Shumeng Gu. The Impact of Screen Size: A Usability Evaluation of Mobile Devices for Scholarly Reading. A Master's Paper for the M.S. in I.S degree. April 1st, 2014. 49 pages. Advisor: Bradley M. Hemminger

This study aims to present a comprehensive evaluation of usability related to performing scholarly readings across mobile devices with different screen sizes. The primary research questions are: 1) What are the perceived advantages and disadvantages of mobile devices with different screen sizes for scholarly reading? 2) Is screen size a major factor affecting usability? The author conducted a qualitative and quantitative methods study, including observation, questionnaire and semi-structured interview.

The study found the screen size of mobile devices is a major factor that impacts usability when it is smaller than a certain scale. No significant difference was found between full-size 9.7-inch tablet and 7.9-inch mini-tablet in terms of ease of navigation, reading speed, reading effectiveness and overall experience. The 4-inch phone is the least desirable device for scholarly reading, and has the lower performance of the presentation of texts and figures. Other possible factors include the device weight, portability and physical design.

Headings:

Electronic information resources – Use studies

Electronic book readers

Reading

Surveys

THE IMPACT OF SCREEN SIZE: A USABILITY EVALUATION OF MOBILE DEVICES FOR SCHOLARLY READING

by
Shumeng Gu

A Master's paper submitted to the faculty
of the School of Information and Library Science
of the University of North Carolina at Chapel Hill
in partial fulfillment of the requirements
for the degree of Master of Science in
Information Science.

Chapel Hill, North Carolina

April 2014

Approved by

_____

Background Statement

An e-book is defined as an electronic version of a printed book which can be read on a personal computer or handheld device designed specifically for this purpose (Heikkilä, 2011). The origins of e-books can be traced back to 1971, to the beginning of Project Gutenberg, an organization dedicated to digitizing texts. People began reading e-books using personal computers. Since the introduction of the first hand-held mobile device— NuovoMedia's Rocket eBook and Softbook in 1998 (Richardson, 2011), e-book mobile readers have been gaining more and more popularity and attention in recent years. For example, the growth for one of the e-book mobile devices—tablets, is expected to expand from 17 million in 2010 to 70 million in 2012. Also, MobiThinking recently released a statistical report, which shows 34.7% of the phone users are using their phones for reading (MobiThinking, 2013). Three types of mobile device have been widely used for e-book reading: 3-4 inch phone, 7-inch tablet (such as Kindle, iPad mini) and 10-inch tablet (such as iPad). Inevitably, the usage of e-books and mobile devices for reading has been outpacing the use of traditional PC-like computers and laptops. Besides, Cox (2004) indicates "an e-book can support the academic mission effectively, saving time and adding value as a collective online reference, and for dynamic and cost-effective collection management".

As e-books have become increasingly popular for leisure reading, there is a concomitant interest in exploring their potential in the academic environment,

particularly for university and college students (Thayer, Lee, Hwang, Sales, Sen & Dalal, 2011). E-book usage in academic libraries is increasing. In 2007, half of all of all survey respondents at University College London reported having read at least one e-book (Rowlands, Nichola, Jamali & Huntington, 2007); In 2008 58% of those surveyed at the University of California reported e-book use (Li, Poe, Potter, Quigley & Wilson, 2011), and 18% have used at least one mobile device for scholarly reading in the past one month.

E-book reading usability studies have been widely conducted by many library and information professionals. However, past research has the following limitations: First, though much research has focused on the qualitative usability issues about mobile devices, the impact of screen size of e-book mobile device is still uncertain. Some studies compared e-book mobile devices with similar screen sizes, while the other compared devices with different screen sizes, such as iPad and Kindle, but failed to recognize the direct impact of screen size due to other variables such as screen display technology, physical design interface, etc. Second, although e-books have been widely used in an academic context, only a few have aimed at exploring the usability for scholarly reading. Besides, among those studies, the majority of them only focused on the difference of learning effectiveness when comparing reading e-books with reading conventional printed books (Wilson, 2003; Aaltonen et al., 2011; Gupta & Gullett-Scaggs, 2010). Few have investigated usability across different mobile devices, especially taking into account the impact of screen size. Thus, an increasing number of e-book mobile devices with various screen sizes leaves room for more investigation of usability, especially with respect to scholarly reading.

