Increasing the accessibility of pen-based technology: An investigation of age-related target acquisition difficulties

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Abstract

This paper describes the author's dissertation research on improving the accessibility of pen-based technology. The first step for this research was to gather information on the underlying causes of target acquisition difficulty. To meet this goal, a controlled laboratory study was conducted, which uncovered three sources of difficulty: slipping, drifting, and missing just below. The remaining work will be to address these difficulties by implementing new interaction techniques and experimentally evaluating their effectiveness.

Introduction

The average age of the world's population is increasing. As of the 2000 Census, 12.4% of the U.S. population (approximately 35 million individuals) was aged 65 or over. Moreover, it is projected that by 2050 this proportion will have risen to over 20% [4]. Many older adults prefer to live independently [9]; however, the prevalence of cognitive and sensory age-related impairments can make this challenging.

Technology is increasingly being promoted as a means of addressing these age-related impairments and enabling individuals to live more independently (e.g., [2, 6, 7, 10] to name a few). Because they are small, mobile and powerful, handheld technologies such as Personal Digital Assistants (PDAs) and Tablet PCs are appealing platforms for these endeavors. However, for these technologies to be viable for this purpose, it is essential that older users be able to perform basic interactions with them (such as selecting an icon or menu item).

Age-related impairments rarely occur in isolation, and as such many individuals have associated impairments; often these impede their ability to interact with small devices. For example, in our own work designing mobile technology for cognitively impaired individuals [6], we informally observed many participants struggling with target acquisition using a stylus (e.g., selecting an icon or a menu item). This has motivated us to gain a better understanding of pen targeting difficulties and to ascertain the extent to which age is a factor.

The high-level objective of this thesis is to increase the accessibility of pen-based technology (such as Tablet PCs), by investigating mechanisms for assisting individuals, and in particular older individuals, to select more easily using pen technology.

Background

There has been considerable research aimed at developing improved target acquisition techniques. However, despite these advances, point and tap (i.e., selection by (i) tapping down, (ii) possibly moving the pen, and (iii) tapping up, with selection determined based on the location of the tap up) remains the de facto standard. Unfortunately, as noted above, many users find this action difficult to perform accurately and efficiently.

We have identified three characteristics that span the majority of previous work and that we believe have limited its ability to address the basic acquisition needs of a wide range of users. Firstly, there has been a narrow focus on young-healthy adults, who can more easily adapt to different techniques. There are many parameters, including a user's sensory and motor ability, that are likely to affect target acquisition and manipulation skill. Thus, a broader perspective can be gained by examining a range of users and abilities. Secondly, there has been a focus on evaluation with a single, typically highly constrained task. It is important to include multiple tasks to capture both concrete comparative measures and complex interaction. Finally, much of the focus has been on designing and evaluating novel techniques over developing a deeper understanding of how users manage basic tapping. Focusing on developing new techniques and evaluating them against the status quo (point and tap) has led research towards gross measures of overall speed and accuracy. While these measures provide comparative data about which technique is superior, they do not reveal underlying limitations or tell us where innovation is still needed.

In light of this, our approach is to try to fill this niche by adopting the following three-phase approach: (1) gather information on the underlying causes of target acquisition difficulties across a range of ages and tasks, (2) develop new interaction techniques to better support pen-based interaction, and (3) experimentally evaluate these new techniques against standard point and tap. In the following sections we elaborate on these phases. To date, we have completed the first phase. The second and third phases are currently underway.

Understanding the Sources of Difficulty

In the first phase, we conducted a controlled laboratory experiment to examine target acquisition difficulties across the adult lifespan. Specifically, our main goal for this study was to perform a detailed analysis of the types of difficulties users encounter while tapping to acquire targets. Additionally, we were interested in determining whether these difficulties vary in terms of their nature and severity with age or task situation. Full details of this study can be found in [5]; here we provide a summary, highlighting the key findings.

To address the goals outlined above, we performed an evaluation of two selection tasks (multi-dimensional discrete tapping and menu selection) across three adult age groups (young: 18–54, pre-old: 55–69, and old: 70–85). Participants completed both tasks, which were counterbalanced. We included two tasks to gain a better understanding of how task might affect targeting ability, especially in terms of accuracy. A tapping task was selected because, it is the gold standard for evaluating input techniques, and provides well understood measures of speed and accuracy. A menu task was selected because it provides a greater degree of realism than the tapping task, and may require slightly more cognitive effort.

