Walk 'n Scroll: A Comparison of Software-based Navigation Techniques for Different Levels of Mobility

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ABSTRACT
In this paper, we present a field study comparing software-based navigation techniques (scrollbars, tap-and-drag, and touch-n-go) on mobile devices. In particular, we were interested in exploring the efficiency and user preference of these navigation techniques for different levels of mobility (sitting, walking, and standing) in a naturalistic environment. Results show that while there was no significant difference in performance between tap-and-drag and touch-n-go, both techniques significantly outperformed scrollbars for simple, multi-directional navigation tasks. In addition, the users preferred the touch-n-go technique over the other two methods. The results also revealed that users' interactions and preferences differed between the levels of mobility.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *interaction styles, evaluation/methodology.*

General Terms
Performance, Design, Experimentation, Human Factors.

Keywords
Mobile device, handheld, PDA, input, scrolling, navigating, field study, evaluation.

1. INTRODUCTION
Mobile devices, such as handhelds or personal digital assistants (PDAs), provide convenient access to information virtually anywhere, anytime. The small screen and limited input capabilities however, impact users' interactions with these devices. This is further complicated by the very nature of these devices – their mobility. Mobile devices are often used in dynamic, noisy environments, and users may be moving (i.e. walking or in a vehicle). This makes designing interaction techniques for mobile devices challenging, and classical approaches used on desktops may not always be appropriate.

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For example, [3] conducted a field study to examine how location-aware computing affected user rendezvousing behavior. In this experiment, participants used maps on handheld devices. The tap-and-drag interaction technique was used to navigate the maps in this study because the researchers believed this technique would be superior to scrollbars for mobile activities. However, after completing the experiment, many participants commented that they would have preferred to have used scrollbars to navigate the map.

These unexpected user comments demonstrate how important it is that we fully appreciated the environments in which these devices will be used, and the types of activities that will be performed. In particular, some interaction techniques can be very sensitive to movement or the reduced cognitive attention which can exist when users are mobile or distracted. It is, therefore, important that mobile devices not only be designed from this perspective, but are also evaluated in a manner that is consistent with the true mobility of these devices. It is in this context, that we designed a field study to further explore this issue of mobility and how it impacts the user interaction with the device. There are two main objectives of this research. First, we wanted to compare two common navigation techniques (scrollbars and tap-and-drag) used on mobile devices with a new interaction technique called '*Touch-n-Go*' [4]. Second, we wanted to investigate the effect (if any) that different levels of mobility have on users' level of performance and preference when using each of these navigation techniques.

This paper presents the results from our field study where participants performed simple lookup tasks using three different navigation techniques for three levels of mobility. We first present work related to input interactions for mobile devices and the usability challenges for evaluating interactions on these devices. We then introduce the methodology for the field experiment, concluding with the results and discussion of the findings.

2. BACKGROUND
2.1 Input Styles for Mobile Devices
Providing appropriate input on mobile devices is a major challenge. Many tasks such as text entry, target selection, and navigating information spaces are challenging. Input approaches can be classified into three broad categories: hardware, software and hybrid. Hardware-based input utilizes physical components on the device, which are external to the actual application and may be add-ons to the device. Software-based input methods are built into the actual application such as software buttons or scrollbars. Hybrid input choices combine hardware and software input techniques.

2.1.1 Hardware-based Input

Most mobile devices have hardware accessories that can be used to provide different types of input. For example, buttons can be programmed to be the "home" button and a scroll wheel can be used to scroll vertically through a document. In 1996, Rekimoto [22] introduced the idea of navigating on a mobile device by using the device itself and added a sensor that could detect tilt angles and rotations when the user moved the device. The use of tilt for navigation and selection tasks [1, 5, 6, 8, 9, 22, 24] and for text input on mobile devices [19, 25] has been extensively explored. In addition, researchers have also explored the use of tilt in conjunction with other external inputs such as buttons [19, 24], gestures [1], and other sensors [8]. Other hardware-based inputs include NaviPoint [11] and ScrollPad [7].

A key advantage of many hardware-based interaction techniques is that they can provide one-handed interaction. This is particularly appealing when users are mobile. Disadvantages of this approach include display issues when the device is tilted at certain angles [1, 5, 6, 8] and difficulties related to overshooting targets [5, 8].

