# Evaluation of Thumbwheel Text Entry Methods

**Peter Tarasewich**
College of Computer and Information Science
Northeastern University
Boston, MA 02115 USA
+1 617 373 2078
tarase@ccs.neu.edu

**ABSTRACT**
Text entry becomes increasingly complex as devices shrink in size. This paper presents the findings of a comparison study of two thumbwheel text entry methods for mobile devices. In the first method, the character set (letters, numbers, punctuation) was implemented as a continuous loop. In the second method, characters were arranged in a two-level menu structure. Thumbwheel methods provide a viable and realistic alternative to keyboard, keypad, stylus, or voice text entry on ultra-small mobile devices.

**Keywords**
Text entry, handheld devices, mobile, thumbwheel, PDA

**INTRODUCTION**
This study compared two methods that use a thumbwheel for text entry on a personal digital assistant (PDA). While research such as [2] has explored the performance of similar text entry methods, this study is unique in that it 1) used numbers and punctuation in addition to letters, 2) used a realistic mobile device form factor rather than a simulated environment, and 3) used a thumbwheel for text input, rather than a set of keys or buttons. A comprehensive review of text entry methods for mobile computing can be found in [3]. In addition, [4] provides a discussion of interface design and usability issues for mobile devices.

**METHODOLOGY**
A Sony Clié PEG-S320 PDA, which has a thumbwheel at the top of its left-hand side, was used for this study. Pressing the wheel performs a function similar to clicking a mouse button. Two text entry methods were developed. The Loop method implemented a character set as a continuous loop (Figure 1). When the thumbwheel was turned downwards (upwards), the character set was traversed left-to-right (right-to-left). Scrolling past "!" advanced to the space character ("_"). Characters were displayed on the PDA's screen. Pressing the wheel wrote the currently displayed character to the screen and returned to the space. Only upper case was implemented.


*CHI 2003, APRIL 5–10, 2003, FT. LAUDERDALE, FLORIDA, USA.*
*ACM 1-58113-630-7/03/0004.*

_ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789.?!

**Figure 1 – Loop Method Character Set**

The Hierarchical method arranged the same character set as a two-level menu (Figure 2). The space, "A", "N", "0", and "." characters were on the first level. Selecting the space wrote a space to the screen. Selecting any other first-level character presented a second menu of choices. Selecting a second-level character wrote that character to the screen, and then returned the user to the first level at the space character. The thumbwheel allowed both forward and backward movement through the characters on each level.

| | | |
|---|---|---|
| (space) | | |
| A | → | ABCDEFGHIJKLM |
| N | → | NOPQRSTUVWXYZ |
| 0 | → | 0123456789 |
| . | → | .?! |

**Figure 2 – Hierarchical Method Menu Structure**

The purpose of the study was to compare these two methods in terms of task completion times, error rates, and user satisfaction. Subjects were student volunteers from an information science class. Participants were instructed to hold the PDA in their left hand and use their left thumb to operate the thumbwheel. Their right hand could be used to further steady the device if desired. Subjects were told to complete the data entry tasks as quickly and accurately as possible. If an error was made, subjects were instructed to continue with the next character (no erase function was implemented).

Two task sessions were conducted with each subject. In each session, subjects entered four sentences (Figure 3). The first session consisted of either sentence set one or set two (randomly chosen), and the second session used the other set. The sentences were taken from a larger set used by [2]. In one of the two sessions (randomly chosen), the Loop method was used; in the other session, the Hierarchical method was used. The first sentence in each set was used for training purposes. Data was collected on completion times, error rates, and keystrokes (wheel turns and clicks) for each sentence.

Appears in *Extended Abstracts of CHI 2003,* 756-757

| Set | No. | Text of sentence |
|---|---|---|
| 1 | 1.0 | WE ARE HAVING SPAGHETTI. |
| | 1.1 | MY WATCH FELL IN THE WATER! |
| | 1.2 | PREVAILING WIND FROM THE EAST. |
| | 1.3 | THE ADDRESS IS 195 MAIN STREET. |
| 2 | 2.0 | TIME TO GO SHOPPING! |
| | 2.1 | I CAN SEE THE RINGS ON SATURN! |
| | 2.2 | PHYSICS AND CHEMISTRY ARE HARD? |
| | 2.3 | HE CAN BE REACHED AT EXTENSION 482. |

**Figure 3 – Sentences Used in Experiment**

## RESULTS

Four female and twelve male subjects (median age = 19 years) completed the experiment. To see if the type of method (Loop versus Hierarchical) affected entry times or error rates, an independent samples t-test was performed for each of the sentences (Table 1). Error rates were not significantly different for the two methods. Entry times, however, were significantly longer for the Hierarchical method for all of the sentences in set 2 (at the .01 level). Entry times were also longer using the Hierarchical method for each of the sentences in set 1, but the differences were not significant. There was no significant difference in means for entry time or error rates when looking at whether a sentence was entered in the first or second session for a particular method. Also, no significant interaction effects were found between method and session.

