Paradiddle, we could improve initial performance and learning of the technique significantly.

### 6.2 Future Applications

As described in the introduction, one area where we believe this technique could be useful is as a text entry method for touch-sensitive tabletop or wall-mounted displays. It would have the benefits of allowing text input directly on the display, without the need to target virtual keys, since input would be based not on which virtual key was pressed but on which finger was used. Input could be initiated and orientation set by first placing the entire hand on the display. From that point on the system could track finger positions to determine which virtual key was pressed. This would allow in-place typing anywhere on the screen, at any orientation. We hope to prototype such a system in the future.

## 7. CONCLUSION

We present an exploration of a rhythmic five-key text input method. In an initial pilot study, its performance mimics the performance of chord-based and other multi-tap techniques, and its use of five-keys mapped uniquely to each finger makes it ideally suited for applications where in-place, eyes-free input is desired.

## 8. ACKNOWLEDGMENTS

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