2.1.2 Software-based Input

Software-based input typically uses a stylus or finger on a touch sensitive display. For navigating an information space, the most commonly used technique is software-based scrollbars. Although this technique is familiar to users, scrollbar techniques have limitations on the desktop [11, 27] and when used on the mobile device may be even more challenging [11]. [27] identified three ways that users interact with scrollbars and possible issues with each approach. Users can drag the handle or "thumb" down the length of the scrollbar by maintaining continual pressure on the mouse button. This can be difficult and can result in *skipping* [23] caused by users unintentionally letting go of the thumb on the scrollbar and when they reselect the thumb they skipped part of the document. On a mobile device this problem could potentially be more problematic due to the smaller widget size. Second, users can click (or hold) on the arrows at each end of the scrollbar to move the documents which can be slow. Navigating a long document on the mobile device by continually clicking or holding the small arrows on the scrollbars would be tiring. Users can also click on positions in the scrollbar to jump to a new location in the information space but this can be disorienting [5, 27], which is compounded on a mobile device with less visual space to help orient users. In general, the use of scrollbars requires the user to shift their attention from the displayed information to the scrollbar, which may require perceptual and cognitive effort and additional motor resources [9, 27] that may be more problematic if the user is mobile. Additionally, scrollbars only provide movement in one direction at a time (vertical or horizontal) and take up screen real estate, which is already limited on mobile devices.

Another software-based method for navigating information on a mobile device is *tap-and-drag*. This technique requires the user to tap the screen with their stylus and pull the document across the display area in any direction. Again, this is a familiar form of input used in desktop applications. Johnson [10] compared different drag techniques with edge navigation (scrolling information while the stylus is at the edge of the screen) on a touch screen and found that users were faster and preferred using drag to navigate. One major disadvantage to dragging is that it is not suitable for documents that contain many selection targets, without some way to determine when the user's input is a target selection versus information navigation. As well, dragging is limited by the size of the screen as the user can only drag the document in increments that are the size of the screen [11]. This can be tedious for long or particularly large information spaces.

Research has also been conducted using gestures on touch screens. For example, Harrison et al. [8] used finger gestures to mimic turning pages of a book in order to move through a digital document. Pirhonen et al. [20] added gestures to the iPAQ MP3 player that allowed users to use their thumbs to input commands. Lumdsen and Brewster [15] and Lumdsen and Gammell [16] examined the use of gestures for mobile device input. DuelTouch [18] combined touch and stylus gestures as a two handed input technique to perform actions such as scrolling (with the stylus) and rotating maps (with the thumb). The Radial Scroll tool [23] for touch screen devices uses a gesture based scrolling technique that supports two dimensional smooth scrolling. Users move the stylus in circular motion over radial lines advancing the document. Radial scroll performed better than scrollbars for navigating short distance, although, scrollbars were better for longer distances.

The advantages to software-based input are that the input method is built into the application itself and can be designed to use paradigms familiar to desktop applications. The main disadvantage is that these inputs often require both hands to provide input. Sometimes, however, users may prefer to have one hand hold the device steady to avoid missing information or a target when interacting with the device with the other hand. In [5], users noted that they would prefer having touch screen zooming over tilt based zooming for certain tasks or multitasking.

2.1.3 Hybrid-based Input

Hybrid-based input combines the use of external hardware-based input with software-based input. Usually this involves using the hand holding the device to navigate or scroll the space (e.g. tilt) and to use the free hand to make selections. For example, Peephole displays [26] use a spatially aware device that can be moved around to reveal different parts of an information space while making selections with a stylus. Eslambolchilar and Murray-Smith [5] and Eslambolchilar et al. [6] coupled a SDAZ (Speed Dependent Automatic Zooming) system with tilt to navigate and scroll through information while using a stylus to perform the selection. When compared to traditional scroll and zoom using only the stylus, users preferred the coupled option [5].

Interaction techniques for mobile devices all face the common challenge of needing to be used effectively while mobile. In general, it is difficult for users to navigate *and* select items while mobile, regardless of which input approach they use. Research has shown that the use of tactile [21] or audio feedback [2, 6, 15, 16, 20] can improve users' accuracy and efficiency when performing navigation and selection tasks.

