TNT – A Numeric Keypad Based Text Input Method

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ABSTRACT

With the evolving functionality in television-based (TV-based) information and entertainment appliances, there is an increased need to enable users input text through remote control devices. We present a novel text input method, The Numpad Typer (TNT), for interactive TV, multimedia home terminals or other similar applications. Embodied in a TV remote control and guided by a visual map on the TV screen, TNT was designed for consistent spatial Stimuli-Response (S-R) compatibility and consistency of use. Five users tested TNT in ten sessions of 45-minutes. This initial investigation showed that users on average could type 9.3 and 17.7 correct words per minute with TNT doing the slowest and the fastest session respectively. The study also showed that the users found the TNT method easy to grasp and fun to use. Subjectively the participants felt they mastered the method rather quickly in comparison to their actual speed improvement.

Categories & Subject Descriptors: H.5.2 Information Interfaces and Presentation: User Interfaces.

General Terms: Design, Experimentation, Human factors.

INTRODUCTION

Interactive TV, Web TV, Multimedia Home Terminal and the like are set to become increasingly common household technologies. Enhanced with computer and Internet technologies, these devices will offer the user experience far beyond the traditional television. However, a host of user interface issues need to be understood and addressed before such a vision can be realized. Entering text and symbols is one of the primary problems that we address in this paper.

For example, while sitting on a couch and watching TV, a user may want to search for certain content by typing its title or keywords. S/he may also want to write a short email without getting up to use a computer "workstation", or search the web with a text query or go to a specific website by typing an URL. All these activities involve typing a task most commonly associated with keyboard. However, the traditional keyboard form factor is opposite to what is desired for a home terminal control device: small size and one-handed control for increased usability and enjoyment in a variety of sitting postures and activities.

Primarily driven by mobile computing, recent research has led to several alternative methods for text entry. Many of these, including handwriting with novel alphabets (Graffiti™, Unistroke [4]), pen gesture (Quikwriting [14], Cirrin [12], Dasher [18], SHARK [19]), and optimized stylus keyboard (OPTI [10], ATOMIK [20]), are presented or reviewed in the recent HCI special issue on text entry [11]. These methods, however, require a stylus, touch-screen or other input devices that are not well suited for the home entertainment setup where the user focuses on the TV screen while resting at a distance from the TV. They also accommodate one-handed use to a various degree.

What is available and well suited for the home entertainment environment is the remote control. The current project addresses how to make use of a remote control device for text input on the TV screen. One obvious choice is to implement a miniaturized QWERTY physical keyboard as part of the remote control. Some vendors have indeed done so. For example the Nokia Mediaterminal remote control can be opened like a clamshell exposing a miniaturized standard QWERTY keyboard. The problem is that to type on such a keyboard is difficult, particularly "touch typing", since the keys are smaller than the fingers. Another possibility is to make use of the numeric keypad on the TV remote control. The design challenge here is to map the 10 numeric keys to 52 letters (26 letters in each case) plus other symbols for efficiency and ease of learning.

The same problem of using a numeric keypad for text entry has been tackled in mobile phone design. The two most common solutions are the multi-tap and the T9 methods. The former uses the number of taps to determine which of the three letters that share the same key is to be selected. The latter uses legitimate letter sequences to disambiguate multiple letter choices. Both methods have pros and cons. For example, multi-tap often causes confusion between selecting one of the three letters vs. entering a new letter because the elapse time is used as delimiter. This is particularly a problem when a user gets faster with the method.

With T9, words not in the "dictionary", the delayed feedback until one finishes spelling the entire word, and multiple choice selection of words that share the same numeric key sequence (e.g. "bell" vs. "cell") are among some of the drawbacks (See [17] for a more formal analysis and [1] for somewhat unfavorable but rather short empirical study).

Given the background of the problem we attempt to address, we laid out the following basic rationales as starting points for our design.

