# ASSESSING THE PERFORMANCE OF COMMON TASKS ON HANDHELD MOBILE COMPUTERS

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The goal of this study was to examine three interfaces for handheld mobile computing (HMC) on the iPhone and then assess against a standard personal computer (PC) interface. While designers originally envisioned similar performance between HMC and PC, our results indicate differences between these platforms. However, specialized mobile sites and applications (Apps) greatly enhanced HMC performance on the iPhone. In particular, mobile content that required larger amounts of data entry benefited much more from these sorts of interfaces than mobile content for data acquisition.

## INTRODUCTION

Research has shown the proliferation of handheld mobile technology across all ages, cultures, and socioeconomic levels (Pew, 2008; Townsend, 2002). The iPhone and similar technologies are changing the way we communicate and access information. Users can perform tasks on a mobile phone that once could only be accomplished on a personal computer (PC). The role of handheld mobile technology is changing from a platform to make phone calls to a platform used for texting, email, and internet-based tasks.

These changes have been seen in the adoption of handheld computing in various organizations (e.g., education, health care, & military). Students are using the iPhone to hear lectures and complete homework (McKinney, Dyck, & Luber, 2009). Health care professionals are using iPhone Applications (Apps) to monitor the stages of labor. Soldiers in the United States Army are using the iPhone to (among other things) collect, analyze, and distribute intelligence.

HMCs, like the iPhone, also have ubiquitous personal computing capabilities. Major services like Google, Wikipedia, and Amazon are widely accessible with wireless and network connections. Many Apps leverage location awareness to enhance these services. For example, numerous Apps help you find nearby restaurants based on your location. Users also have a pervasive capability to text, email, and stay in touch with friends through Facebook with their HMCs.

### Usability of Handheld Mobile Technology

The changes in the way mobile phones (i.e., HMCs) are being used in personal and professional settings have redefined the primary ways we interact with this technology. Fingers (or thumbs) have become the more frequently used input mechanism replacing voice (acknowledging that voice recognition capabilities are developing to compensate at some level). However, according to Nielsen (2009), mobile phone usability is poor for these sorts of tasks due to small screens, awkward text input, and long network times. Touch screens are becoming more widespread to address some of these usability issues. Yet, these screens give little to no tactile feedback. Typing with limited or no visibility is difficult as well.

Handheld computing devices also have smaller screens which detract from performance (Nielsen, 2009). Web designers are compensating by designing web-sites specifically for small screens. In addition, the iPhone employs a simple scroll method which makes reading large amounts of text easier and more intuitive.

The benefits of handheld computing include increased mobility, decreased cost, and innovative features not available on traditional PCs. Because of these benefits, more personal and professional computing tasks are being done on HMC. Some say HMCs will replace all computing in three years (Hardy, 2010).

This study examines the performance of six common tasks on HMCs. Specifically, we analyze the three main HMC interfaces (standard web pages, HMC optimized web pages, and application-based services) on an iPhone. Performance on each interface is also compared with the PC on these common tasks.

## METHOD

### Participants & Materials

Twenty-nine undergraduate students participated in this study. The average age of the students was 18.7 years. Each student received extra credit in exchange for their time. Students used iPhones they owned to complete the tasks. The majority (85%) owned their iPhone for over 6 months. PC-based tasks were completed on a Dell Computer using a 19-inch flat screen monitor.

### Procedure

When subjects arrived, they completed a survey assessing demographic information, experience levels with technology, and previous iPhone usage. Before they started completing tasks, we used a script to describe the nature of the tasks and how we would time the experiment.

A within-subjects design was used to compare completion times of six common tasks across four computing methods. The four computing methods consisted of the three iPhone interfaces and one Windows-based PC interface. The six common tasks included (1) reading two short paragraphs about a children's game on Wikipedia, (2) searching for information on Google, (3) searching for a product on Amazon, (4) registering for the New York Times, (5) composing and sending an IM or SMS text message, and (6) composing and sending an email.

The tasks were changed slightly for each iteration to address order effects. For example, subjects searched for 'baseball statistics' on the PC, but searched for 'football statistics' on the iPhone App. Additionally, the order of tasks was counterbalanced with a latin square design. Participants kept the task description (written in 20 pt. bolded Arial) in front of them until they finished.

The Google and Amazon tasks were structured to elicit a specific set of responses. The Google search task required subjects to type in google.com (no shortcuts were allowed), search for 'baseball statistics', scroll down to the bottom of the results, and select the last result. Similarly, the Amazon task was to type in amazon.com, search for 'princess bride', and select the final item in the search results. Once the final result was selected, we stopped the clock and recorded the time.

The other two internet-based tasks consisted of reading a large amount of information and entering text on a registration page. In the former, participants searched for a specific children's game in Wikipedia (e.g., forty forty), read the entire description, and answered two simple questions related to the game. We stopped timing when they said "ready" indicating they were ready to answer the questions. The questions were intentionally easy, but required subjects to read every word. Every subject but one answered the questions correctly.