2.2 Challenges of Testing Mobile Devices

There are definite advantages and disadvantages in deciding whether to test applications in a managed laboratory experiment or a more realistic field study. Laboratory settings offer a controlled environment where all participants are subject to the same conditions and data collection is often straightforward [17]; however the setting is artificial and the user's motivation and responses may not be reflective of real life use of the application. A field study (or some variation) provides a more realistic setting that is usually a closer representation of how and when an application may be used, although, it is much more difficult to control since the environment can be dynamic, noisy and filled with interruptions [17]. For these same reasons, it can often be difficult to capture data in an unobtrusive or consistent manner.

For evaluating some desktop applications, a laboratory setting could be designed to represent a realistic setting but, it is difficult to devise a realistic laboratory setting to evaluate mobile device applications since the device is often used in a dynamic and often busy environment, and the user may actually be moving. In addition, data collection during a field evaluation of mobile devices is very challenging. In recognition of these challenges, some researchers have performed usability tests in the laboratory while trying to establish some elements of the real world [2, 13, 14, 15, 16]. For example, Lumdsen and Brewster [15] and Lumdsen and Gammell [16] set up a walking course in a laboratory and had participants walk through the course while using the handheld device. They acknowledged that having users test the mobile device while walking was more realistic than sitting in a laboratory but wanted control over testing data and conditions.

In 2003, Kjeldstov and Graham [12] conducted a large survey of mobile research. The results indicated that only 41% of the mobile research surveyed conducted an evaluation, with 71% of these being laboratory evaluations and 19% being field experiments. Although mobility can be added to a laboratory setting to provide more realism, it may still lack realism and produce different results [2]. Kjeldskov and Stage [14] explored the potential of simulating mobility in a laboratory experiment. This research compared the results of five laboratory experiments of varying levels of mobility (sitting, walking on a treadmill at constant and varying speeds, and walking at a constant and varying speed in a changing course) while using a mobile device and a field study of users with mobile devices walking on a pedestrian street. They evaluated the different experiments by measuring usability, performance and workload. It is interesting to note that none of the experimental setups identified all the usability problems and there were no significant differences found in terms of task completion times. In addition, no differences were found between sitting and walking at a constant speed, although walking at varying speeds was different than sitting.

In other work, Kjeldskov et al. [13] compared four evaluation approaches (field, laboratory, heuristic walkthrough, and rapid reflection), to identify usability problems when testing a mobile guide. They found that each technique had its own advantages and suggested that researchers may want to utilize multiple methods.

The work of Brewster [2] and Kjeldskov et al. [13] stress that further research is needed to better understand when laboratory experiments or field studies should be utilized to assess mobile applications. The goal of the study reported in this paper is to determine whether levels of mobility affect user performance and preferences on a focused interaction style.

3. MOBILE NAVIGATION STUDY

3.1 Study Design

A 3 (navigation techniques) x 3 (mobility conditions) within subjects field experiment was conducted to explore software-based navigation techniques for use in mobile environments. Participants used three different software-based screen navigation techniques: scrollbars, tap-and-drag, and touch-n-go. The scrollbars and tap-and-drag techniques are common approaches used on desktops and mobile devices. The touch-n-go technique is a new interaction style we developed for multi-directional navigation. These three techniques were examined during three different mobility levels; sitting, walking while stopping to interact with the device, and continuous walking. Our hypothesis was that there would be a difference in user performance and preference between the three navigation techniques and that there would also be differences based on the three mobility levels.

3.2 Participants

Eighteen, right-handed university students (14 male, 4 female) were recruited to participate in the study. Six of the participants had previous experience using a handheld device.

3.3 Tasks

The task was designed to simulate searching a large information space for a specific target (such as finding a city on a map). Participants were required to navigate through the space to select a solid black circle on a page of hollow circles (Figure 1). The page was 800 pixels wide by 1040 pixels high and approximately 1/9th of the page could be viewed on the display.

Because we wanted to directly compare navigation times across techniques, it was important that participants know which direction they needed to move in order to reveal the target circle. Without this, the task times would be confounded by the time to perform the visual search (and also would have significantly impacted participants' search paths). Therefore, a compass type indicator was put in the centre of the screen to guide participants in the direction of the solid black target circle (Figure 1).