Our results revealed three primary sources of target acquisition difficulty: missing just below, drifting and slipping. Slipping was specific to older users and common to both tasks, while the other two errors, drifting and missing just below, were specific to the menu task, but affected users of all ages.

Missing just below occurs when a user’s tap distribution is downwardly shifted, resulting in frequent erroneous selection of the top edge (i.e., the top 10% or 2 pixels) of the item below the target item, and infrequent selection of the corresponding top edge region of the target item itself (see Figure 1). Our results indicated a general trend towards missing just below: none of our participants made notable use of the top edge of the target item, while a substantial subset made use of the edge of the item below. Specifically, our data suggested that a selection along the top edge of an item is 11 times more likely to be intended for the item above it.

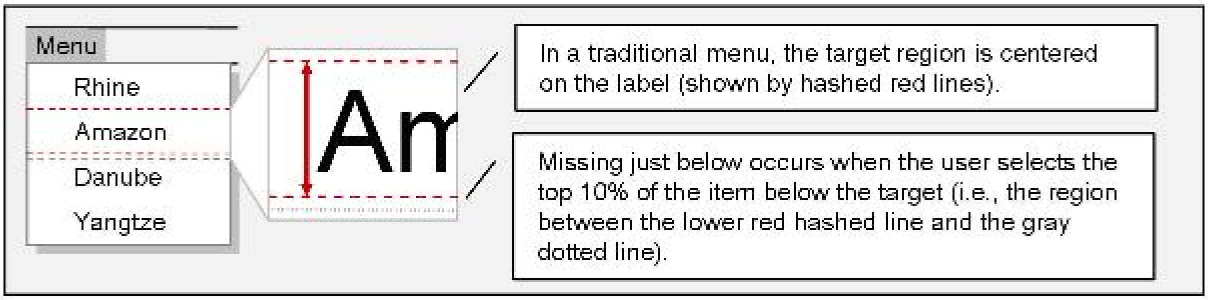

Figure 1. Missing just below.

Drifting, though not one of our planned measures, was a dominant pattern observed during the menu task sessions, occurring when the user accidentally enters the hover region of an adjacent menu. As with a mouse, this action causes the open menu to switch. The problem is that with a Tablet PC hand occlusion often results in users lifting their hand up and away to see the menu contents. Depending on the distance lifted and the angle of this action, the pen may accidentally "drift" to the next menu, resulting in the target menu unexpectedly closing. Thirty-five out of 36 participants drifted at least once, and this behavior did not improve over the course of the study; that is, participants did not get used to eh designed interaction. Moreover, drifting impeded performance: trial time almost doubled when drifting occurred.

Figure 2. Drifting occurs when the user accidentally hovers over an adjacent menu (e.g., Edit in this example), causing it to open, and the desired menu (e.g., File) to close.

Finally, a slip error is the result of landing on the desired target, but slipping off before lifting (as shown in Figure 3). For the old age group, it accounted for approximately half of the errors in each task. In addition, while missing remained relatively constant across age, slipping clearly increased. Although slips were a major source of errors, they were relatively short; for the tapping and menu tasks, the average lengths were 12 and 10 pixels, respectively.

An additional finding of this study was that the behavior of older participants enabled us to uncover difficulties common across the lifespan. The most prominent example of this was drifting, although it also applies to missing just below. Drifting was not a behavior we predicted; rather our observations of the older users during the experimental sessions prompted us to investigate it in detail. It was only upon closer examination of the data that we discovered that all participants were impacted by drifting. Because the older participants moved more slowly overall, it was easier to follow their actions and catch inefficiencies. Also, they were more overt about their interactions. Younger individuals, on the other hand, recovered more quickly and were considerably less verbal about their experience; thus we were not able to detect the effect for them from our observations alone.

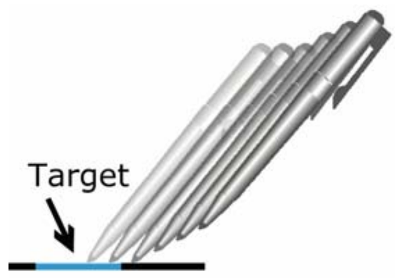

Figure 3. A slip error occurs when the user correctly lands on the target (show in blue) but slips off before lifting the pen.