The data entry task required subjects to register for the New York Times. On the registration page, participants had to answer questions by typing in personal information and selecting items in scroll bars. Each subject was given information to enter into the user identification and password blocks. No other constraints were put on the registration process; subjects used their personal information for every other item.

The email and texting/IM tasks allowed open-ended responses. On their iPhones, subjects were asked to compose an email, describe their room in three sentences, and send the completed message to a dedicated email address. On a PC, subjects were asked to do a similar task except describing a classroom (instead of their room) at Rice University. The platform the questions appeared on was counterbalanced across users. The time was stopped once they selected send. In both conditions, subjects used their own email accounts to control for experience.

Subjects also used their own SMS account for sending a text message on the iPhone. Subjects were asked to compose a message, answer what they had for breakfast that morning, and send it to a phone number we gave them.

## RESULTS

Network times were removed from overall completion times before statistical analysis (Table 1). In order to accomplish this, the authors performed the tasks used in this study over a period of three days at different times. The longest network times for each type of internet connection were recorded and subtracted from the respective completion times. Safari produced the longest network times on the 3G network.

We examined the results (Table 2) obtained from web-sites and communication (i.e., SMS/IM and emails) separately. First, we assessed the differences between the iPhone Mobile Sites accessed through Safari and PC Web-sites accessed through Internet Explorer. Second, Apps were compared to Mobile Sites. Third, the PC version of the web-sites on the iPhone were compared to the same sites on a PC. Finally, email and SMS completion times were compared between platforms.

Planned contrasts with Bonferroni adjustments for multiple comparisons were used to compare the PC condition to the Mobile Site and App (iPhone) conditions. The iPhone automatically loads the mobile version of the web-site for Google, Amazon, and Wikipedia. Thus, we did not include the regular (PC) versions of web-sites for the iPhone in our contrasts. As expected, the PC condition was reliably more efficient than the iPhone conditions in the Google search task ($t(28) = 8.63$, $p < .001$), Amazon search task ($t(28) = 6.92$, $p < .001$), and the Wikipedia reading task ($t(28) = 3.95$, $p < .001$).

**Table 1**. The amount of network time removed from each type of internet connection.

| Type of Internet Connection | Amount of Network Time Removed per HTTP Request |
|---|---|
| Internet Explorer (PC Ethernet) | 0.12 seconds |
| Apps (iPhone 3G) | 0.46 seconds |
| Safari (iPhone 3G) | 1.53 seconds |

**Table 2.** Mean completion times in seconds for each task as a function of computing method (standard deviations are in parentheses).

| | iPhone | | | PC |
|---|---|---|---|---|
| | **Safari on Mobile Site** | **App** | **Safari on Regular Site** | **Internet Explorer** |
| **Google** | 30.24 (8.31) | 38.59 (17.93) | 39.4 (10.98) | 18.19 (3.33) |
| **Amazon** | 31.86 (10.25) | 33.92 (11.31) | 67.13 (24.22) | 21.83 (3.09) |
| **Wikipedia** | 62.25 (33.41) | 59.14 (26.43) | 65.71 (24.92) | 47.64 (18.94) |
| **NY Times** | NA | NA | 131.12 (27.66) | 56.64 (11.83) |
| **Text/IM** | NA | 30.3 (13.15) | NA | 13.45 (5.66) |
| **E-mail** | NA | 61.25 (16.5) | NA | 54.55 (20.22) |

Planned contrasts were also performed to compare Apps with the mobile web-sites. No substantial differences were found between the Amazon App and the Amazon mobile web-site on Safari ($t(28) = 0.86$, $p = .40$). Similarly, no real differences were found between Wikipanion (iPhone App) and Wikipedia's mobile web-site ($t(28) = 0.58$, $p = .58$). It took considerably longer to perform a search on the App compared to the Google Mobile Web-Site ($t(28) = 2.83$, $p = .01$). This is likely because the Google Mobile App accessed Safari after a search term was entered. The current version of the Google Mobile App does not automatically access Safari for searches.

In order to assess the value of designing a mobile web-site, additional contrasts were conducted on regular sites for the iPhone against mobile sites on the iPhone. The Google and Amazon mobile sites were more efficient than the regular version of the sites (Google: $t(28) = 3.99$, $p < .001$; Amazon: $t(28) = 8.92$, $p < .001$). But, no real differences were found between the regular version of Wikipedia and the mobile version of Wikipedia ($t(28) = 0.52$, $p = .61$).

The New York Times registration web-site did not have a mobile version of the site or an App available for the iPhone. Thus, subjects interacted with the same interface on the PC and iPhone. As can be seen in the table above, the time it took to complete the text entry task on the iPhone was substantially longer than the amount of time to complete compared to the PC ($t(28) = 12.90$, $p < .001$).

