Bending Blindly: Exploring Bend Gestures for the Blind

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Abstract
This paper explores the novel context of using bend gestures as a primary method of interaction for the blind. Our preliminary study assesses if this more tactile experience could enhance the usability and accessibility of technology for blind users, by comparing bend and touch interactions with simulated blind participants. Both input techniques showed similar results, indicating that bend gestures have potential in this context. We identify results that can help shape future research in this accessibility area, and potentially increase the overall interaction experience for screen reader based smartphones.

Author Keywords
Bend gestures; Deformable user interfaces; Blind; Visually Impaired; Accessibility; Mobile.

ACM Classification Keywords
H.5.2. User Interfaces–*Interaction styles*

Introduction
Living in complete darkness or through a blurred filter is a challenge faced by over 280 million people every day [33]. When their visual sense is severely impaired, individuals are forced to depend on remaining senses to interact with the world around them. Technology, in particular smartphones, present many unique

Figure 1 Enhanced non-visual interaction with bend gestures

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challenges for these individuals, who cannot interact with traditional graphical user interfaces.

To resolve these accessibility problems, designers have created and evaluated a range of technologies [2,3,4,7,28]. Although more tactile methods do exist as external inputs [7,28], the majority of common devices rely on audio augmentation of basic touch experiences such as VoiceOver [2] or TalkBack [10]. Several usability concerns exist with the touch interactions with these audio systems, specifically, the need for highly accurate touch gestures, multi-finger interactions, and the learnability of the gestures themselves [6,22].

Deformable devices offer an opportunity to embrace an enhanced tactile interaction model with the ability to physically manipulate and bend certain parts of a device [13,18,20,29,32,34,35]. Bending and squeezing easily locatable and distinguishable parts of a smartphone such as corners and edges could be ideally suited for users as a way to interact with an audio-based interface. Yet, we found no prior work using deformation as an interaction technique in the area of accessibility, or as a potential application for blind users.

In this paper, we explore this novel concept to understand if this alternative tactile interaction experience could enhance the accessibility of technology for blind users (Figure 1). We compared bend to touch gestures to evaluate if bends improve the usability of mobile technology and screen reader based interfaces such as VoiceOver. As we completed this study with simulated visual impaired participants [23,27,36], we also sought the input of one fully blind and one partially blind participant.

Related Work

We review the previous work completed in the areas of deformable interactions and accessibility.

Flexible Displays

We seek to determine parameters best suited to create a set of bend gestures for basic interactions on an iPhone-sized device. After Schwesig et al. [29] set the stage for future research in bendable displays with Gummi, two research directions followed: one that considers bend gestures in the context of paper manipulation [e.g. 8,13,35], the other for mobile technologies [1,9,12,18,20]. We focus on the latter. Participants prefer top corner and center squeeze gestures for frequent tasks [34], up gestures to down, the corner closest to the thumb for primary actions [9], and smaller devices [21], which require less effort to manipulate and could be performed using one hand [21]. We use these to define the set of seven bend gestures as the foundation for our studies.

Accessibility Technology for the Blind

Designing for the blind requires an understanding of usage and usability concerns with current touch based screen readers such as VoiceOver [2], Talk Back [10] and BlindSquare [25]. These include precision on screen selection, high level of dexterity, lack of logical navigation order and orientation, inconsistent focus, conflicting app and system controls and difficult text input [6,16,22]. Kane and Ladner [15] recommend that touch interactions avoid the use of symbols found in print, favour edges and corners, reduce need for specific location accuracy, limit time restrictions for gestures, use familiar patterns and layouts used in other applications and more multi-touch gestures.

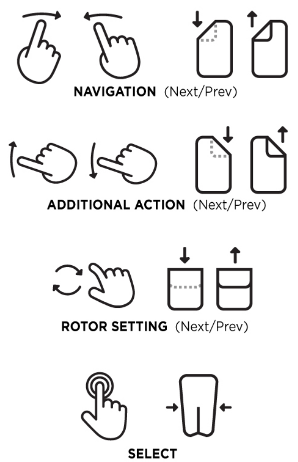

Figure 2 Seven touch gestures (left on each row) and bend gestures (right on each row).