Purpose

This study aims to present a comprehensive evaluation of usability concerns across three mobile devices: iPhone 5, iPad mini, and iPad, with a particular focus on the impact of screen size of mobile devices on scholarly reading. The study population was graduate students in University of North Carolina at Chapel Hill, since graduate students were the major group that shows intense need for academic learning and research. The author chooses to recruit graduate students due to the limited time and study scope; therefore, the results of this study should not be generalized to other educational groups.

Research Questions

1. What are the perceived advantages and disadvantages of mobile devices with different screen sizes for scholarly reading?
2. Is screen size a major factor affecting usability?
3. What improvements could be made to mobile devices that would increase their desirability for scholarly reading?

Literature Review

Since the rapid emergence of e-book reading, there have been many studies related to its usability in the field of information and library science. Two streams of studies have been identified. One is to compare the usability of e-book reading with traditional printed book reading, with little emphasis on what devices will be used to present the e-book file. Wilson (2002) suggests that in order to render e-textbooks to have

similar user experience and functionality as with printed books, the e-book interface must be improved in terms of on-screen appearance, scannability, and adherence to the paper book metaphor, like similar page breaks and flipping. This study specifically referred to the computer as the e-book presenting carrier, but did not take into account the interface design as with other mobile devices. Kang, Wang & Lin (2010) compared the usability between e-books, which were shown in a 6-inch tablet, with c-books (conventional printed books), and indicated that there is no significant difference in terms of reading comprehension and efficiency. However, users tend to read slowly using e-books, and some of them think the navigation and annotation functions are cumbersome on the e-book device. Other studies that compared e-books with printed books drew various conclusions, such as perceived lower enjoyment of e-book reading process than printed book reading (Lam et al. 2009) and improvement of e-book functionality due to easy navigation and large storage capacity (Landoni & Hanlon, 2007).

The second stream of usability studies explored the usability of e-book mobile devices, which is currently the most used carrier that presents electronic article. This type of study aims at tackling possible improvements for the design and development of the current e-book mobile devices and their software apps. Many issues have been addressed that may affect the usability of e-book devices, including screen size (Allmang & Bruss, 2010; Gibson & Gibb, 2010), weight (Connell et al., 2012; Allmang & Bruss, 2010), navigation interface (Mentch, 2010), screen display technology (Richardson, 2011), interaction (Mentch, 2010; Princeton University, 2010) and physical design (such as the placement of page flipping and navigation buttons)(Mentch, 2010).

However, among the studies which focus on the usability of e-book mobile devices, there hasn't been any study specifically to investigate the factor of screen size. As for those that took screen size as a consideration, the other variables besides screen size that may affect e-book reading usability were not fully controlled. For example, Richardson (2010) compared the reading experience among five mobile devices: The Amazon Kindle Keyboard 3G, the Apple iPad, Barnes & Noble's Nook, Borders' kobo reader and the Sony Digital Reader, among which iPad and Sony Reader are 9-12 inches, and the rest are 6-8 inches. There are other variables that would affect usability among these five devices, including different display technology (only iPad uses LED display screen and the rest use E-ink technology) and different interface design (the author did not specify which app iPad uses for displaying articles, and the rest use their own interface design which are all distinct). In this case, it is unlikely to tell the impact of screen size as the only factor, as users may be biased due to other variables among the mobile devices. Similar concerns also exist in Allmang and Bruss's (2010) research, in which they compared the usability among Kindle Keyboard 3G, Kindle DX (a 12.9-inch display device with e-ink technology), and Apple iPod Touch. The three devices did have different screen sizes, but they also have distinct interfaces and display technology.

