Design Touch Feedback for Blind Users

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Abstract. Touch-screen interfaces do not offer tactile cues for the visually impaired users to distinguish interaction controls. As touch based interactions become more pervasive in our everyday lives, they present critical accessibility concerns. The recent advancement of touch screen technology makes design solutions possible. This research investigates the usability of accessible solutions on touch interfaces. Findings from our user study suggest that (1) proper voice feedback enables blind users to navigate touch-screen interface; and (2) different touch gestures have significantly different impacts on blind users' touch performances, such as efficiency and accuracy.

Keywords: Accessibility, touch interaction, gesture, auditory feedback.

1 Introduction

With the rapid advent of smart phones such as iPhone and Droid, touch screens are becoming pervasive across a wide range of technologies in our everyday lives. Touch based interactions are used in not only smart phones, but also personal computers (e.g., Windows 8), public kiosks, bank ATMs, printers, and various home appliances. This presents critical accessibility concerns for the 285 million world-wide visually impaired people [1].

Different from the physical controls on traditional interfaces, touch interfaces do not offer tactile cues to distinguish interaction controls and are extremely visual-demanding. In addition, the action controls and their positions vary from screen to screen, which makes it impossible for blind users to learn and remember the function and location of each control. As the physical keypad, knobs, buttons disappear from mobile phones, microwaves, and printers, it significantly reduces the degree of independence and equal opportunities for the visually impaired community.

A large body of research has been carried out in the last decade to improve the accessibility of touch interfaces [2-7]. These innovative techniques can be categorized in three areas: (1) gesture based interaction, (2) screen overlays with haptic or vibration for tactile feedback, and (3) earcons or readout as auditory feedback. These approaches alleviate the accessibility concern, but not without problems. Gesture interaction allows fast but less accurate input. It brings new challenges to the blind users as 82% of the blind people are 50 years and older [1] and many have cognitive or motor disabilities [8]. It is difficult for them to remember, distinguish, and accu-

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rately reproduce the required gestures like sighted users [9]. Tactile feedback helps because many visually impaired users are spatial and pressure sensitive [10]. However, the static physical overlays suffer from its inflexibility. Similarly, very limited information can be conveyed via the non-speech earcons or vibro-tactile feedback.

New solutions are made possible by the recent advancement in interaction technology. Tactus [11] provides a tactile solution by enabling application-controlled transparent physical buttons that dynamically rise up from the touch surface on demand. Neonode [12] introduces Z-force to allow accurate detection of different pressure on the touch screen. With such opportunities becoming available, this research investigates the usability and feasibility of accessible solutions on touch interfaces. We are particularly interested in understanding how to design touch gestures and feedback that are natural and effective, easy to use, and optimized for efficiency.

2 Experiment Design and Procedure

Our investigation comprised the following three phases:

Phase I. We carried out one-on-one interviews with 6 visually impaired participants (36 to 74 years old, 3 females and 3 males) to identify their needs and concerns with touch based interactions. All interviews focused on the discussion of how everyday activities were supported (or limited) by technologies. The outcome of the interviews has confirmed the increasing accessibility challenges introduced by touch screen interaction. For example, several participants mentioned that they had to add Braille tags on their home appliances to be able to identify the control buttons. Participants' top requests for accessibility improvement include:

- Equal opportunities to access information and technologies as sighted people.
- To use mainstream devices via effective yet inexpensive assistive technologies.
- Adjustable speed for screen read-out to optimize efficiency.
- Auditory feedback on the touch interface of home appliances and office devices.
- Simple and intuitive touch gesture that is easy to discover, remember, and use.

Phase II. We implemented the following five interaction methods (see Table 1) to investigate users' task performance (speed and accuracy) and satisfaction.

Table 1. Gestures examined in the users study

		Gesture to activate the selection			
		Press down	**Lift finger**	**Single tap**	**Double tap**
Gesture for speech feedback	**Touch**	Method 1	Method 2	Method 3	Method 4
	Single tap	(N/A)	(N/A)	(N/A)	Method 5

Eight (8) participants were recruited for this within-subject evaluation. Each participant completed 15 tasks, 3 tasks on each of the five prototypes. They were asked to start from a pre-defined screen position to locate a pre-defined target (on a 3x 3 grid-layout) as quickly and accurately as possible. Task assignments were randomized to reduce learning effect. We evaluated the five methods by examining participants' (1) task completion time, (2) error rate, and their perceived (3) ease of use, (4) learnability, (5) satisfaction. We also asked participant to indicate their preferred readout speed and overall ranking of the five interfaces. (Note: We will complete the data collection in Phase II with a total of twelve participants.)