1. Use the existing remote control form factor, with the numeric keypad as the basic input mechanism.
2. Take advantage of the large color screen space and let the display (feedback and guidance) play a stronger role in the input process.
3. Direct the user's visual attention to the TV screen, not to the remote control device. The method should require minimum attention switching back and forth between the screen and remote control.
4. Given the application domain, novice users should be able to use the input method easily without much practice. This means that the method should be conceptually clear to the user.
5. The method should be also "expert friendly". One should be able to pass the initial learning stage and reach a reasonable typing speed, although it is not a requirement to reach the level of full keyboard typing.

With these points in mind, we designed a method — The Numeric-keypad Typer (TNT).

THE DESIGN OF TNT

An iterative design exploration led us to the current TNT method. TNT works by letting the user press two numeric keys to produce a letter on the screen. As shown in Figure 1, a total of 81 letters, symbols, or commands are laid out on two layers of 3 by 3 grids, *spatially corresponding* to the 3 column and 3 row numeric keys in the keypad. The first key press selects a group, and the second selects a member in that group. For example, in order to produce the letter "b", the user first presses 1 on the keypad as shown to the left in Figure 2. This will produce feedback on the screen by highlighting the first group of letters as shown to the right in Figure 2. After this, the user knows that the first group is activated. S/he then proceeds to press key 2 on the keypad, which selects the corresponding letter "b" in the group.

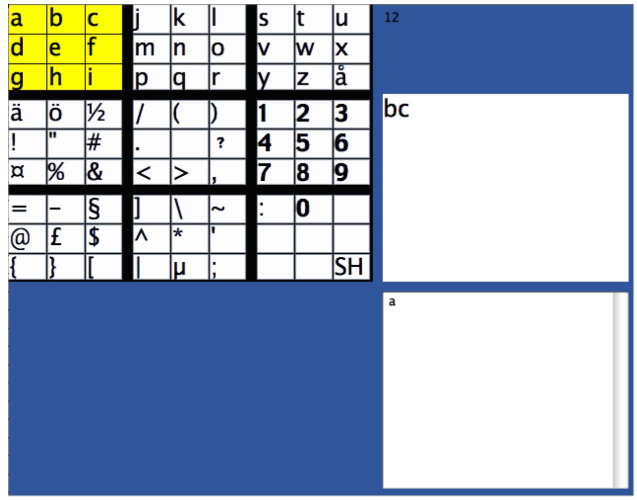

Figure 1: A screenshot of The Numpad Typer (TNT) display as used in the experiment

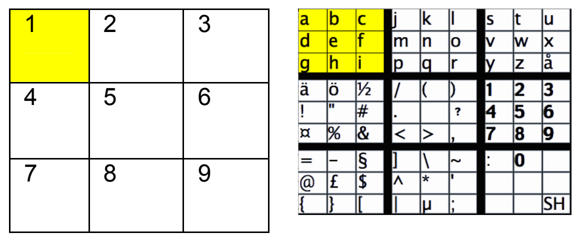

Figure 2: TNT correspondence between the keypad (left) and the visual feedback on screen (right)

Noticeably TNT has the following basic characteristics:

1. Visual guidance: TNT shows the user where s/he can find the letter of his/her choice, by having a dynamic "visual map" clearly visible on the TV screen.
2. Visual feedback: The application provides highlighting of the item(s) selected, indicating the result of the last key press.
3. Alphabetical layout: The layout of the letters is alphabetically ordered, first in three groups of letters and then by individual letters in a group. This is to help users find the target letter. It is possible to optimize the layout for movement efficiency based on Fitts' law and letter transition frequency to improve expert user's performance [20], but that would cause a rather large expense for the novice user while only producing a small gain for the expert, due to the small maximum distance between the keys in the numeric keypad (one key in between in the worst case).
4. S-R compatibility: It is well known that spatial stimulus and response compatibility between input and output plays an important role in human performance [3]. In the TNT design, the display of the output information

is spatially compatible, in fact identical, to the input control layout (the keypad). To select the top left group of letters on the screen, for example, corresponds to pressing the top left key in the keypad. Selecting the center letter within the highlighted group corresponds to pressing the center key in the keypad.