In addition, the lack of emphasis on screen size as a usability factor for e-book scholarly reading is even more obvious. As Rauch (2011) suggests, to ensure that content displays appropriately for small device, a best development practice is to build new file format in order to come up with a reflowable solution, which can adjust the font size and text presentation based on the screen size of the mobile device. Currently, .MOBI and .EPUB File formats have been widely used for leisure reading materials such as

novels and magazines. However, few similar e-book formats exist for scholarly reading; most works are still presented in traditional PDF formats. Besides, according to Allmang and Bruss (2010)'s study result, users prefer using large screen size for reading scholarly articles primarily because of its capacity of presenting the scholarly article in pdf format with appropriate font size. In this regard, it is even harder for researchers to look into the impact of screen size of mobile devices for scholarly reading because most academic articles are in pdf format and are difficult to read in small size devices like smart phones.

To address the previously mentioned limitations of existing studies, this research aims to measure the impact of screen size of mobile device for scholarly reading. This study uses three mobile devices with similar physical design: the 4-inch iPhone 5, 7.9-inch iPad mini and 9.7-inch iPad and the same embedded App (Kindle software), in order to effectively control other variables that may affect the usability. What is more, this study uses open-source software called "k2pdfopt" to convert scholarly articles from normal pdf format into three different versions which can present appropriate reflowable font sizes in three mobile devices.

Research Design and Methods

The author conducted a qualitative and quantitative mixed methods study, with an emphasis on qualitative analysis, to evaluate the usability of mobile devices with different screen size for college students. The specific methods will include observation, questionnaire and semi-structured interview (See Appendix III and IV).

Before the usability test, the author used an open-source software "k2pdfopt", which optimizes PDF/DJVU files for mobile e-readers and smartphones, to convert and

reflow ten open-source scholarly articles into iPad, iPad mini and iPhone readable pdf versions, including both the texts and tables/figures (See Figure 1, 2, 3 below). Because k2pdfopt was still under development and couldn't convert pictures without any error, the author manually changed the presenting formats for tables, figures and graphs to enable optimal display. See the pictures below for the examples of displaying texts, figures and tables.

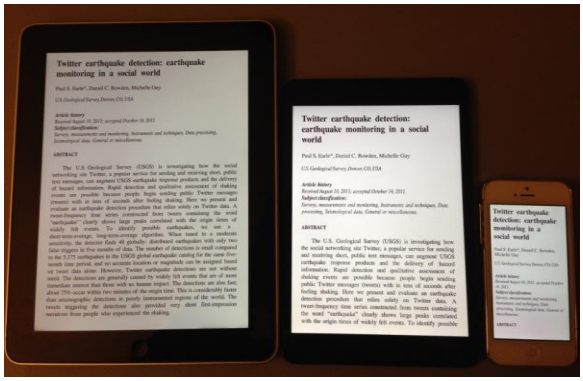


Figure 1. The texts of the converted versions of one sample article shown on three devices