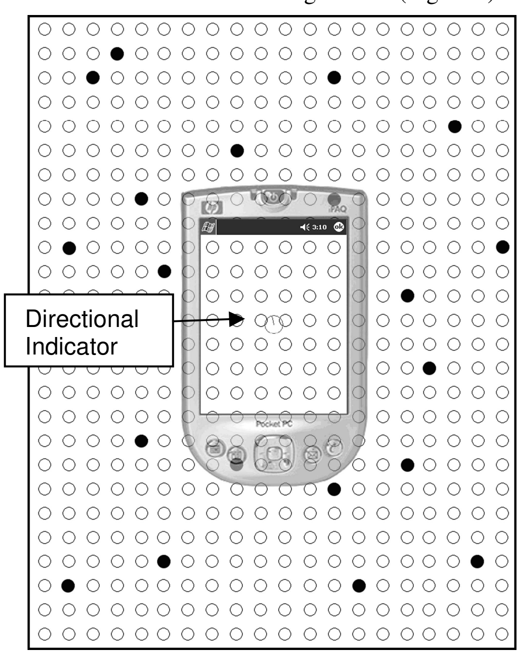


Figure 1. Page of circles with the directional indicator. All 20 targets used in the study are shown on this page. During the experimental tasks, only one target (black filled circle) was visible at a time.

Twenty random locations were selected from the page of 520 circles (20 x 26 circles) as the target locations (Figure 1). Participants were required to perform 40 navigation tasks per navigation technique, selecting each of the 20 targets twice. The ordering of the solid black circles was random to ensure that participants could not anticipate the location of the next circle.

A navigation task consists of first clicking a 'Start' button located in the centre of the screen then locating and selecting the solid black target circle. The screen defaulted to the centre of the page at the beginning of each task. Once the 'Start' button was clicked it disappeared and only reappeared after the solid black circle was successfully selected. Participants continued to locate and select target circles until all 40 navigation tasks had been completed.

3.4 Navigation Techniques

3.4.1 Scroll Bars

Standard vertical and horizontal scroll bars were placed on the screen to navigate the large page of circles (Figure 2a). The vertical scroll bar was placed on the right side of the screen and the horizontal scroll bar was placed on the bottom of the screen.

3.4.2 Tap-and-Drag

The tap-and-drag technique provided participants with the ability to tap anywhere on the screen and then drag the stylus in the direction they want to move the page of circles (Figure 2b). Continuous pressure on the screen was required for the page to be dragged.

3.4.3 Touch-n-Go

The Touch-n-Go [4] technique incorporated two parameters: direction and speed. Direction was determined by where participants touched the screen, relative to the centre (Figure 2c). This caused the page of circles to move in the corresponding direction. The page continued to move as long as contact with the screen was maintained. Speed was determined by how close to the centre the participants touched the screen. Speed could be adjusted dynamically by moving the stylus while on the screen relative to the screen centre. Closer to the centre moved the page slower, while farther from the centre (close to the edge of the screen) moved the page faster.

3.5 Mobility Conditions

3.5.1 Sitting ('Sit')

Participants were instructed to sit while performing the navigation techniques. They were not allowed to rest the handheld computer or their arms on the table.

3.5.2 Walking with Stopping ('Stand')

Participants were instructed that they were required to walk but then stop and stand still when they were performing the navigation task. Five navigation tasks were performed at a time, followed by a random amount of walk time (between 5 and 15 seconds). The mobile device beeped and vibrated when it was time to stop and perform a series of navigation tasks. The participants then stood still and performed another five navigation tasks. This continued until the session was complete.

3.5.3 Continuous Walking ('Walk')

Participants were instructed to walk continuously while performing the navigation techniques. They did not stop walking till the session was completed. The walking pace and the path they chose were not controlled, however, participants were instructed to try and maintain a constant pace for all techniques.

