# Scrolling and pagination for within document searching: The impact of screen size and interaction style

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**ABSTRACT**
Increasingly, users are performing more sophisticated types of tasks, like web browsing and particularly information search, across computing platforms including desktops/laptops, tablets, and smartphones. While much research has been done to improve efficiency for each of these devices in the area of information search, no investigations have taken a pragmatic approach to determining the real efficiency costs across current state of the art devices and typical browser-based searching paradigms. We examine comparative task execution times for within document searching tasks under three different conditions: varying screen sizes (desktop, tablet, smartphone), varying interaction devices (mouse & keyboard and touchscreen) and varying interaction techniques (scrolling and pagination). In addition, we examine components of the task: scanning, skimming and raiding and combine reading rates and KLM measures to try to predict task execution time.

**Keywords**
mobile device, smartphone, tablet, desktop computer, within document search, information search

**INTRODUCTION**
Increasingly, users own and operate multiple computing devices. Typically, these devices have different form factors including different screen sizes and interaction devices/techniques. Switching between these devices to perform the majority of tasks has been considered costly in terms of efficiency and usability for some types of tasks. Only under certain circumstances, like being in a mobile context, would the typical user try to perform a complex task on a mobile device in the same manner as they would at the desktop. The smaller the device, the smaller the keyboard and screen for input and output interaction. Until recently, this difference was considered significant enough to relegate use of small scale devices to only certain types of tasks, particularly communications and personal information management tasks like calendaring, managing contacts and email. As the small screens on these devices have improved and more intuitive forms of interaction, like touch screens and multi-touch, have been perfected, the high overhead for using these devices for tasks more similar



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A.

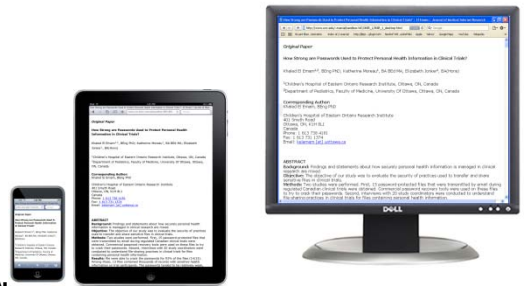
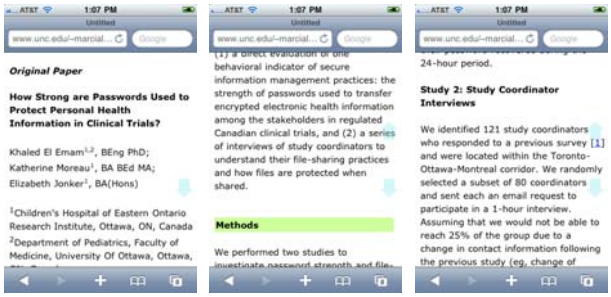


**Figure 1A: Same Content Presented on the three devices tested in the study.**

B.

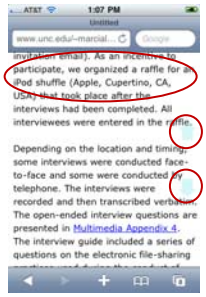



**Upper Left:** start of document. User begins scanning for main heading.

**Upper Middle:** user pages through document by tapping on arrows until they find "Methods" section.

**Upper Right:** User pages, skimming, until they locate the subsection "Study Coordinator Interviews"

**Lower Right:** User pages, rauding, until they find the answer text.



**1B:Example screens showing interaction sequence for user searching task using paging interface on the iPod.**

to those performed in the 'gold standard' desktop environment has decreased.

### Research Aims

**RQ:** To what extent is within document searching typical of the desktop environment inhibited by display size and/or interaction style?

> **RQ1:** How do display size, interaction technique and task complexity affect task execution time?
>
> **RQ2:** How do display size, interaction technique and task complexity affect task load?
>
> **RQ3:** How do display size, interaction technique and task complexity affect usability?
>
> **RQ4:** Can a predictive model based on reading rates (Carver) and KLM measures (Card, Moran and Newell) be constructed and fit to accurately predict task execution times?