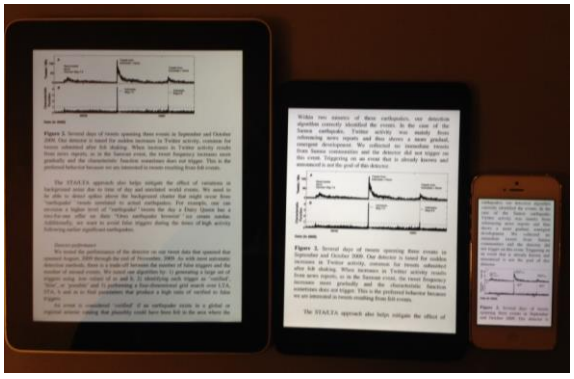


Figure 2. One figure of a sample article shown on three mobile devices

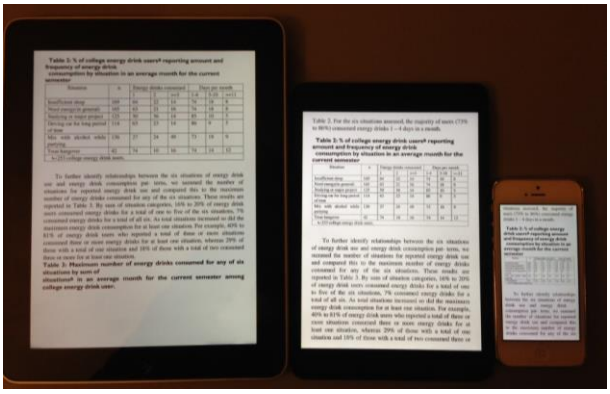


Figure 3. One table of a sample article shown on three mobile devices

The qualitative methods that the author used include behavior observation and semi-structured interviews (See Appendix IV), and the quantitative methods consist of counting the reading time of each article, and questionnaire survey (see Appendix III). The questionnaire was developed based on Marcial's one related study (2011). Wilson and Landoni (2002) proposed an evaluation model, or general methodology, from which "ebook usability experiments in a range of areas can be extracted and remain comparable at a basic level" (p1). They suggested that the four most effective ways to evaluate e-book reading usability include subjective satisfaction questionnaires, behavior observation, think-aloud protocols and interviews. Based on their proposed model, this study choose not to include think-aloud methodology, because the quantitative analysis requires recording the time spent on each reading using each device, and think-aloud will impact the participant's reading and make the recorded time inaccurate.

The author used t-test for the quantitative analysis of participants' reading time, because this statistical method is use for giving the probability that the difference between two means can be attributed to chance (Wildemuth, 2009). The study used the p

value, which is the probability that the difference between the two means is caused by chance, to evaluate the participants' reading time difference on three mobile devices.

The Kruskal–Wallis test was conducted to analyze data from the questionnaire results, which is a set of likert items with a scale from 1(not at all) to 5(extremely). It is a non-parametric method for testing whether samples originate from the same distribution, and is used for comparing more than two samples that are independent, or not related. The p value derived answers this question: If the groups are sampled from populations with identical distributions, what is the chance that random sampling would result in a sum of ranks as far apart (or more so) as observed in this experiment? (GraphPad Software.com)

The author applied qualitative content analysis to condense raw data from observation and interview answers into categories or themes, and then draw conclusions based on the frequency and interpretation of each category.

The three main qualitative and quantitative methods that this study chose to use (direct observation, questionnaire and semi-structured interview) have their own advantages which can compensate each other and make the data more valid. As Wildemuth states, direct observation allows the researcher to collect accurate information about events, and also gather more previse data about the timing and duration since it won't interrupt the participants in the process. Thus, this method is particularly suitable for counting the total time of reading (2009). Survey research enables researcher to statistically "estimate the distribution of characteristics in a population" (Dillman, 2007, p. 9), and interviews can help get full range and depth of information (McNamara, 2006),

and also can clarify some of the behaviors that the author notices during the observation process in this study.

Data Collection Methods

This study took 11 open-source scholarly articles as the test materials. The articles have an average length of 10-12 pages, and the original pdf files are two-column and single spaced. Every article includes at least one table, figure or graph.

Twenty-four university graduate students were recruited and they were assigned to read a different article on each of the three mobile devices in order to counterbalance the bias caused by the article contents (See Appendix V for article assignment table). The sample size was similar to other previous qualitative study on e-book usability. For example, Pattuelli and Rabina (2010) analyzed opinions of 20 students of Pratt Institute's School of Information and Library Science about their use of the Kindle 2. Also, Herther (2009) interviewed six college and four high school students in the US about their use of the Kindle DX. Since this study will put major emphasis on qualitative analysis, the sample size of 24 observers should be adequate to provide valid analysis data.

During the usability test, each participant signed a consent form, and went through a training procedure to get familiar with three mobile devices. Then, they was asked to read three articles using three mobile devices, during which the author observed their behaviors as they interact with the devices. After the reading task, they completed a questionnaire survey and answer several semi-structured interview questions.

This study recruited participants through three UNC on-campus email listservs (SILS master listserv, CS (Computer Science) graduate student listserv and education

student listserv). The author selected the participants based on the following three requirements: They must be more than 18 years old (it is required in this study's IRB application form); they must be graduate students and they must have previous experience using multi-touch devices (such as smart phones or tablets). To ensure the confidentiality of the data, the records of this study did not include any information that made it possible to identify the participants. Research records will be kept on SILS fileserver; only the researcher will have access to the records.

The author does not anticipate any risks to the study subjects for participating in this study other than those encountered in day-to-day life. There are also no specific benefits to the participants either, but they may become more accomplished at reading scholarly articles at different types of mobile interfaces.