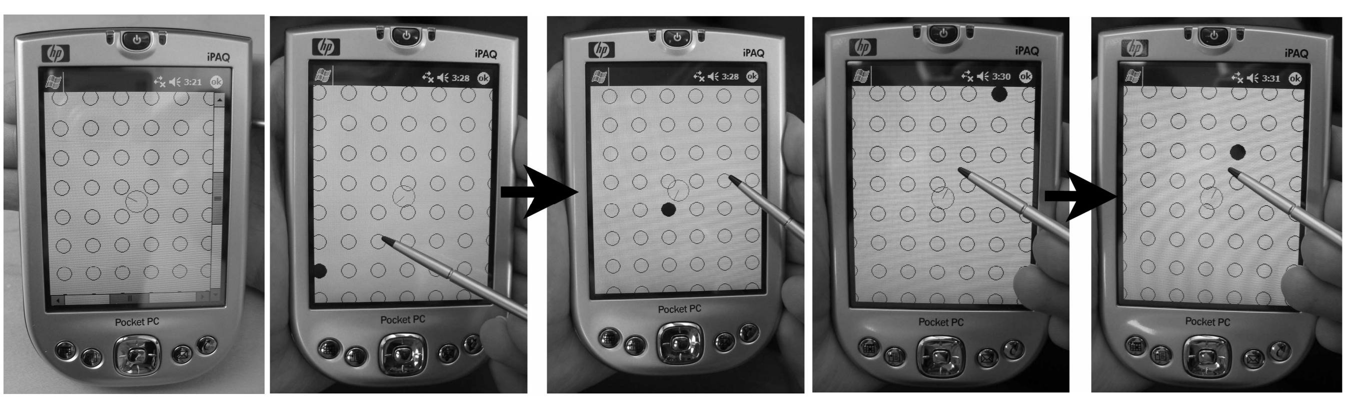
3.6 Equipment and Location

Participants used an HP iPAQ h4100 Pocket PC and stylus for all input techniques for each mobility condition. The experiment took place in the lower level of Dalhousie University's Computer Science Building, which is a common meeting place for students and faculty. A coffee shop is located at one end of the area and a kitchen area equipped with microwaves is at the other end. Couches and coffee tables are available throughout the space as well as tables and chairs. To ensure that participants would be exposed to similar levels of noise and congestion in the area, all testing took place during the busiest times of the day (11:00 a.m. to 4:00 p.m.).

3.7 Procedure

The ordering of the mobility conditions (sit, walk, and stand) and navigation techniques (scrollbar, tap-and-drag, and touch-n-go) were counterbalanced across participants; however, for each participant, the order of navigation technique was consistent across mobility conditions.

Each participant first signed a consent form and was given a brief explanation of the three navigation techniques and the three mobility conditions. Participants were required to complete three sessions: one session for each mobility condition. During each session the participant used all three navigation techniques. Prior



(a) Scrollbars **(b) Tap-and-Drag** **(c) Touch-n-Go**

Figure 2. Navigation Techniques

to the first use of each navigation technique, the participant was given a demonstration of how to use the technique to locate and select the solid black circle. Scrolling behavior was not restricted. The participant was free to use any of the navigation techniques in a manner that was comfortable to them. The participant performed three training trials for each technique, ensuring they understood how to use each technique. Additionally, prior to each session a thorough description of the mobility condition was given. Upon completion of each of the three sessions a post-condition questionnaire was administered that asked participants to rate each navigation technique according to ease and preference for the specific mobility condition just completed. At the end of the experiment, the participants were asked to complete a background and post-experiment questionnaire.

4. RESULTS

4.1 Timing Data

Data logging was used to capture detailed timing data. Target selection times were used as the main performance metric to determine navigation efficiency. Target selection times were calculated from the time the participant selected the *start* button until they clicked on the target. All outliers, (trials whose time exceeded 3 SD above the mean), were removed from the data set (approximately 1% of trials). The average target time was computed for the two repeated trials for each target and selection times for all targets were then averaged to provide an overall target selection time for each condition.

Target selection time data were analyzed using a 3 (navigation techniques) x 3 (mobility conditions) repeated measures analysis of variance (ANOVA), employing the Huynh-Feldt correction when the sphericity assumption was violated. Table 1 shows the average target selection times.

Table 1. Mean and standard deviations for target selection times for the three mobility conditions and three navigation techniques.

	Sit M (SD)	Stand M (SD)	Walk M (SD)	Avg. M (SD)
Scrollbar	3955 ms (499)	3996 ms (658)	4229 ms (470)	4059 ms (542)
Tap-and-Drag	3082 ms (470)	3193 ms (706)	3504 ms (1223)	3260 ms (800)
Touch-n-Go	3297 ms (323)	3408 ms (400)	3597 ms (557)	3433 ms (427)
Avg.	3445 ms (431)	3532 ms (588)	3777 ms (750)	3585 ms (590)

A significant main effect of navigation technique was found across the three experimental conditions, $F(2,34)=26.163$, $p<.001$, partial $\eta^2=.606$. Further pair-wise comparisons revealed that the scrollbar technique was significantly slower than both the tap-and-drag and the touch-n-go techniques ($p<.001$ for both). No significant difference was found between the tap-and-drag and touch-n-go techniques ($p=.196$).