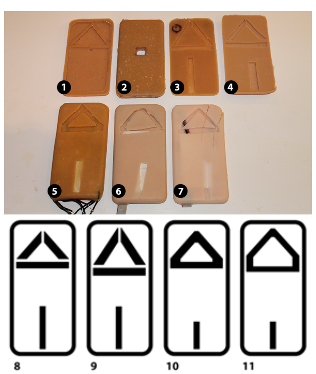

Figure 3 Various prototypes testing groove location, depth and material density.

Researchers have also explored alternative input methods such as the phone's keypad, and a modified touchpad [23,30,38]. Others investigated the use of the Braille language with touch, such as entering Braille characters [7,26,31] reading Six Dot Braille [28] and representing Braille using haptics [14].

Study: Bend Vs. Touch Gestures

We explored in this preliminary study, the use of bend gestures for common tasks, compared to touch in the context of a screen reader environment such as VoiceOver. We captured completion times for each task, as well as user preference for each interaction techniques, hand position and movement. We predict that due to screen occlusion, and the user's sole reliance on non-visual feedback (tactile cues and audio), bend gestures will be a preferred method of interaction. This is also reflective of past work identifying user preference for a more tactile method of interaction [18,35].

Gesture Classification

We adopted predefined touch gestures established in the VoiceOver software to ensure consistency with a real-world application. These included swiping left and right for navigation, swiping up and down to navigate additional actions, rotating with two fingers clockwise and counter clockwise to change the rotor setting (Figure 2) and double tap to select the focused item.

We used a set of previously evaluated bend interactions on one-handed gestures for a device in portrait orientation [9]. We mapped the top right corner, closest to the thumb, for navigation, as it is the most repetitive task [9]. We associated the top left corner to additional actions, and the center squeeze to selection. We mapped the rotor setting to bending the top center up or down (Figure 2).

Hardware and Software

We fabricated two prototypes in portrait orientation: a ridged silicone prototype with an embedded capacitive pad for touch gestures, and a flexible silicone prototype with four embedded bi-directional sensors for bend interactions. These prototypes allowed the users to perform bend and touch gestures to navigate the interface and complete the defined tasks. We created an audio-based interface with HTML and Speak.js an open source JS library [37] to replicate the experience of using VoiceOver. We made both prototypes out of silicone resin [19,24], in size to an iPhone 6 (120 mm x 72 mm).

IMPROVING BENDABILITY WITH STRESS JOINTS

To improve the definition of the bending locations and allow participants to bend more easily, we embedded grooves into the mold during the casting process. We borrowed the concept from "strain relief" used in today's power and computer cables. These thinner depths at specific locations created flexible joints. We tested several versions (Figure 3) with a small group of individuals, iterating variations in groove location, width and depth. Version 11 resulted in the preferred design.

Methodology

We designed a 2x3 repeated measures within-subject design study, with the factors: interaction (bend, touch), and task set (navigation, action, setting), counterbalanced by interaction and randomized by task. We tested the three core interaction paradigms, through three task sets: navigating up and down a list (navigation), performing additional actions on a focused

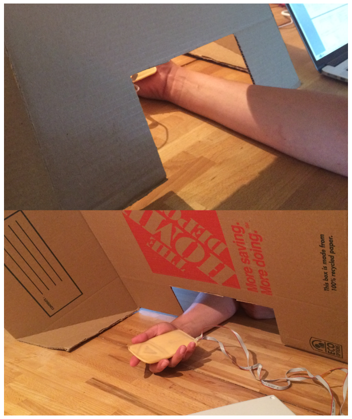

Figure 4. Setup to create visual impairment.