Because efficiencies of use can be weighed pragmatically and can be scaled, it is important to evaluate the differences in efficiency cost between 'state of the art' devices, particularly for fundamental information searching tasks. One important type of these tasks is within document searching. What is the efficiency cost to perform a similar within document searching task on a smartphone (iPod Touch) versus a tablet (iPad) versus a desktop (gold standard)? See sample task in Figure 1. Under what circumstances might they become even more commensurate?

It remains the case that the vast majority of electronic content is still primarily available through browsers in a format designed for the desktop environment. Increasingly, users are looking for ways to access this information across platforms of varying display size and interaction technique. It is therefore important to examine differences in task execution time for typical within document searching behavior across these conditions

## BACKGROUND

As small form factor devices become ubiquitous, specialized applications that leverage the resident featureset of these devices have increased. Although they offer sometimes significant improvements in usability, specialized applications can be associated with other types of usability 'overhead' like application and library management as well as novel interaction. Browsers appear to still be an important choice, even for smartphone users, because they are consistent across platforms, leveraging much of the resident featureset of each device. They are increasingly customizable, standardized portals for serving up content.

Much work has been done in the area of interaction techniques to compensate for small screen size on mobile devices. While the desktop remains the gold standard for most tasks due to display size and interaction style, new devices with touch interaction and high quality small (or smaller) displays make performing tasks typically relegated to the desktop achievable for the first time. Coupled with improved processing speeds and shorter latency times, users are increasingly attempting to perform searching tasks similar to those done at the desktop on a variety of smaller form factor devices, particularly smartphones. In fact, this is considered to be one of the fastest growing areas of computing development currently. Little research has been done to date comparing execution times for within document searching tasks across devices of differing display sizes and interaction techniques.

Prior research indicates that paging may be more efficient and may be preferred to scrolling while searching for information within documents of a certain length (Piolat, Roussey and Thunin, 1997). Indeed, when a document is very long, fewer interactions are required to 'page' through the document than to scroll through it. Drawing from our 'gold standard' interaction for reading, sitting down with a book, many e-reading tools employ paging as the primary form of interaction. As content has migrated away from print versions to electronic resources, the 'book' paradigm has not always been maintained. Much content now exists in native .html format where the dominant interaction paradigm for reading is scrolling.

Some research has demonstrated that new paradigms can be introduced to overcome efficiencies lost due to small screen size (Chittaro, 2006). Some researchers have identified issues with inconsistencies around desktop web-based interaction versus mobile web-based interaction which make transitioning across these devices more difficult (Keinänen, 2011 and Shrestha, 2007). Recent work on paging versus scrolling on the desktop (Baker, 2003, Bernard, Baker and Fernandez, 2003, Eyuboglu and Orhan, 2011, Grace, 2005, Kim and Albers, 2001, Peytchev, Coupe, McCabe and Crawford, 2006 and Santosa, 2011) suggests that no statistically significant difference exists between the two interaction techniques for within document searching. The work of Santosa (2010) found that differences do exist for 'textbook' style interaction (less preferred). Eyuboglu and Orhan (2011) investigated the impact of cognitive style combined with paging or scrolling on achievement and satisfaction and found no statistically significant differences. Sanchez and Wiley (2009) found that paging had a positive effect on cognitive ability (and conversely, scrolling can have a negative one) under certain conditions for lower working memory capacity readers.

For small screen displays, interaction technique is a pivotal factor in the searching experience (Church and Smyth, 2009 Kamvar, Kellar, Patel and Xu, 2009 and Wobbrock, Forlizzi, Hudson and Myers, 2002). Kim and Albers (2001) suggest that regardless of screen size or interaction technique, certain tasks can be performed at the same level of accuracy. In their study on scrolling versus paging using

| First Device | Second Device | Third Device |
|---|---|---|
| Training for interaction technique | Training for interaction technique | Training for interaction technique |
| Testing (4-5 accurate trials) | Testing (4-5 accurate trials) | Testing (4-5 accurate trials) |
| NASA TLX | NASA TLX | NASA TLX |
| Training for interaction technique | Training for interaction technique | Training for interaction technique |
| Testing (4-5 accurate trials) | Testing (4-5 accurate trials) | Testing (4-5 accurate trials) |
| NASA TLX | NASA TLX | NASA TLX |
| **Usability Survey (one final comparative survey at the end of testing)** | | |

**Table 1. Schedule for a single participant (down a column, then on to the next column)**

mobile devices compared with a desktop computer, no significant difference was found between paging and

scrolling on either the small or large device in terms of accuracy. There were, however, differences in time to complete the task with a break point at about 225-350 word-lengths.

