TabLETS Get Physical: Non-Visual Text Entry on Tablet Devices

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ABSTRACT

Tablet devices can display full-size *QWERTY* keyboards similar to the physical ones. Yet, the lack of tactile feedback and the inability to rest the fingers on the home keys result in a highly demanding and slow exploration task for blind users. We present *SpatialTouch*, an input system that leverages previous experience with physical *QWERTY* keyboards, by supporting two-handed interaction through multitouch exploration and spatial, simultaneous audio feedback. We conducted a user study, with 30 novice touchscreen participants entering text under one of two conditions: (1) *SpatialTouch* or (2) mainstream accessibility method *Explore by Touch*. We show that *SpatialTouch* enables blind users to leverage previous experience as they do a better use of home keys and perform more efficient exploration paths. Results suggest that although *SpatialTouch* did not result in faster input rates overall, it was indeed able to leverage previous *QWERTY* experience in contrast to *Explore by Touch*.

Author Keywords

Blind; Text-Entry; Touchscreen; Tablet; Non-Visual Interaction; Bi-Manual Interaction; Spatial Audio.

ACM Classification Keywords

H.5.2. User Interfaces: User-centered design, Input devices and strategies, Interaction styles.

INTRODUCTION

Touchscreens have become pervasive, mostly due to the success of small, portable smartphones. In recent years, we have also seen a shift into tablet devices. Unlike smartphones, these devices are able to accommodate full-size *QWERTY* keyboards, similar to that of a personal computer. However, virtual keyboards lack the tactile feedback, not just in the physical perception of key presses, but also in the ability to feel the home keys (*F* and *J*) [2]. Visually impaired people usually rely on resting their fingers on the home keys to orientate their position within the keyboard and locate desired keys. Still, current accessibility solutions (*VoiceOver*[1] and *Talkback*[2]), do not support screen exploration techniques that would allow blind users to interact this way. These solutions resort to an *Explore by Touch* paradigm where users browse the screen content by moving a single point around the interface that reads aloud the element in focus. This approach tends to be very slow particularly for novice users [7].

Previous research to support non-visual text-entry includes alternative keyboard layouts [1, 6, 7, 9], which enable faster input but require additional learning (e.g. learn *Braille*), as they have not yet offered support for non-visual multitouch exploration of *QWERTY* keyboards (the *de facto* method).

In this paper, we investigate QWERTY text-entry performance in tablets by novice blind users. In detail, we have the following research goals: 1) Assess novice users' text-entry performance with *QWERTY* keyboards in tablets; 2) Compare the performance between single- and multi-touch text-entry approaches; 3) Understand the strategies and advantages of each method. We developed *SpatialTouch*, an input system for blind users that leverages previous experience on physical *QWERTY* keyboards, by supporting multitouch exploration. Our system combines spatial and simultaneous audio feedback with multitouch selection techniques to mimic traditional two-hand keyboard interaction. *SpatialTouch* enables blind users to rest their idle hand on a key (e.g. *F* or *J*), while simultaneously exploring the keyboard with their active hand and receiving auditory feedback about the character location. Our character selection technique allows disambiguating between the different touch inputs, mitigating unintentional insertions from the idle hand. We contribute an analysis and discussion on the performance and emerging behaviors of *QWERTY* tablet text-entry using both *Explore by Touch* and *SpatialTouch*.

CHI 2015, April 18 - 23 2015, Seoul, Republic of Korea
Copyright 2015 ACM 978-1-4503-3145-6/15/04 $15.00
http://dx.doi.org/10.1145/2702123.2702373

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[1] apple.com/accessibility/osx/voiceover/

[2] developer.android.com/design/patterns/accessibility.html

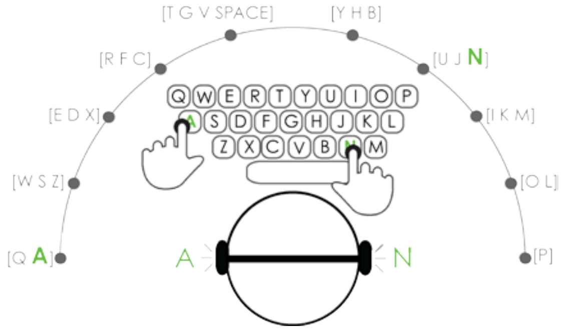

Figure 1. The keyboard and the characters spatial position in the 3D audio space. Example of simultaneous interaction.