**Table 1 – Comparison of Entry Times and Errors***

| Sent | Loop | | Hierarchical | | Significance | |
|---|---|---|---|---|---|---|
| | Time | Errors | Time | Errors | Time | Errors |
| 1.1 | 104 (13.8) | 0.63 (0.7) | 118 (15.9) | 0.50 (0.5) | 0.09 | 0.71 |
| 1.2 | 121 (15.3) | 1.13 (1.0) | 138 (24.9) | 1.13 (1.1) | 0.14 | 1.00 |
| 1.3 | 124 (19.6) | 1.50 (0.9) | 125 (17.7) | 1.25 (0.7) | 0.94 | 0.55 |
| 2.1 | 102 (12.0) | 1.00 (0.9) | 138 (21.6) | 1.13 (1.0) | 0.00 | 0.80 |
| 2.2 | 114 (21.2) | 1.25 (1.2) | 144 (20.6) | 0.88 (0.6) | 0.01 | 0.44 |
| 2.3 | 112 (24.6) | 1.00 (0.8) | 148 (22.5) | 1.63 (0.7) | 0.01 | 0.12 |

*Standard deviation given in parentheses, time in seconds

The average number of keystrokes required to enter each sentence was significantly lower (at the .001 level) for the Hierarchical method. Table 2 shows the average keystrokes per character (KSPC) for each sentence for both methods. The theoretical minimum KSPC for each sentence for each method is given in columns four and five. The Hierarchical method showed reductions in KSPC on the average of 20% to 28%. Theoretically, the Hierarchical method allowed up to a 40% reduction in KSPC for the six sentences.

Based on post-experimental questioning, most subjects (10/16) preferred the Hierarchical method to the Loop method. The Hierarchical method was perceived as being quicker, although most subjects qualified this by saying that there was a definite learning curve involved.

**Table 2 – Keystrokes Per Character Comparison**

| Sent | Average KSPC | | Theoretical Minimum KSPC | |
|---|---|---|---|---|
| | Loop | Hierarchical | Loop | Hierarchical |
| 1.1 | 10.6 | 8.5 | 9.5 | 6.0 |
| 1.2 | 11.5 | 9.2 | 10.5 | 6.3 |
| 1.3 | 11.6 | 8.4 | 10.4 | 6.4 |
| 2.1 | 10.7 | 7.8 | 10.0 | 6.0 |
| 2.2 | 11.0 | 8.2 | 9.9 | 6.2 |
| 2.3 | 8.8 | 6.9 | 8.1 | 5.5 |

## DISCUSSION

Users took longer to enter text with the Hierarchical method than with the Loop method, but there was no difference in error rates between the two. Most users still preferred the Hierarchical method, however, since it reduced the number of keystrokes required to find and enter characters. With additional training and continued use, entry speeds would most likely increase for both of these methods. Better-designed thumbwheels would also positively impact entry times and error rates. Given the reduction in keystrokes achieved with the Hierarchical method, it is realistic to hypothesize that users would become more efficient with this method versus the Loop method over time.

While thumbwheel entry methods may not be suitable for large amounts of text, they should work well for short notes and messages. Mobile devices continue to shrink in size, and even wristwatch-size PDAs are now available (e.g., Fossil's wrist PDA). Such devices may one day be used for wireless messaging. Their small screen sizes, however, are not conducive to virtual keyboards or to gesture recognition. Voice input is one alternative for these devices, but voice recognition technology requires large amounts of processing power, has high error rates, and is sometimes inappropriate to use due to environmental conditions (e.g., in noisy factories or during a theater performance). Thumbwheels may provide one of the few feasible ways of entering text on very small devices in a wide variety of settings. Good interface design also dictates providing multiple pathways for user task completion, and thumbwheel methods are useful alternatives for text entry.

## REFERENCES


1. MacKenzie, I. KSPC (Keystrokes per Character) as a Characteristic of Text Entry Techniques. In *Proceedings of HCI Mobile '02* (Pisa, Sept. 2002), 195-210.
2. MacKenzie, I. Mobile Text Entry Using Three Keys. In *Proceedings of NordiCHI 2002* (Aarhus, Denmark, Oct. 2002), ACM Press, 27-34.
3. MacKenzie, I. and Soukoreff R. Text Entry for Mobile Computing: Models and Methods, Theory and Practice. *Human-Computer Interaction 17* (2002), 147-198.
4. Tarasewich, P. Wireless Devices for Mobile Commerce: User Interface Design and Usability. In *Mobile Commerce: Technology, Theory, and Applications*, B. Mennecke and T. Strader, Eds. Idea Group Publishing, Hershey, PA, 2002, 26-50.