In 1992, Carver published a seminal work on reading rate and described a set of 5 reading 'gears' as he called them. Reading gears 5, 4 and 3 are scanning (find a target word), skimming (find transposed words) and rauding (combination of reading and auding; comprehend complete thoughts in sentences), respectively. Typical college undergraduate reading rates for these processes can be used in conjunction with Card Moran and Newell's Keystroke Level Model predictive values to generate possible models for within document task execution time.

## METHODS

Our primary aim is to determine the extent to which within document searching typical of the desktop environment is inhibited by display size and/or interaction style. We review experimental tasks performed by participants using an Apple iPod, Apple iPad and a desktop system in a laboratory environment. Interaction is constrained to right hand only and the devices are fixed to a tabletop surface. Participants are trained to perform each task. Repeated measures of similar within document searching tasks (see Figure 1) are video-recorded. Each participant completes tasks on each device (smartphone, tablet, and desktop computer) under each condition (scrolling, paging). Time to complete the search (task execution time) is recorded as the quantitative measure. Task load and usability of the devices are the qualitative measures taken via a post task NASA Task Load Index survey and a post-study survey/semi-structured interview combined with review of video recorded observations. Expert performance is presumed and error trials are discarded for evaluation.

To facilitate the study, journal articles of roughly equal length and format have been selected and related tasks have been created for each document. The Safari browser is used to access the relevant .html files from each device. Support of the scrolling condition is embedded in the browser, the .html pages have been simplified to only allow this interaction. For the paging condition, a simple simple Javascript application was built to handle this interaction, constraining all other types of interaction (e.g. pinch/expand). Format of the pages is tailored to each device within the .html but otherwise does not use any native functionality of the devices.

This is a within subjects design (~24 college students >18 yo, prior experience with touchscreens required) where the three device conditions are counterbalanced for presentation order and each interaction technique is treated independently. Because the within document searching task is repeated (each repeat unique), task blocks (of 5) are also counterbalanced. Task blocks are balanced on overall interaction time (position in document, word count to each heading, subheading and task response) and counterbalanced across participants.

## RESULTS

Task execution times with five repetitions for each device-interaction condition (6) yield 30 task execution times for each participant (24). All participants perform the same task blocks under counterbalanced combinations to allow for comparisons using repeated measures ANOVA.

Our quantitative results include:

- Task execution times for each device-interaction combination for similar within document searching tasks

Our qualitative results include:

- Task load measures for each task block (device-interaction condition)
- Comparative usability assessment across all devices and conditions.
- Semi-structured interview details to assess factors not addressed by the task load index or the usability questionnaire.

Our results address the following hypotheses for task execution time:

- longer when display size is smaller
- not significantly different for devices of similar display size (desktop and tablet)
- not significantly affected (positively or negatively) by interaction technique
- not significantly different when the interaction technique is limited to paging or limited to scrolling, regardless of display size

Task load:

- significantly correlated with task complexity

- significantly correlated with screen size

Usability:

- no significant relationship to task execution time
- not significantly correlated with screen size
- not significantly correlated with interaction device
- not significantly correlated with interaction technique

## CONCLUSION

Our aim is to inform current practice on user efficiency across devices and future design in improving efficiency, paticularly on the small screen device. Measuring task execution time for similar tasks across devices offers a quantitative assessment of a critical component of success. Task load and usability may actually play a crucial role in performance, especially among novice users. Randomizing subjects to device presentation order, using balanced task blocks and providing training for each device-interaction combination controls for bias, experience and learning effects. Capturing video ensures the ability to achieve fine levels of granularity for total and component task execution time as well as qualitative information about usability. Expected results include:

- Whether scrolling or paging on any of the device-interaction combinations, task execution time is similar
- Task execution times between the desktop and smartphone and the tablet and smartphone are significantly different
- Differences in task execution time between the desktop and tablet are not significant
- Comparative usability between the devices is not be correlated with task execution time and that task load is correlated with task complexity and task execution time
- Design implications aimed at decreasing differences in efficiency.

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