TEXT ENTRY ON TABLETS

Mainstream touchscreen technologies support non-visual access through the use of built-in screen readers such as *VoiceOver* and *Talkback*. Still, they restrict the exploration to a single point and therefore don't leverage the multitouch support of such devices. Guerreiro and Gonçalves [4] demonstrated that screen reader users are capable of receiving and interpreting simultaneous speech sources, suggesting that current screen readers could be imposing limitations on the possible interaction methods used for non-visual access of touchscreens. In the particular case of tablets, their dimensions are similar to the ones of a physical *QWERTY* keyboard, where users are able to use two hands. We propose an investigation of non-visual text entry strategies on tablet devices using screen readers that support both single- and multi-touch exploration.

Supporting Multitouch Interaction with *SpatialTouch*

SpatialTouch extended the existing interaction method of *Explore by Touch*, allowing users to interact simultaneously with two fingers and receive independent feedback for each finger. We relied on studies that support the use of concurrent speech and point out configurations that enhance speech segregation and perception [3, 4].

Multitouch Feedback. Previous research has shown that hearing more than two simultaneous sound sources significantly decreases speech perception [3, 4]. Thus, in order to prevent auditory overload, *SpatialTouch* supports two simultaneous input points and voices. To further enhance speech intelligibility, we use different voice genders for each touch input [3]. The first finger to touch the screen is assigned the male voice, whilst the second is allocated the female voice. These assignments are only updated when both fingers are removed from the screen. *SpatialTouch* maps the characters auditory feedback relative to their location in the keyboard. Spatial locations vary on the frontal horizontal plane as illustrated in Figure 1 to help segregate both speech sources [3].

Multitouch Selection. We conducted a pilot study with five users in order to choose the target selection method (release finger vs double tap) and define the parameters that arose from having two possible insertion points. Based on the number of errors and user preferences, we selected the *Talkback* default method where a character is inserted by releasing the finger on the key. The character selection depended on which finger was lifted from the screen. The remaining parameters were reached empirically through the analysis of interaction logs, where we tried different values and chose the ones that provided better results overall. The parameters are: after receiving audio feedback for a character, users have 2 seconds to insert it by lifting their finger, allowing rested fingers to be lifted and repositioned without unintended inserts; to prevent users from inserting erroneous characters from a quick tap on a key, we introduced a 200ms delay between insertions; and we discard a second character when both fingers are lifted at approximately the same time (less than 1 second). When a character is inserted, the system provides a short beep.

USER STUDY

The purpose of the user study was to investigate novice blind users' *QWERTY* text-entry performance and strategies in tablets. We evaluated and compared two interaction methods: *Explore by Touch* and *SpatialTouch*.

Apparatus

We used a Samsung Galaxy Tab2 with a multitouch 10.1 capacitive touchscreen. It was fixed on a table in landscape orientation, connected to a laptop computer via Wi-Fi. The laptop controlled the evaluation stimuli and provided the auditory feedback (via Ozone Onda ST headphones). The spatial audio was provided by *Text-to-Speeches* [4], integrated with *System Wide Assistive Technology* (SWAT) [8] to control and log all interactions.

Procedure

The user study was conducted within an institution for visually impaired people and was divided into two sessions: 1) gathering experience and demographics, 2) and text-entry evaluation. Each session was conducted on separate days to avoid over exerting participants.

Gathering Experience and Demographics. We asked participants to rate their experience and proficiency with touchscreens and *QWERTY* text-entry (on touchscreens and physical keyboard). Moreover, users performed a text-entry test in a computer physical *QWERTY* keyboard (silicon marks on letter *F* and *J*), where they wrote three individual sentences. The session took approximately 15 minutes.

Text-Entry Evaluation. Each participant performed only one interface condition. Once assigned the condition, the participants were given a 10-minute practice with the system, where the researcher explained how the condition behaved. Participants were encouraged to perform simple text-entry tasks such as typing their name, which allowed them to become familiar with the method.

Participants completed five trials. Sentences were randomly selected from written language corpus, each one having five words with an average size of 4.48 characters and a minimum correlation with the language of 0.97. For each trial, the researcher would read aloud the stimulus sentence and then participants repeated it to ensure they understood what was said. Participants would then type the sentence using the current interface condition. Error correction was disabled to ensure that all errors and typing behaviors were captured. Once the participant finished all five trials they were asked to complete an oral questionnaire to obtain subjective opinions regarding the interface condition.