5. Consistency: It is also well known that consistent mapping is a key to the transfer from controlled to automatic processes in human performance [15]. Although each letter in TNT is entered with two key strokes, the basic mapping between the input buttons and output information has the same simple spatial mapping in the two steps.
6. Capacity: The TNT design can contain a large number of letters and symbols (9*9=81) with 9 keys (or 10 if more are needed). This means that TNT can have English letters, non-English letters (currently Swedish), numerals, and other symbols all as "first class citizen". Furthermore, we assigned the last TNT character (99) as a SHIFT key, which switches, among other commutations, lower case letters to upper case (displayed accordingly on the visual map).

There are a few design variations of TNT that we could adopt. One of them is to zoom up the selected group to the entire visual map area. The positive effect of such a measure is a greater degree of S-R compatibility: the same key will always correspond to the exact same location on the visual map. The drawback of such a measure is that zooming needs some transition time to maintain the "visual momentum". Such a transition period could become a hindrance for an expert user who acts faster than the zoom animation. After some informal testing we decided against such an idea.

There are also potential drawbacks with the TNT method. The two-key two-phase process could be slow. The mapping, while conceptually clear, still needs empirical verification to see if users can understand it all and apply it in "real time". The focus in this study is on the concept and text-input, when is comes to the final UI design it could probably be improved and adjusted to different tasks such as web browsing or email writing.

EXPERIMENT

Experimental setup

The experiment was designed as follows: Five paid volunteers were recruited to participate in ten sessions of Swedish text entry with TNT. In each session, they sat approximately 2 meters away from a Phillips 28" TV (Figure 3). They used one finger (thumb) to press the numeric buttons on a Nokia Mediaterminal remote control, since this, according to the participants, appears the most natural way of operating a remote control in a home setting.

Figure 3: The experimental setup

The five participants, two female and three male, range in age (from 27 to 32 years) and had different backgrounds with regards to work and education. All the participants were familiar with the use of a QWERTY keyboard and they had also tried the T9 system on their own mobile phones.

Figure 4: The NOKIA Mediaterminal remote control

Each experiment session was 45 minutes long. During the session the participants continuously wrote text using the system. The same text was used throughout all sessions and the participants started out from the beginning each time. The text used was a Swedish novel "Markurells i Wadköping". This was preferred over random letters or words for a number of reasons. First we wanted the situation to reflect real language use. This approach also helped the user not to get bored. Finally the improvement made by the user is visible to the user in the way that s/he sees were s/he passes the previous result within the same time duration, increasing the motivation to get better in each session

Text typing in fact involves rather complex and multi-faceted perceptual, cognitive and motor processes [2]. Because of this complexity, there is no one standard or best evaluation approach in the field of text input research. Depending on the purpose, ranging from theoretical understanding of upper limit speed [10] [17] to user's initial reaction [16] [1], a variety of methods have been reported in the literature. Any particular method is a trade-off decision along many dimensions, such as:

1. The level and extent of practice (expertise), both early initial experience of a novice user and the performance of a well-practiced expert user, as well as the speed of learning can be a researcher's primary interest.
2. The linguistic fidelity and balance - a single sentence may not represent the frequency distribution of letters or words which may for example influence the efficiency of a keyboard layout. There could also be learning specifically gained from the one or a set of sentences used in the test hence the measured performance should be judged as such.
3. The degree of measurement control vs. naturalness of the task - a completely natural typing task is likely to involve composition whose speed and content (actual words used) vary from task to task, from individual to individual, from moment to moment.