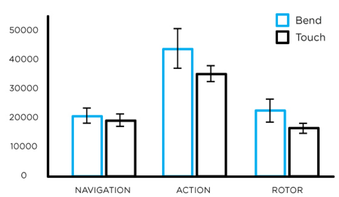

Figure 5. Results of task completion times for bend and touch averaged for each of the three task sets

item such as “Archive, move to trash” (action), and changing the function of VoiceOver’s rotor setting (rotor). Participants performed three trials for every task set (9 trials total), with each prototype. We introduced participants to the system, allowing them to practice each interaction and listen to the audio feedback. Participants then performed 9 trials of each bend and touch gestures. We ended with preference questionnaires and a short post-experiment interview. The study lasted 45 min. Figure 4 illustrates the screen placed between the prototype and the participant during the whole experiment. This simulated visual impairment is comparable to past work [36].

Participants

17 participants (10 male) between the ages of 21 and 44 year old (mean of 31) self-identified as having normal vision with or without corrective lenses. 16 were right-handed. Their median technical proficiency was 5.5 (1=poor, 7=excellent). Only two users had tried VoiceOver a couple of times. Participants were compensated $10.

Results

Task Completion Time

We measured the completion time for each task, from when the participant squeezed the device to when they completed the appropriate action. We ran a two-way within-subject repeated measures ANOVA on the completion time with factors: gesture type and task set. We found no significant difference between completion times for each of the sets, though touch outperformed bend slightly for each (Figure 5).

Bend and Touch Preference

Participants rated their comfort level using bend and touch gestures in general, and for each specific task set, using a 5-point Likert scale. We conducted a Wilcoxon signed-rank test to compare bend to touch, and found no significant difference in any of the task set comparisons. Navigation produced a close to significant effect ($z = -1.941$, $p = .052$), where 7 participants found bend gestures very comfortable to interact with, and only 3 for touch.

All participants except one used the same number of hands for both prototypes. We observed that all participants held the touch prototype in a similar manner throughout the tasks, probably due to the familiarity to daily interactions with smartphones. Most participants did not identify physical effort, strain or phone size as a problem during the study with only two participants mentioning the prototype being too big.

Regripping During Tasks

We observed that participants regripped often during the bend interactions, which may have led to slightly higher task completion time (Figure 6). For action and rotation task sets, participants needed to switch from performing basic navigation gestures to a secondary gesture. We noticed seven participants paused to reposition their hand(s) from a navigation position to perform an action gesture. Five participants switched grips before doing the rotor task (bending the top of the device. No participant regripped during navigation, which might have led to the reduced differential.

Regripping also occurred when participants squeezed the device to complete a task. Seven regripped from the navigation, action or rotor position to the selection

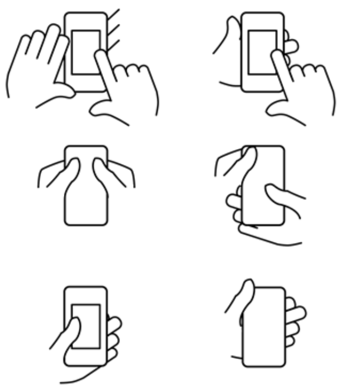

Figure 6. Common hand positions used during the study. Including touch and bend hand grips.

position. In comparison, the majority of users switched from swiping horizontally to vertically with ease to complete the tasks with touch interactions. All who held the touch prototype in one hand needed to reposition to complete the rotor-setting tasks as the gesture required a counter-clockwise motion with two fingers, with the second hand.

Post-Experiment Interviews

10 participants preferred using bend gestures to complete the tasks. Several participants commented on how easy bend gestures were to use, specifically the top corner for navigation. A majority mentioned that bending up and down mapped better to the direction in the list they were navigating. Three indicated that swiping left and right to navigate through a list as weird, and identified that touch gestures did not map as well as bend gestures to this direction of navigation. Four participants who preferred touch referred to the familiarity with the current interaction paradigms of today's smartphones.