Results

Participants

The majority of participants were aged 20 -30 and female; six were male. All of them were graduate students or alumni; twenty-two major in library and information science, one in computer science and one in education. All participants were familiar with using multi-touch mobile devices such as tablets or smart phones.

Six participants have had experience of reading scholarly articles using tablets, such as iPad, iPad Mini, Kindle or Nook, prior to this study. None have ever read scholarly articles with their phones, although most of them often use the phones for quick searching and leisure readings like novels or short stories while travelling. Twenty-two

participants are used to reading scholarly articles on their computers or laptops, or printing them out and then read on paper.

User experience

(1) Reading speed

Based on the t test results, there are no statistically significant differences in terms of the reading speed on the three mobile devices (See table 1), though the average reading time of scholarly articles using iPad (964s) and iPad Mini (948s) was slightly shorter than that using iPhone 5(1090s). Other work has shown the phone to be slower (Marcial), and it is likely that a larger sample size would have demonstrated a statistically significant difference in reading speed between the phone and tablet and mini-tablet.

t-Test: comparison of reading time between iphone and iPad mini (in second)		
	Variable 1	Variable 2
Mean	1090.458333	948.0833333
Variance	162589.4764	138342.9493
Observations	24	24
Hypothesized Mean Difference	0	
df	46	
t Stat	1.271466333	
P(T<=t) one-tail	0.104977107	
t Critical one-tail	1.678660414	
P(T<=t) two-tail	0.209954214	
t Critical two-tail	2.012895599	
t-Test: comparison of reading time between iphone and iPad (in second)		
	Variable 1	Variable 2
Mean	1090.458333	964.5833333
Variance	162589.4764	118105.9058
Observations	24	24
Hypothesized Mean Difference	0	
df	45	
t Stat	1.16393163	
P(T<=t) one-tail	0.125292958	
t Critical one-tail	1.679427393	
P(T<=t) two-tail	0.250585916	
t Critical two-tail	2.014103389	
t-Test: comparison of reading time between iPad mini and iPad (in second)		
	Variable 1	Variable 2
Mean	948.0833333	964.5833333
Variance	138342.9493	118105.9058
Observations	24	24
Hypothesized Mean Difference	0	
df	46	
t Stat	-0.15962069	
P(T<=t) one-tail	0.436939355	
t Critical one-tail	1.678660414	
P(T<=t) two-tail	0.873878709	
t Critical two-tail	2.012895599	

Table 1. Comparison of reading time among three devices

However, the questionnaire results indicate that participants think the quick (speed) performance of reading the texts, figures and pictures of scholarly articles using iPhone 5 was much worse than using iPad and iPad Mini($p<0.05$), but no difference was found in terms of the difference of iPad and iPad Mini usage for reading texts or images. As shown in figure 4 below, most participants did not think iPhone enabled speed performance especially for reading figures, pictures or tables, and rated its performance satisfaction degree as 1(not at all) – 3(moderately). In contrast, they thought the rest two devices can enable quick reading very much (4) or extremely (5).