In addition to experimental task design, task performance measurement is similarly complex and varied in the literature. In particular the treatment of error may influence the result significantly. Theoretical predictions of upper performance limit for stylus keyboard [10] [21], for example, are based on Fitts' law parameters ideally measured with an error rate of around 4-5% (per key tap). In empirical studies, some experimenters allowed a certain percentage of errors in text without correction [10]. The amount of time needed to correct errors depends on the design of the error correction method; hence there are no set rules to trade-off errors with speed. Traditionally in a typing contest each error caused a deduction of 5 words.

Our evaluation paradigm aimed at balancing these factors to reach a practical estimate – a baseline performance indication in a task with reasonable linguistic fidelity. We were also interested in how practice improves users' performance, hence the relatively large number of sessions for a study of this type. Like any other method of test, its results should be interpreted with the specific task requirement and set-up in mind.

The experiment started with an experimenter explaining the task and the system to the participants, together with a short demonstration. It was explained to the participants that the purpose of the experiment was to test and evaluate the TNT method, not their ability. The participants were also instructed to focus on the concept and not on specific UI issues when giving their subjective evaluation. As an incentive, the person with the highest speed would receive a \$50 cash reward in addition to the \$8 they received as compensation for each session.

Participants were instructed to write as fast as possible, using one finger, with as few errors as possible. The system only accepted correct characters, so there was an implicit delay in form of lost keystrokes if a wrong letter was entered, which in turn discouraged the participants from making errors. The text to be typed was displayed on the same screen (top right window in Figure 1, which shows the user has entered "a" correctly and is half way through entering the character "b"), paced by the participant's typing speed. When the correct letter is entered, the letter is moved from the top right window to the bottom right window. As such the current letter to be written always appeared at the same position on the screen, which eases the user's visual scan behavior. Note that the system is not meant to be used as a "copy typing" tool. In real use the words to be written would come from the users themselves (generative typing). For testing purposes the text was selected for the users hence we attempted to minimize the visual scanning time.

In the experimental setup the 0-key was not assigned any function. This was because the experimental setup was designed in the way that made the users' mistakes result in a time delay, not a wrong letter. In a real situation it might be useful to use the 0-key as a backspace or Cancel button.

If an error (a wrong character) were typed, the system would recognize this and store the event in the log-file. Furthermore, it would not move forward in the text since the correct letter had not been entered. In real application, errors would have to be corrected, which may take more time than the penalty received here. The measured speed should be viewed with this in mind.

RESULTS

General Observations

All of the participants preferred to use their thumb to press the numeric keys. Since there are only 9 buttons to operate, it is possible that the thumb "knows" where it is relative to the buttons. Indeed, the participants in the experiment were able to "touch type" the keypad and focus their attention on the terminal screen after some practice. As a design recommendation, it should be helpful to make the center button "5" with a tactile mark, as is common on the F and J keys in a QWERTY keyboard, as well as on the 5 key some telephone keypads.

Performance

Each 45-minute session necessarily included short pauses, hand adjustments and occasional interrupts. We use session "peak mean speed" to reflect the best average performance in each session. Peak mean speed is defined as the maximum of the moving average with a one-minute window in each session. Figure 5 shows peak *correct* word per minute (wpm the fastest, slowest and average) scores averaged across 5 participants in each session. It also shows the fastest performer as well as the slowest performer. Word count is based on the conventional measure of five (correct) characters including space. On average, participants could type up to 9.3 correct words per minute in the first session, and eventually up to 17.7 wpm in later sessions.