A significant main effect of mobility condition was found across the three experimental conditions, $F(2,34)=3.51$, $p=.041$, partial $\eta^2=.171$. Pair-wise comparisons revealed that participants performed the target selections faster when sitting then when walking ($p=.032$). No other pair-wise comparisons revealed significant differences.

No significant interaction effect was found between navigation technique and mobility condition, $F(4,68)=0.38$, $p=.719$, partial $\eta^2=.022$.

4.2 Questionnaire Data

Background questionnaires collected handedness information and computer and handheld usage history. At the end of each mobility condition, participants were asked to rank (from 1=best to 3=worst) each navigation technique in terms of ease of use and preference. Participants were also asked to rate each navigation technique on a scale of 1-5 (1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Agree Strongly) based on how easy they felt the technique was to use. Both the ranking data and the ease-of-use ratings were analyzed using Friedman two-way ANOVAs. Post-hoc pairwise comparisons were made using Wilcoxon Signed Ranks Tests with a Bonferroni adjustment ($\alpha=.017$). The mean ranks are summarized in Table 2. The mean ease-of-use ratings are shown in Table 3.

4.2.1 Navigation Technique Ranking

Regardless of whether participants were sitting, standing, or walking, significant differences were found between the navigation techniques in terms of ease of use ($\chi^2=20.11$, $p<.001$, $\chi^2=22.11$, $p<.001$, and $\chi^2=23.44$, $p<.001$ respectively). Pairwise comparisons further revealed that the scrollbar technique was always ranked significantly lower than the other two techniques ($p<.005$). No significant pairwise differences were found between the tap-and-drag and touch-n-go techniques when participants were sitting or standing but participants did feel that the touch-n-go technique was significantly easier when walking ($p=.012$).

Again, regardless of whether participants were sitting, standing, or walking, significant differences were found for which techniques participants preferred ($\chi^2=16.33$, $p<.001$, $\chi^2=24.11$, $p<.001$, and $\chi^2=20.33$, $p<.001$ respectively). Pairwise comparisons further revealed that the scrollbar technique was always ranked (from 1=best to 3=worst) significantly lower than the other two techniques ($p<.015$). No significant preference differences were found between the tap-and-drag and touch-n-go techniques for any of the mobility conditions.

Table 2. Results of participant rankings (from 1=best to 3=worst) of ease of use and preference for navigation technique and each mobility condition (mean ranks).

	Ease of Use			Preference		
	Sit	Stand	Walk	Sit	Stand	Walk
Scrollbar	2.83	2.83	2.83	2.72	2.78	2.89
Tap-and-Drag	1.78	1.89	1.94	1.89	1.94	1.83
Touch-n-Go	1.39	1.28	1.22	1.39	1.28	1.28
p	<.001	<.001	<.001	<.001	<.001	<.001

4.2.2 *Ease of Use Rating*

Again, regardless of whether participants were sitting, standing, or walking, significant differences were found between the navigation techniques in terms of the ease of use ratings (χ^2=18.56, p<.001, χ^2=25.24, p<.001, and χ^2=19.344, p<.001 respectively). Pairwise comparisons further revealed significant differences between the mean ratings for all navigation techniques when participants were standing or walking, with touch-n-go being the easiest, followed by tap-and-drag, and scrollbar being significantly less easy to use (p<.17). When participants were sitting, the only significant pairwise comparison was that the touch-n-go technique was rated significantly easier than the scrollbar technique (p<.001).

Table 3. Mean ease-of-use ratings for each of navigation techniques on a scale of 1-5 (1-Strongly Disagree; 5-Strongly Agree) for each mobility condition.

	Ease of Use Ratings		
	Sit M (SD)	Stand M (SD)	Walk M (SD)
Scrollbar	3.33 (.84)	3.06 (.80)	2.72 (1.18)
Tap-and-Drag	4.00 (.97)	4.17 (.92)	3.89 (.96)
Touch-n-Go	4.72 (.46)	4.78 (.43)	4.67 (.59)
p	<.001	<.001	<.001

4.3 Participant Comments

In the post-experiment questionnaire, participants were asked to comment on what they liked and disliked about each navigation technique.