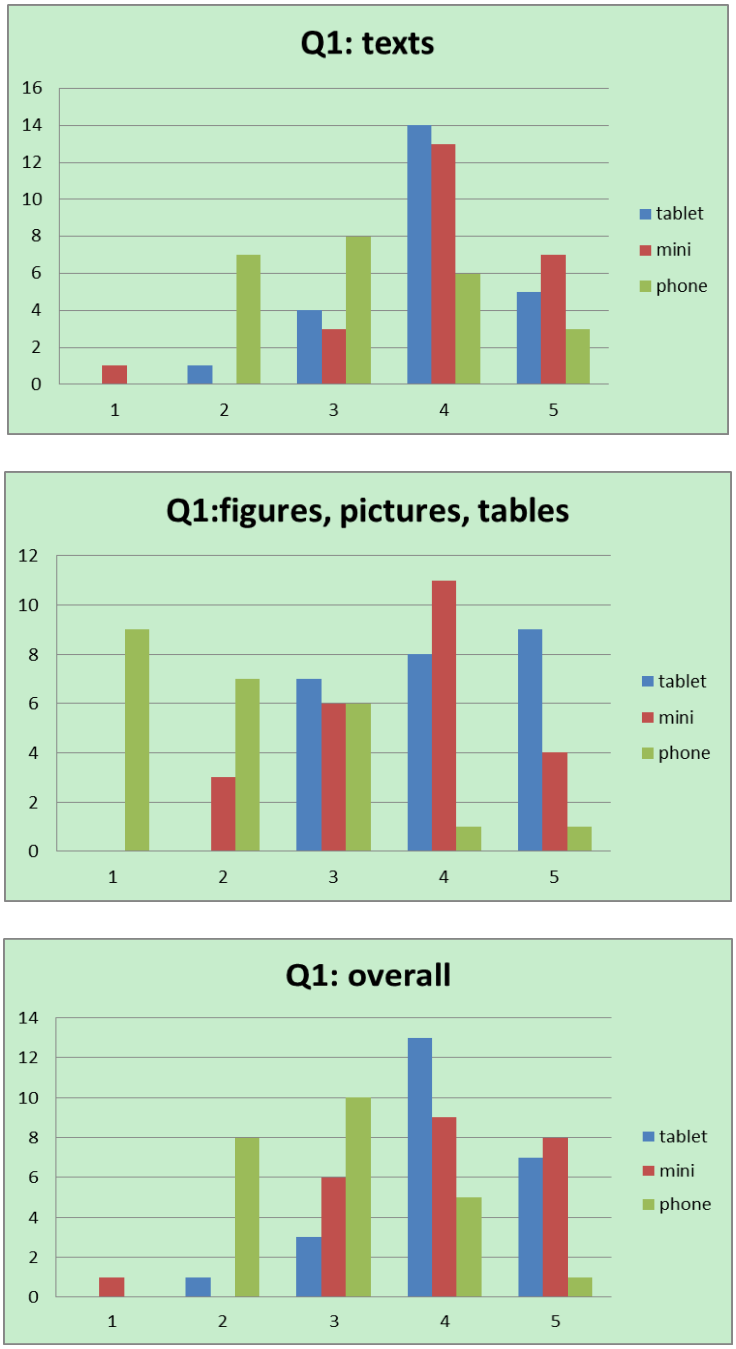


Figure 4: Quick performance of three devices

The reason that participants thought iPhone had lower performance in terms of reading speed were mainly due to the smaller screen size of iPhone. With the presentation of texts with comfortable reading font sizes, iPhone can only hold 90-120 words each

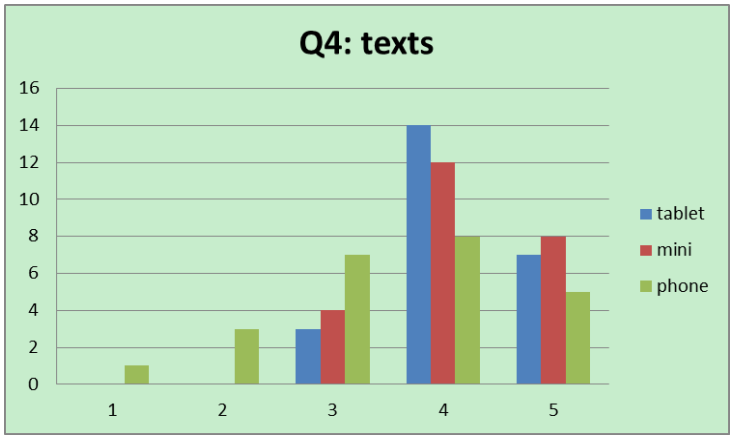
page, whereas iPad Mini can show 320 – 370 words and iPad 450 -500. In this case, each section or paragraph of the article would normally be divided into separate pages, and users would need to flip the page frequently to enable continuous reading of a section. Though a few users thought flipping the page within a short period of time gave them the feeling of reading faster than other two devices, their reading behaviors were distracted and sometimes they needed to flip the page back and forth to understand a certain section. Fourteen participants flipped the pages back and forth when reading with iPhone, among whom 5 did such behaviors for more than 5 times. Compared with that, only 9 participants did the similar actions using iPad Mini, and 6 using iPad.