Phase III. Based on the results from Phase II, we will adjust the proposed solution accordingly to develop a prototype that simulates the printer interaction experience. Participants in Phase II will be re-recruited in this follow-up study. The evaluation in Phase III includes more complex tasks such as making copies with changed settings, faxing a document to a given 10-digit number, and sending a scanned document to an email address. The complexity of these tasks allows us to further examine users' perceived effectiveness and efficiency of various (1) speech feedback and (2) audio confirmation of selection.

3 Preliminary Findings

As of the submission of this paper, we have completed the data collection of the first eight participants (4 totally blind, 4 legally blind.) in Phase II. One-way Analysis of Variance (ANOVA) was used to analyze the quantitative data collected in this study. Preliminary findings are discussed in the following sections.

3.1 Task Completion Time

Task completion time was defined as the time elapsed from starting to selecting the target item. Different gestures had a significant effect on completion time ($F_{4,115}$=5.04, p=.001), see Table 2. However, the difference was not significant ($F_{3,92}$=0.47, p=.704) amongst the first four gestures (touch-press, touch-lift, touch-tap, and touch-double tap). The main contributors to the difference in task completion time are (1) navigation gestures (touch vs. tap), where $Mean_{touch}$=25.88s, $Mean_{tap}$=60.14s ($F_{1,118}$=19.59, p<.001); and (2) selection gestures (non-double-tap vs. double-tap), where $Mean_{non\text{-}d\text{-}tap}$=26.06s, $Mean_{d\text{-}tap}$=42.73s ($F_{1,118}$=6.29, p=.014).

Table 2. Task Completion Time (in seconds)

	Touch-Press	Touch-Lift	Touch-Tap	Touch-Double Tap	Tap-Double Tap
All	23.41	31.50	23.27	25.33	60.14
Totally Blind	42.46	45.61	35.52	35.11	103.14
Legally Blind	11.98	23.03	15.92	19.46	34.33

Participants' vision status also affected their task efficiency. In general, legally blind participants (i.e., central visual acuity of 20/200 or less) were able to complete tasks faster than totally blind participants (i.e., no vision): $Mean_{LegalBlind}$=20.95s, $Mean_{TotalBlind}$=52.37s ($F_{1,118}$=25.11, p<.001). A significant interaction between Gesture and Vision was identified in this study ($F_{4,110}$=5.84, p<.001).

3.2 Error Rate

Error rate was measured as the total number of wrong selections divided by the total number of tasks. Results indicated that error rate was significantly impacted by different gestures ($F_{4,115}$=3.28, p=.014), see Table 4. Error rate with tapping-for-feedback was about 5 times higher than touching-for-feedback: $Mean_{Touch}$=10.42%, $Mean_{Tap}$=50.00% ($F_{1,118}$=10.15, p=.002). Double tapping for selection had much higher error rate than other selection gestures: $Mean_{non\text{-}d\text{-}tap}$=9.72%, $Mean_{d\text{-}tap}$=31.25% ($F_{1,118}$=4.30, p=.040). Error rate was also affected by participants' vision ($F_{1,118}$=5.26, p=.024) and age range ($F_{1,118}$=5.30, p=.023), but not gender ($F_{1,118}$=2.33, p=.128).

Table 3. Error Rate

	Touch-Press	Touch-Lift	Touch-Tap	Touch-Double Tap	Tap-Double Tap
All	0.00%	4.17%	25.00%	12.50%	50.00%
Totally Blind	0.00%	11.11%	55.56%	33.33%	66.67%
Legally Blind	0.00%	0.00%	6.67%	0.00%	40.00%

3.3 Subjective Ratings

Subjective ratings were collected on a Likert Scale (Perception: 1-lowest, 7-highest. Ranking: 1-lowest, 5-highest). No significant difference was found among the perception ratings (see Table 4), except Ease of Use ($F_{4,35}$=3.46, p=.017). Whether to touch or tap for speech feedback had a significant impact on perceived Ease of Use, where $Mean_{touch}$=6.3, $Mean_{tap}$=4.5 ($F_{1,38}$=13.91, p=.001). Perceived Learnability was rated higher by younger participants: $Mean_{35\text{-}44yr}$=7.0, $Mean_{55\text{-}74yr}$=6.4 ($F_{1,38}$=10.69, p=.002).