Figure 1 shows all of the regular (PC-version) sites on the iPhone against the respective sites on a PC. We expected to see (and found) reliable differences between the iPhone and PC for every task. However, relative differences between platforms grew as a function of the amount of data entry. The Wikipedia task required large amounts of reading and low amounts of data entry. The New York Times Registration task, in contrast, required a high amount of data entry and low amount of reading.

Completion times from emails and text messages were also compared with paired-samples *t*-tests using alpha set at the .05 level. Subjects used far fewer characters to write three sentence emails

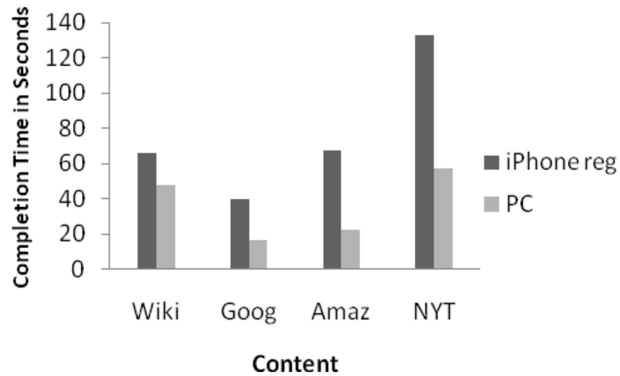


**Figure 1.** Completion time differences between the regular versions of web-sites on the iPhone and PC.

on the iPhone ($M = 83.94$, $SD = 27.13$) compared to the PC ($M = 112.94$, $SD = 38.11$). Still, the task of composing and sending an email was more efficient on the PC compared to the iPhone ($t(28) = 2.76$, $p = .01$). Correspondingly, it took subjects far less time to write and send an IM on a PC compared to a text message on their iPhone ($t(28) = 8.20$, $p < .001$).

## DISCUSSION

Since network times were removed, differences in performance between the two platforms were likely due to problems driven by difficult text entry and smaller displays on the iPhone. These differences were greatest on sites not adapted to mobile phones. Additionally, non-adapted (i.e., regular, PC-version) sites seemed to be more time-consuming as the amount of interaction increased.

Interestingly, no real advantages were found for the Wikipedia App and mobile site when compared to the regular version of the site on the iPhone. This could be due to the lack of interaction in the task (subjects only had to enter a few words, select the search button, and read two paragraphs). Additionally, subjects that participated in this study are young and probably have better vision compared to older adults. This cut down on the amount of scrolling required when text is smaller. In general, the benefits of an App or HMC-optimized web-site may not be as great for products or services requiring low data entry.

Future research can help determine the causes of these completion time differences between platforms. iPhone users looked at the keyboard to make inputs. This probably increased completion time in line with research in attention and procedural knowledge. For example, Keele (1973) found that performance was worse for pianists that focused attention on their fingers or the piano keyboard. We think that constraining users' visual attention to the keyboard in text entry detracted performance. Thus, physical keyboards still have an advantage in terms of efficiency. We will examine this for HMCs in more constrained environments in future studies. Other factors related to typing on HMCs (e.g., smaller buttons, not enabling users to use all ten fingers, no feedback on buttons) likely contributed to performance decrements as well.

**Design Implications**

While handheld mobile devices still underperform compared to PCs, the use of mobile sites or Apps significantly enhanced performance. Designers should build a mobile site or App if usability and efficiency is important. This is more critical for mobile content requiring high amounts of data entry.

Designers can compensate for hardware constraints by enhancing the display of the mobile content by reducing scrolls and gestures for users. Text entry should be avoided whenever possible. Use of pull-down menus, predictive text, or avoidance of user input all together is recommended. Additionally, accuracy is dramatically improving in voice recognition for the Google App and image recognition for the Amazon App. Thus, designers should use appropriate advanced technologies and find ways around input limitations on handheld mobile devices when possible.

For software or web-sites that do not require large amounts of data entry, a mobile site or App may not yield huge benefits. As previous research has shown (e.g., Duchnicky & Kolers, 1983), reading and comprehension on small screens is only slightly slower compared to large screens.

Our results showed real time savings yielded when subjects interacted with a mobile site or App for the iPhone. The lack of a reliable difference between performance on the App and mobile site suggests that designers might only need to do one or the other. However, the App yielded lower network wait times compared to accessing Safari. Overall time savings were best when using an App.

At this point, HMCs seem better suited to complement fixed-based computers and not completely replace them. Designers must determine the tasks optimized in HMC and not force-fit content. For example, high data entry requiring space for viewing objects (e.g., programming with graphic design) may be more appropriate for a fixed-based computer and not a HMC. While the gap in network times may continue to close, mobile web and software designers still must consider difficult text entry methods and smaller screens in implementing mobile content.

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