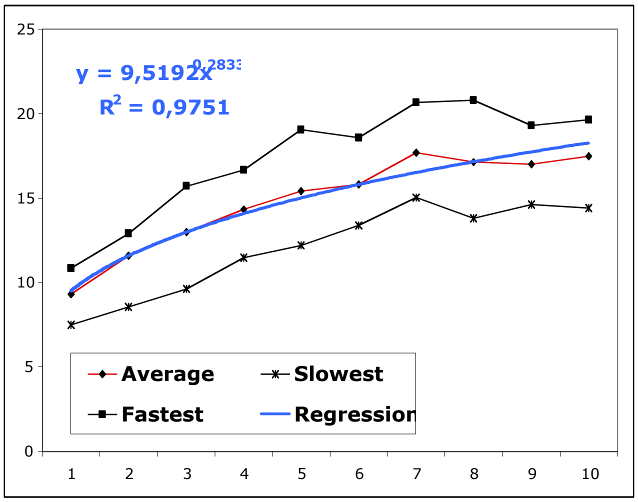

Figure 5: Correct words per minute as a function of session number

Regression analysis shows that the average speed in the experiment follows the power law of learning as follows:

$$\text{Speed} = 9.52\, N^{0.2833}\ \text{(wpm)} \qquad (1)$$

where N is the session number. This can be used as a predictor for future performance, such as people's average speed after 20 sessions of practice. However, the curve in figure 5 suggests that even though the power law of learning seems to be valid, the data after the 7^{th} session indicate that peak speed has reached the top level and might not improve further.

Participants occasionally made incorrect key presses, ranging from 4.2% (first session) to 3.3% (last session). Note again an incorrect key press only increased the time to enter the correct one, hence reducing the correct WPM score.

Taken together, the performance results of our experiment are quite positive. Previous study shows on a QWERTY-keyboard a *regular* computer user's speed is about 30 corrected wpm [7], which is achieved with 10 fingers and with only one keystroke per character. For another comparison, the text entry speed of the most commonly used text input techniques, Graffiti and Jot, is in the range of 4.3 -7.7 wpm depending on the nature of the text for new users [16]. For more advanced users, it may reach 14-18 wpm [16]. The speed of multi-tap on mobile is *estimated* at 20.8 to 24.5 wpm for an expert user whose only time expenditure is on button presses (no cognitive or visual processing time needed, and accepting 4% errors in Fitts' law performance) [17]. Actual use, particular of the non-expert users, will be much lower than that. These performance comparison numbers available in the literature should be interpreted with caution, for the various reasons we outlined earlier on the influence of experimental task design and performance measurement method.

In summary, TNT offers a typing performance comparable or superior to the current PDA hand writing or multi-tap methods with a form factor (remote control) that is well suited for home entertainment settings. For other environments a numeric keypad, like those in a full physical keyboard, can be used to write with the TNT technology. In that case the user may use 10-key touch typing with a whole hand to reach a higher level performance. It is also possible to further enhance users' performance by word prediction [6]. This will be further discussed later in the paper.

Subjective Experience

Our evaluation of TNT also went beyond the quantitative performance. We also wanted to learn how users *feel* about the TNT-concept through post experiment interviews. We wanted to reach qualitative descriptions of the concept [9] to be able to interpret users' experience. The interview design was created to not disturb the user while writing and using the tool, but at the same time to catch the reaction that was closely connected to use.

The interviews were conducted immediately after each session by an interviewer in order to capture participants' spontaneous reactions after using TNT [5] (p 273). A longer, more in depth, interview was conducted after the final session. The longer interview included how they felt about the TNT concept and how it compares with other devices such as a regular keyboard or the T9 method on a mobile phone, with all of the participants were familiar. The comparison to the T9 felt natural to the participants. They used it as a reference when they wanted to explain why something was good or bad.

In order to obtain a certain degree of independence and also to avoid unnecessary, polite reactions from the participants, the interviewer was neither the designer nor the programmer of the TNT. [13]. The interview was directed towards the concept rather than surface features such as colors, shape etc. The goal was not to evaluate the surface layer of the UI, instead we wanted a discussion about the new interaction techniques connected with the TNT and the use of the concept.