Seven participants commented that they liked the familiarity of the scrollbars. Three participants felt that the scrollbars took them directly to the black circle while two commented that they did not like anything about using scrollbars. Ten participants said they disliked the two-dimensional scrolling (moving horizontally and vertically separately) and five found the scrollbars to be slow. Other dislikes included that the scrollbars were not easy to use, inconvenient, and that they were difficult to use when moving.

Eight participants liked tap-and-drag because it was fast and there were eight comments that it was easy. Other comments included that they liked being able to control the speed of scrolling and that they could navigate in any direction. Still, five participants said they disliked having to lift the stylus off the screen to scroll. Three found it hard to learn and another three commented that tap-and-drag required a lot of work.

For the touch-n-go technique, nine participants said it was fast and nine commented that it was easy to use. Six noted that there was less stylus usage required and six said they preferred this technique. Other comments included that they liked it when walking and it was direct. Eight participants noted they did not dislike anything about touch-n-go. Five commented that they sometimes found it hard to control (too fast). Two participants noted they overshot the target and two noticed that the stylus obstructed the view of the target circle at times.

5. DISCUSSION

The results of this study support our hypothesis that there would be significant differences in user performance and preference between the three navigation techniques. First, the scrollbar technique was found to be worse on all measures compared to the tap-and-drag and the touch-n-go techniques. In particular, participants were slower using the scrollbar technique and the majority ranked it last in terms of ease of use (15/18) and preference depending on the mobility condition (13-16/18). These results were consistent across all three activity states. The results for the remaining two techniques – tap-and-drag and touch-n-go – were comparable on most measures. The only significant difference came from the ease-of-use results where participants felt that touch-n-go was easier when walking than either the scrollbar or the tap-and-drag technique.

Although statistically significant differences were found between the navigation techniques, it is also important to reflect on the practical significance of the results. First, the actual time difference between the scrollbars and the other two techniques ranged from 626ms to 799ms (less than 1 second). This is arguably a very small time difference and may not warrant redesigning software to incorporate one of the faster techniques (although this difference did account for approximately 18% of the selection time). However, the fact that most users preferred the tap-and-drag and touch-n-go techniques and felt that these techniques were easier to use is a compelling argument for adoption of one of these techniques.

Our second hypothesis was that significant differences would be found between the three levels of mobility. The overall timing data indicated a significant difference between the mobility conditions, with sitting being the fastest followed by standing and then by walking. However, the practical significance of this result was exceptionally small (88ms to 332ms, approximately 6% of the selection time). The remaining data (ease-of-use and preference) did not demonstrate significant differences between the mobility levels.

Reflecting on the results as a whole, of the three navigation techniques examine, the touch-n-go technique is likely the best choice for navigation on small devices, particularly if mobility is important. The touch-n-go technique was comparable to the tap-and-drag technique, but was rated highest for ease-of-use (in all mobility levels) and was preferred by most participants in the walking condition (14/18).

6. CONCLUSION AND FUTURE WORK

We had two main goals for this research. First we wanted to compare common software-based navigation techniques with our new touch-n-go approach on a mobile device. Second, we were interested in determining if a user's level of mobility affected their performance on the mobile device.

Overall, we found that the techniques of touch-n-go and tap-and-drag outperformed the traditional scrollbar technique for the simple navigation tasks. In terms of preference, users indicated that they found touch-n-go easier than the other two techniques during all levels of mobility and often ranked touch-n-go higher for ease and preference during the different levels of mobility.

Although the trend was similar between the different navigation techniques (i.e. no navigation technique x mobility condition interaction effect) for each of the mobility conditions of sit, walk and stand, we cannot conclude that usability testing of mobile devices can be done at the lowest level of mobility. While not significant, a difference in performance was observed between each condition. Participants performed the tasks faster while sitting and were slower while walking for all of the navigation techniques. Our testing was performed using a task that was not cognitively demanding. We speculate that a more complex task may impact the results found in this experiment. With a more complex task user performance may significantly change across mobility levels.

In the future, we will expand on the results found in this study by comparing touch-n-go with hardware-based input techniques. In particularly we plan to compare touch-n-go to the tilt technique for navigation tasks. We also plan to continue our evaluation with different levels of mobility for more realistic and cognitively demanding tasks. Finally, we would like to explore the issue of navigating while mobile in a more realistic longitudinal study.

7. ACKNOWLEDGMENTS

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