Tactile feedback played an important role in this study, as participants were unable to see the device during the interactions. Seven mentioned the preferable tactile nature of the bend gestures. Two indicated using the groves on the back of the device as a reference for the corner locations. One participant identified that bend gestures were harder to confuse the different gestures where touch was too similar.

Discussion

Our goal was to gain insights into how users perform bend gestures in a visually impaired environment when compared to touch. We did not identify any significant differences between bend and touch input techniques in task completion time, though participants performed tasks slightly faster with touch. We interpret this to be a positive result, as it means that participants performed bend gestures at a somewhat equivalent level to touch, and preferred them. With improvements to the prototype and an extended training period, we expect to reduce or even reverse this time gap.

We intended to reduce the need to reposition hands by using an iPhone-sized device in portrait mode, but most participants were unable to complete tasks without regripping. We expect that this frequent regripping negatively influenced the task completion time. Even though participants had an opportunity to utilize a trial period and become familiar with bend gestures, they did not have the same level of experience as touch. The range in hand positions observed also supports this: participants held the touch device in a small set of positions, while participants held the bend prototype in a larger range of positions, often changing throughout tasks. This is additional evidence of their unfamiliarity with a deformable user interface.

Several participants identified bend as providing a more tactile form of interaction. The grooves on the back of the phone primarily created as stress points unintentionally provided participants with an easy way to identify the different corner locations. Some participants used this to help them differentiate between tasks and avoid confusion. Several participants noted that the corners were easier to distinguish than the flat screen resulting in less confusion during interaction, and is reflective of past work by Kane and Ladner [15].

These qualitative findings add additional value for bend gestures being a more tactile form of input. Through additional training and prototype refactoring, we might reduce the task completion time and amount of regripping, making this interaction technique potentially validity as a primary form of interaction for the blind.

Initial Testing with Blind Users

We further evaluated findings from this study with two visually impaired participants, one fully blind, and one with low vision, through a local council for the blind. Each participant informally interacted with the bendable prototype. We recorded their impressions.

Both identified the tactile nature of bend gestures. One participant quickly related bending to past experiences: "Bending is something we have done ever since we are little, touch gestures are not". She teaches VoiceOver and touch interactions to the newly blind, and felt that bend gestures would be "easier out of the box than touch". She identified utilizing the grooves for training: "These are for bending the corners, this is for squeeze." Both participants recommended making the grooves more pronounced, and further explore clear physical affordances and different material textures to identify bend locations. Both discussed how the spatial separation of the interactions was positive for bend, and could result in fewer errors during task completion.

Finally, one participant noted that bend gestures could be an ideal candidate for those who do not have full-hand dexterity. Visual impairment often comes with other physical disabilities and tremors. Precision touch gestures are often harder to perform for these individuals. Bend gestures may be more forgiving and could be performed with less fidelity. In all, both interviews support our hypothesis that bend gestures as a viable interactive model for the blind.

Conclusion

This paper explored deformable interactions to enhance the usability of technology for blind users. We compared the effectiveness of bend gestures to touch as primary forms of input to receive audio feedback in a device-occluded environment. We did not find a significant difference in completion time between bend and touch gestures. However, bend interactions show promise in the area of accessibility and interaction paradigms for the blind. Further research with improvements to the prototype, such as smaller size and additional training could reduce regripping and greatly improve the effectiveness of bend interactions.

The main limitation of our work is the use of sighted participants with simulated vision loss: while we reproduced prior methodologies, sighted users are not a true representation of our target demographic. The heightened senses of hearing and touch in blind users are not achievable with simulating visual impairment and an integral reason to test with this target group [5,11,17]. We plan to repeat this study with fully blind users.

Overall, this paper is the first to introduce the use of deformation, through bend gestures, for the blind. We contribute the usability of bend gestures versus touch in an audio output application. This work leads to further research in this area with the ultimate goal of providing new technology and interaction patterns to improve the overall accessibility and usability of smartphone technology for the blind.

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