The general reaction from the participants was that the method was very easy to understand and to use. After using TNT for half of the first session all the participants thought that they did not have to think about the concept any longer. Instead they could focus on how to write faster and to find the less common letters. The short learning curve made the tool fun to use and encouraged the participants to also learn how to write fast. Another perceived advantage of the TNT was that the simplicity of the concept made it easy enough to use that without needing an instructional manual. Simply visually mapping the buttons on the remote control to the display on the screen was enough. This was an opinion that had to be investigated more carefully with users with less technological experience. Compared to the T9 system, one participant described the TNT as less frustrating since the behavior of each key did not change with the context. The fixed behavior made it easier to focus on the text written rather than the mode the button is in.

Participants also indicated that the method was more fun to use than T9. They particularly indicated that after a while (mostly second session) they were able to focus attention on the text written instead of shifting attention between the keypad and the TV screen. None of the participants considered the button on the keypad as numbers, rather they thought of them as positions, which suggested that the spatial mapping in TNT was successful. After the 7th or 8th session they tended to be less explicit in thinking of positions as an intermediary rather they thought more directly of letters connect onto with their motor sequences.

There is an interesting contrast between the users' subjective level of mastery and the actual performance logged. The subjective impression of learning progressed rapidly. Participants perceived that they had a good grasp of the TNT method once they felt natural with how the method worked, but before their actual performance made substantial improvement. They were surprised with their performance in later sessions, which surpassed their early expectation. After the 6th session one participant felt that he knew where the less common letters were and no longer needed to search for them. As such, he felt he was as fast as he could be, although his actual performance still improved afterwards. One participant expressed that he felt that he had "control" over the tool and that the subjective feeling was that he was better than the actual WPM showed. On the other hand he never thought that he would be really fast and felt that this technique was never going to allow him to write as fast as typing a QWERTY-keyboard (the latter is of course true).

There was a discussion of whether to remove the map after a while when the locations of the letters were committed to memory. The general opinion about this question was that the users still wanted to have the map. This was mainly because they liked the support and the possibility to check how to input uncommon letters.

An interesting strategy in completing the task was observed - the two participants who had the fastest writing speed did not read whole sentences. Instead they read one word at a time and then wrote it using the system. As a result they did not have much comprehension of the text written. Such a strategy has also been reported in traditional copy typing in which a typist makes the typing as much a direct transfer of text from the manuscript to the typewriter as possible with little higher level cognitive involvement [2].

In contrast, the other approach was to read sentences or paragraphs. Participants with this approach had slower text input speed, even though they should have added motivation to write faster to get deeper into the novel. One participant even said that at the later sessions he started to get a relation to the text and really wanted to know what was going to happen next. Another aspect was that one wanted to chunk the text so that he should not have to move his concentration between the text input and the reading area. Note again that the experimental task was designed to measure a controlled user's baseline performance and perception of TNT. TNT's actual use lies in generative typing without input text to read.

The last interview there was a discussion of whether placement of the letters could be more efficient. The general opinion was that it would make it much harder to get started with the system if the position of the letters differed from the alphabetic order. When using the alphabetic order the logic of the system is more transparent to the user.

The biggest drawback of the system, from the participant's point of view, was that the system never felt to be as efficient or fast as a 10 finger QWERTY keyboard. However, as the system was not seen as a tool for writing longer texts, this was not considered a big problem. The relatively short learning curve also helped in making this problem a minor one. The system was not viewed as a tool for mass text input, but a tool suited for a TV-watching or similar situation. The participants saw the area of use mainly in tasks that required shorter texts such as SMS or mail related tasks. They could also see a use for the TNT in public systems, which lack space to accommodate a full sized keyboard, such as information kiosks or ATMs. The system is not suited for mobile phones and other devices with very small displays, since the visual representation demands larger screens.

There were also some complaints about the physical construction of the remote. The remote used in the test was a standard Nokia Mediaterminal remote not particularly designed for one finger use. Rather it is designed to accommodate both regular remote control use and, as a clamshell, full QWERTY keyboard. As a result some of the keys were harder to reach. The letters placed on these keys were more difficult to use and more tiring. This involves all letters having either the first or the second keystroke as a 3, 6 or 9 (Figure 2). Of these keys the 9 was least appreciated, and in general the favorite placing of the letters that were often used was in the two top rows.