Addressing the Difficulties Uncovered

The next two phases of this research focus on addressing the difficulties uncovered in the first phase and evaluating the proposed solutions. These two phases are currently underway. Specifically, we have developed and evaluated solutions for missing just below, and we are in the early stages of exploring potential solutions to drifting and slipping.

Missing Just Below

For the first difficulty, missing just below, we designed and developed two approaches: (1) reassigning selections along the top edge, and (2) deactivating the top edge. Figure 4 demonstrates both of these approaches relative to a standard menu. In the *reassigned edge* approach, the top edge of each menu item was reassigned such that taps in that region resulted in selection of the item above. This approach effectively shifted the target region of each menu item down (in motor space), while leaving the visual appearance unchanged. In the *deactivated edge* approach, the top edge of each item was deactivated such that taps in that region were ignored. This approach effectively shrunk the height of each item (in motor space), and added an invisible menu separator between items. It also left the visual appearance unchanged.

The existence of a downward shift in the tap distribution (as reported in [5]) implies a disparity between where users are aiming and the center of the menu item. Thus, the idea behind the reassigned edge approach is to reduce this inconsistency by matching the target bounds to the user's actions. We suggest that the main advantage of the reassigned edge approach is that it changes the current interaction the least. We predict that most users would not notice the small shift, but would simply benefit from fewer errors. Its disadvantage is that it turns a small number of correct selections into errors (i.e., those on the top edge of the target item itself).

Selecting the wrong menu item can have a high cost; for example, selecting the wrong program from the Windows Start menu not only requires the user to go back and reselect the correct item, but also requires the user to wait for the undesired program to load, before closing it. As such, the motivation behind the deactivated pixel condition is that it is less costly to tap an inactive region of the menu and have to re-tap, than to tap an incorrect item and have to correct the selection. However, we have previously noted that users typically do not wait to see if their tap registers, but rather move on, subsequently realize they have not actually made a selection, and then have to go back to try again [5]. Thus, although we predict that the deactivated condition will remove the greatest number of erroneous item selections, it may have other costs. Moreover, these costs may particularly affect older users as older adults have previously been shown to be less able to adapt to changing task requirements [3].

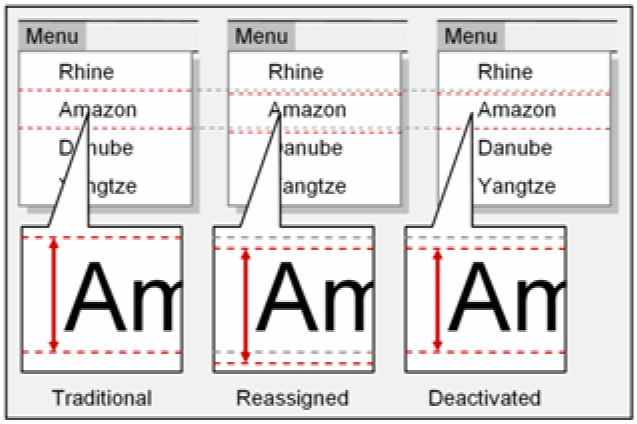

Figure 4. In a traditional menu, the target region (shown by hashed red lines) is centered on the text (left); in a reassigned edge menu, it is shifted down by 10% of its height (center); and in a deactivated edge menu, it is reduced by 10%; taps on the top edge are ignored.

To examine these questions, we ran a controlled laboratory experiment with younger (19–30) and older (66–81) adults to compare these two experimental interfaces, relative to each other and to a traditional edge control condition. In contrast to the first study, we did not see a clearly defined downward shift in the tap distributions, but rather saw two diametric distributions: one that was downwardly shifted (the low hitters) and one that was upwardly shifted (the high hitters). Our performance results reflected these two opposing categories. When we considered our participants as a whole, only the deactivated edge approach showed any benefit over the control condition. However, when we consider the tap distribution groups individually, we see that low hitters did benefit from both the reassigned and deactivated edge approaches, while the high hitters were negatively impacted by the reassigned edge approach, and relatively unaffected (in terms of top edge selection errors) by the deactivated edge approach. Nonetheless, the deactivated edge approach was unpopular with the high hitters as it increased the number of taps required to make a selection, without providing them with any benefit. Moreover, the variability between users suggests that additional research is necessary to explore the practical implications of deploying these techniques.