Design and Analysis

To avoid learning and carryover effects, we used a between-subjects design with 30 novice users. It had one independent variable: interface condition (*Explore by Touch* vs *SpatialTouch*). Participants completed 5 randomly selected sentences, making a total of 150 trials. We applied Shapiro-Wilk normality test to observed values in all dependent variables. Parametric tests were applied for normally-distributed variables; non-parametric tests otherwise. There were no significant differences between groups regarding age ($t_{(28)}$=-34, p=.73), self-reported *QWERTY* experience (U= 104.0, z = -.362, p=.76) and *QWERTY* WPM in a physical keyboard ($t_{(22)}$=-.584, p=.56).

We analyzed users' performance in terms of speed (words per minute, WPM) and accuracy (MSD Error Rate). We also analyzed the following path-related metrics:

Starting Offset. It accounted for how close to an inserted character did the user landed his finger on. It was measured both in terms of spatial (in pixels) and key distance. The latter accounted for the number of keys that separated the two if following an optimal path (distance equals one if both keys edges intersect). For instance, *A* had a distance of one from *Q*, *W* and *S*, while a distance of three to ***F*.** When landing outside the keyboard, we considered the first reached key and added a penalty of one.

Deviation from Optimal Path. For each inserted character, it measured the difference between the actual path (number of keys visited) and the starting offset. For example, from *A* to *S* the optimal path is 1 traveled key; a user that follows that path has a deviation of 0. In contrast, a user that travels *A-Q-A-S* goes through two unnecessary keys.

Participants

30 visually impaired participants, 24 male, were recruited for this study. Their age ranged from 22 to 65 (M=46, SD=11.3) years old. Participants had no previous experience with tablets and only 5 reported having some experience with *QWERTY* in smartphones. However, all users had previous experience with physical keyboards.

RESULTS

No differences in performance. An independent samples t-test ($t_{(28)}$=-1.64, p=.11) revealed that *SpatialTouch* users (M=3.00, SD=1.17) did not write significantly faster than the *Explore by Touch* ones (M= 2.38, SD=0.82). Likewise, a Mann Whitney U test revealed no difference in terms of MSD error rate (U=74.0, z=-1.58, p=.12) between *SpatialTouch* (M=11.52, SD=3.91) and *Explore by Touch* (M=9.95, SD=6.54). Although no significant differences were found in the number of omission and substitution errors, *SpatialTouch* (M=4.72, SD=2.78) users made more erroneous insertions (U=65.0, z=-1.95, p=.05, r=.36) than the *Explore by Touch* users (M=2.83, SD=2.01).

SpatialTouch users landed nearer the targets and followed better paths. Comparisons of both spatial (U=63.0, z=-2.037, p<.05, r=.37) and key starting offsets (U=65.0, z=-1.95, p=.05, r=.36) have shown that *SpatialTouch* users (spatial: M=120.95, SD=7.69; key: M=0.90, SD=0.30) landed closer to the intended characters than *Explore by Touch* users (spatial: M=163.31, SD=17.97; key: M=1.38, SD=0.76). Moreover, an analysis of the *Deviation from Optimal Path* has also shown an advantage ($t_{(28)}$=2.04, p=.05, r=.35) for *SpatialTouch* users (M=.63, SD=.35 vs M=.93, SD=.44 of *Explore by Touch*). It means that *SpatialTouch* users, depending on where they landed their fingers, traveled through less unnecessary keys before reaching the intended target and thus followed better paths.

SpatialTouch performance correlated with physical QWERTY keyboard experience. No correlations were found between physical *QWERTY* WPM scores and *Explore by Touch* metrics. However, *SpatialTouch* users were able to leverage their previous *QWERTY* experience, as shown by strong correlations between their physical keyboard *WPM* scores and their *WPM* (r = .696, p<.01) and *Deviation from Optimal Path* (rho = -.647, p<.05).

SpatialTouch users divided the screen as in physical keyboards. All *SpatialTouch* users divided the screen in half and used the respective hand therein, with two distinct strategies: explore with one hand while keeping the other on the screen as a reference point; or slightly lifting the other finger (but still using it as a reference point). Yet, as aforementioned these strategies did not present a significant influence on performance.