The improvement suggested by the participants was for instance to make the keys closer to the hand, i.e. key 9 and 6 easier to grasp. The current design made it quite hard to move the thumb fast to these keys. A different solution for this problem was also suggested in that one could redesign the keyboard by just letting the two top rows include the alphabet. In that case, the use of key 9 would be much less used and you could still use the logic order that the alphabet offers.

It also became apparent that not only the physical design could be improved, but also the placement of the letters. Participants suggested that some signs (non English alphabet letters) can be better grouped according to their similarity. For instance, one participant commented on the fact that "," and "." were on different key-islands. Another thought that splitting the Swedish characters "å", "ä" and "ö" was confusing. He chunked those letters together himself and since the construction of the program did not, he felt confused. Since these letters are placed at the end of the Swedish alphabet, this chunking behavior becomes natural.

In the layout used in these tests several areas of the keypad were not used (empty spaces) and one key was not used at all (the 0). After writing a couple of times the participants started to come up with ideas of what to do with "the lost space". The most common suggestion was that to use the "0" as a cancel button. Although in the test a wrong letter was not accepted and one cannot move forward until a correct letter is entered, some of the participants commented that a cancel button would still be preferable because it is possible to realize that a wrong key was pressed in the first group selection key press. With a cancel button they could have cancelled it without completing a wrong letter.

One other shortcoming found from these trials is that writing a capital letter or special character that does not fit in the 81 spaces takes four keystrokes with the current design. This is due to the fact that the remote used does not support multiple key presses at the same time, thus it is impossible to get the function of the shift key on a standard keyboard.

DISCUSSIONS and CONCLUSIONS

We have designed a novel text input method, TNT, for multimedia home terminals and similar applications. Embodied in a TV remote control and guided by a visual map on the TV screen, TNT was designed around a set of principles including consistent spatial S-R compatibility. Our initial investigation showed that users on average could type up to 9.3 and 17.7 correct words per minute with TNT during the slowest and the fastest session respectively, measured by a 1 minute moving average of correct words per minute. Text input methods usually has to be positioned on a novice vs. expert friendly spectrum. Some, such as multi-tap or Graffiti™, are easy to get started but quickly reach a low performance ceiling. Others, such as the chording keyboards, are difficult for a novice but eventually offer higher efficiency. TNT provides a reasonable compromise between the two extremes. An important characteristic of TNT is that a novice user and an expert user only differ in the amount of visual guidance used/needed. As a user gains familiarity with TNT, one can rely less on the visual map to determine which two keys to press, and more on chunked operational (of the two key presses) routines. There is not a separate mode of operation for the expert. This thought is consistent with those embedded in the marking menus and articulated by Kurtenbach and colleagues [8].

The subjective evaluation based post-test interviews shows TNT is also "fun to use" and "easy to learn" due to a clear conceptual model of the TNT design. It is interesting to note that the participants described the advantages of TNT mostly in comparison to T9 and other off-desktop text input experiences, showing that participants themselves framed the area of use and the usefulness of the system. In contrast, when the participants talked about the drawbacks of TNT, they had the traditional desktop QWERTY keyboard experience in mind. This shows TNT is well suited for text input tasks in applications where the display is reasonably large and where a full QWERTY keyboard is not convenient.

Some design alternatives surfaced during the evaluation. For example the participants suggested that the more frequently used keys could be rearranged as to minimize the stress on the finger. One way of doing this is to arrange the layout so that the alphabet is presented vertically (keys:1, 4, 7 and so on), instead of as now horizontally (keys: 1, 2, 3 and so on), so that the more common letters are more easily reachable by the thumb. Like many text input methods, TNT could potentially benefit from word or sentence completion based on a lexicon customized for each user [6]. If the situation allows the use of more than one finger, it is likely that TNT speed would increase.

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