Drifting

To address drifting, we note that in the first study, none of the participants intentionally used hovering to switch menus. Thus the simplest way to prevent drifting may be to turn off that feature and require a tap to switch between menus. This may not be the best approach, however. In our first study, participants were all novices to pen-based interaction and were prompted to the correct menu. We suspect that for more expert users, or when the task requires browsing through menus to find the correct item, being able to switch menus without touching the screen may prove more useful. An alternative approach would be to introduce some form of delay to the switch, either by time, distance, or a combination of the two. However, it is unclear whether or not browsing and drifting behavior can be distinguished by these measures. We are in the early stages of exploring these questions, and plan to conduct a user experiment to evaluate the effectiveness of these techniques.

Slipping

Finally, the slipping difficulty was a problem for the older users, a result that is consistent with research on the mouse [8]. However, with the mouse, slipping has generally been attributed to an inability to hold the mouse steady while clicking. As tap selection does not have an analogous button clicking action, it is surprising it was also a problem here.

One approach to preventing pen-based slip errors would be to adapt Steady Clicks [8], a slip assistance technique designed for the mouse that assists the user by freezing the cursor at the mouse down position. However, like many mouse-based interaction techniques, Steady Clicks alters the ratio between mouse and cursor movement. The direct mapping between the cursor and the tip of the pen makes this less ideal. One possibility is to handle the freezing internally, and not manipulate the cursor. The drawback is that some users may find this lack of visual feedback confusing.

Another approach would be to combine freezing with area cursors [1]. With an area cursor, it is not the tip of the cursor that defines the object selected, but rather a larger selection area centered on the tip of the cursor. We believe this small degree of separation may provide the flexibility needed to allow a natural form of freezing. On pen down, the area cursor would freeze. Freezing would break, if the pen crosses the edge of the cursor.

Each of these approaches has inherent benefits and drawbacks. The first approach is cognitively simpler, but the lack of visual feedback may be a disadvantage for some users. In contrast, the combined approach provides strong visual feedback, and requires less positioning precision, but adds complexity to the interaction. Furthermore, even if both approaches are viable solutions, it may be that there are situations in which, or user groups for whom, one solution is better than the other. To evaluate these tradeoffs, we propose conducting a laboratory experiment comparing these approaches to each other and to standard tap and point across a range of adult ages.

Conclusion

To summarize, the expected contributions are:

(1) Empirical evidence identifying pen-based target acquisition difficulties, and demonstrating how these difficulties vary across task situations and with age.

(2) New pen-based target acquisition techniques that build upon existing techniques to address the needs of older individuals using a pen-based device.

(3) Controlled user evaluations that: (i) demonstrate the effectiveness of our techniques and show that existing techniques can be combined and modified to meet the needs of older users and pen interaction, and (ii) ascertain that there are trade-offs, revealing that the choice of technique depends on the constraints of the user population.

Mobile technology is increasingly being promoted as a means of addressing cognitive and sensory age-related impairments and enabling individuals to live more independently. However, for this to be a viable approach, the accessibility of these technologies needs to be improved for older adults. By addressing the usability of basic input for older adults, this research will provide a foundation for broader innovations in these other areas.

Acknowledgements

This research is supported by Canada's Natural Sciences and Engineering Research Council (NSERC), and by the Canadian Institute of Health Research (CIHR). The author also thanks her supervisor Dr. Joanna McGrenere, and her committee: Dr. Peter Graf, Dr. Alan Mackworth, and Dr. Shari Trewin.

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Karyn Moffatt is a PhD student in Computer Science at the University of British Columbia, working under the supervision of Dr Joanna McGrenere. Her research interests are in the area of human computer interaction with a focus on the design of inclusive technology. In 2005, she was awarded a 3-year NSERC post-graduate scholarship to pursue her thesis research on increasing the accessibility of handheld technology for older adults. She also holds a M.Sc. in Computer Science (2004) and a B.A.Sc. in Computer Engineering (2001), both from the University of British Columbia.