Most actions were performed above the touchscreen. Most users tried to take advantage of their mental spatial model of the keyboard, as they usually aimed at landing their fingers on the next character to insert. In fact, their fingers landing locations are distributed across the keyboard (Figure 2). However, *SpatialTouch* users landed more often on characters that are common in the language and/or near the physical *QWERTY* home keys (and less in between). *Explore by Touch* users landed more in the keyboard borders and other less common characters suggesting they aimed at a different target or landed outside the keyboard.

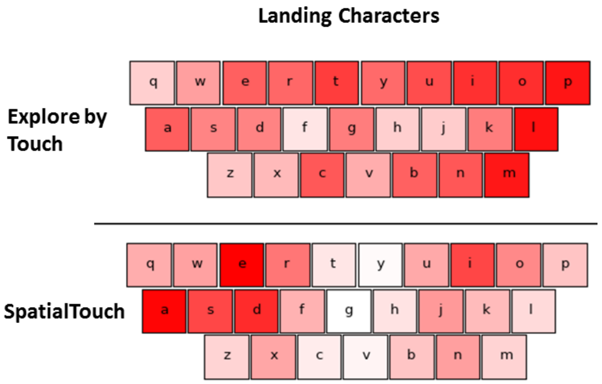

Figure 2. The heatmap of the relative frequency users landed on each character. Lighter means less frequent.

DISCUSSION

New methods needed to speed-up virtual QWERTY input. Participants typed an average of 23.4 WPM (SD=13.0) in a physical *QWERTY* keyboard. Previous research in smartphones contrast with these values, as Oliveira et al [7] reported an average of 2.1 WPM (SD=0.7) in a single session, whilst Azenkot et al [1] reported an average of 3.99 WPM (SD=1.65) after seven sessions, but very similar in the first session. Herein, we provide a baseline for *Explore by Touch* in tablets, which presented similar results (M=2.38, SD=0.82). Moreover, supporting two-handed exploration did not accelerate this task. Despite *QWERTY* being the de-facto standard text-entry method of tablet devices, this study revealed it is still too slow. However, alternative keyboards may require effortful learning. There is a need for new solutions that can still leverage previous knowledge of keyboards and enable higher input efficiency.

SpatialTouch leverages previous QWERTY experience. Two-hand interaction is a common behavior when typing on *QWERTY* keyboards. Users take advantage of the ability to rest their idle hand and quickly locate nearby target keys. This is especially important for non-visual input. *SpatialTouch* enabled users to mimic this behavior and make more efficient onscreen explorations to select target keys, as they landed near the intended targets and followed better paths. Our results suggest that participants were leveraging previous *QWERTY* experience. Future work should seek to exploit natural typing behaviors of blind users by supporting two-hand interaction.

Multitouch input needs better character selection methods. The ability to rest the fingers on a touchscreen was previously explored for sighted users [5], but non-visual input is more demanding. One user searched for the home keys (*F* and *J*) and positioned the other fingers as he usually does to interact with a physical keyboard. This suggests that multitouch may support more accurate reference points, even beyond two-finger interaction provided that the auditory channel is not overloaded. Most users had an accurate mental model of the keyboard layout and were able to leverage two-hand interaction by making more efficient interactions, but with more insertion errors. Having more than one input point adds a selection uncertainty that needs to be effectively addressed. Future research should explore new selection techniques and recognizers for multitouch input. Regarding the audio feedback, participants reported their preference to have each hand associated to a particular voice, instead of being dependent of the touches order.

CONCLUSION

We presented *SpatialTouch*, a non-visual text-entry input system that supports multitouch keyboard exploration. Results show that *QWERTY* is a slow input method in tablet devices and that supporting simultaneous screen exploration was not enough to improve performance. However, *SpatialTouch* showed that, given the ability to interact two-handed, users will leverage their previous *QWERTY* experience by resorting to reference points and taking better paths. This suggests a greater understanding of the keyboard layout. Moreover, faster physical *QWERTY* typists were also faster in *SpatialTouch*, but not in *Explore by Touch.* Future work will explore multitouch selection methods to provide blind users more control over input.

ACKNOWLEDGMENTS

Supported by *FCT* (PEst-OE/EEI/LA0021/2013, PEst-OE/EEI/UI0408/2014; SFRH/BD/103935/2014) and RCUK (EP/G066019/1 - SIDE).

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