Table 4. Subjective Ratings and Overall Ranking

	Touch-Press	Touch-Lift	Touch-Tap	Touch-Double Tap	Tap-Double Tap
Ease of use (1~7)	6.375	5.938	6.375	6.375	4.500
Easy to learn (1~7)	6.500	6.875	6.875	6.750	6.500
Satisfaction (1~7)	5.750	6.188	6.500	6.313	5.125
Overall ranking (1~5)	2.875	3.000	3.625	3.250	2.250

4 Discussion and Future Work

Participants' comments explained why tapping-for-feedback was particularly difficult for blind users: (a) it had no point of reference – for totally blind users, tapping to find target was like "taking a stab in the dark"; (b) it was very easy to miss the target – sometimes they tapped on a target but moved away too quickly and missed the voice feedback; (c) continuous tapping on the same target was registered as a double-tap, which resulted in errors rather than voice feedback; and (d) several participants were able to find the target quickly, but they tapped slightly off the target, and had to spend much more time to re-find and select the target. In addition, the speed of double-tap varied individually, which made it difficult for the system to distinguish a slow double-tap from two quick single-taps. Other interesting findings are summarized below:

- Preferred speech rate for blind users is 256 words/minute (from 187 to 421wpm).
- Touching/sliding to navigate would have worked more effectively if the screen had different textures or haptic feedback for action area vs. non-action area.
- Lift-to-select was easy to use and to learn. But some concerned that they might make many mistakes if accidentally lifted finger off the wrong target.

We expect to finish data collection in Phase II and Phase III soon. Design guidelines will be proposed in the completed paper. We believe that results from this in-depth investigation will shed light on how to improve accessible design on touch interfaces universally. Applications of our design guidelines should provide blind users with easier access to information and technologies.

References

1. World Health Organization. New Global Estimates on Visual Impairment, `http://www.emro.who.int/control-and-preventions-of-blindness-and-deafness/announcements/global-estimates-on-visual-impairment.html` (cited October 10, 2012)
2. Kane, S.K., Bigham, J.P., Wobbrock, J.O.: Slide Rule: Making Mobile Touch Screens Accessible to Blind People Using Multi-Touch Interaction Techniques. In: Proceedings of ASSETS 2011, pp. 73–80. ACM Press, NewYork (2008)
3. Guerreiro, T., Nicolau, H., Jorge, J., Goncalves, D.: NavTap: A Long Term Study with Excluded Blind Users. In: Proceedings of ASSETS 2009, pp. 99–106. ACM Press, New York (2009)
4. Ferati, M., Mannheimer, S., Bolchini, B.: Acoustic Interaction Design through "Audemes": Experiences with the Blind. In: Proceedings of SIGDOC 2009, pp. 23–28. ACM Press, New York (2009)
5. Vidal, S., Lefebvre, G.: Gesture Based Interaction for Visually-Impaired People. In: Proceedings of NordiCHI 2010, pp. 809–812. ACM Press, New York (2010)
6. Parente, P., Bishop, G.: BATS: The Blind Audio Tactile Mapping System. In: Proceedings of ACM South Eastern Conference 2003 (2003)
7. Su, J., Rosenzweig, A., Goel, A., Lara, E., Truong, K.N.: Timbermap: Enabling the Visually-Impaired to Use Maps on Touch-Enabled Devices. In: Proceedings of MobileCHI 2010, pp. 17–26. ACM Press, New York (2010)
8. Kane, S.K., Jayant, C., Wobbrock, J.O., Ladner, R.E.: Freedom to Roam: A Study of Mobile Device Adoption and Accessibility for People with Visual and Motor Disabilities. In: Proceedings of ASSETS 2009, pp. 115–122. ACM Press, New York (2009)
9. Kane, S.K., Wobbrock, J.O., Ladner, R.E.: Usable Gestures for Blind People: Understanding Preference and Performance. In: Proceedings of CHI 2011, pp. 413–422. ACM Press, New York (2011)
10. Oliveira, J., Guerreiro, T., Nicolau, H., Jorge, J., Goncalves, D.: Blind People and Mobile Touch-based Text-Entry: Acknowledging the Need for Different Flavors. In: Proceedings of ASSETS 2011, pp. 179–186. ACM Press, New York (2011)
11. Tactus. White paper, `http://www.tactustechnology.com` (cited October 10, 2012)
12. Neonode Technology, `http://www.neonode.com` (cited October 10, 2012)