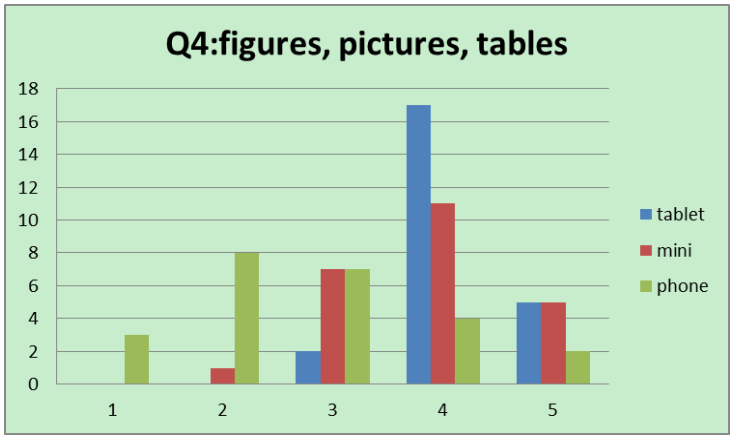
Another possible reason is that because of the narrow width of iPhone devices, the display of figures, pictures and tables are usually much smaller than the other two. Nineteen participants zoomed the images on iPhone during reading, and 10 moved the device closer to face in order to see the contents more clearly; such behaviors existed less obviously during the usage of iPad and iPad Mini. The interaction of article interface may cause the participants' perceptions that reading on iPhone can't enable quick reading speed.

Moreover, 6 users mentioned that because when the articles were shown on iPhone, the number of pages to be displayed will be larger because each page holds less text. They would feel more frustrated during the reading process, because although they flipped the pages a lot, there were still a lot of pages left for them. They felt that the reading time on iPhone seemed particularly long and they got impatient easily.

(2) Ease of navigation

There exist significant difference between iPhone and the other two devices in terms of ease of navigation on both texts and images ($p<0.05$) (see Figure 5). For reading on iPad, 21 users thought navigation was very or extremely easy using iPad, and similar number of users held the same attitudes towards the usage of iPad Mini. However, a majority of users regard the ease of navigation on iPhone as "moderate" or less, which indicates that they are not as satisfied with iPhone particularly while reading images compared to the other two.





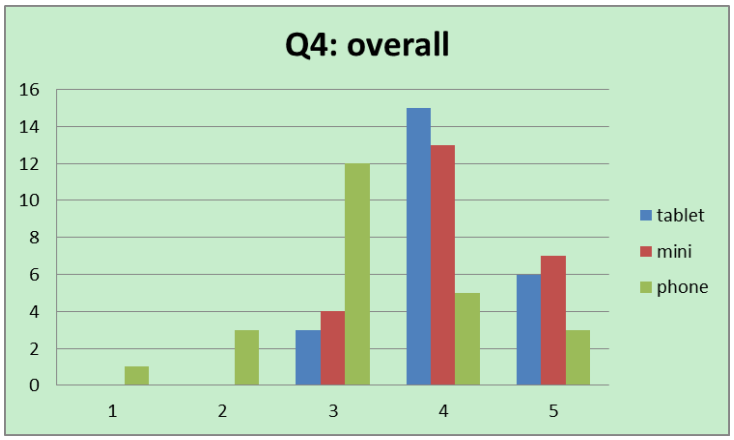


Figure 5: Ease of navigation of three devices

All participants used the navigation bar functionality which Kindle App supports during their reading. They all thought having such functionality helped them to navigate the articles, and interact with the devices more easily. Two suggested that it would be better to have page number in each page, particularly on iPhone. Because the number of pages on iPhone are much more than the other two, the page number will be a beneficial guidance which helps them get a better sense of this article length and their reading process.

(3) Reading effectiveness

Participants thought iPad and iPad Mini enabled more effective performance for reading scholarly articles compared with iPhone, whereas the effectiveness between iPad and iPad Mini did not have significant difference (See Figure 6). Besides, they believed using iPhone will require more mental efforts than the other two during reading both the texts and the images (See Figure 7).

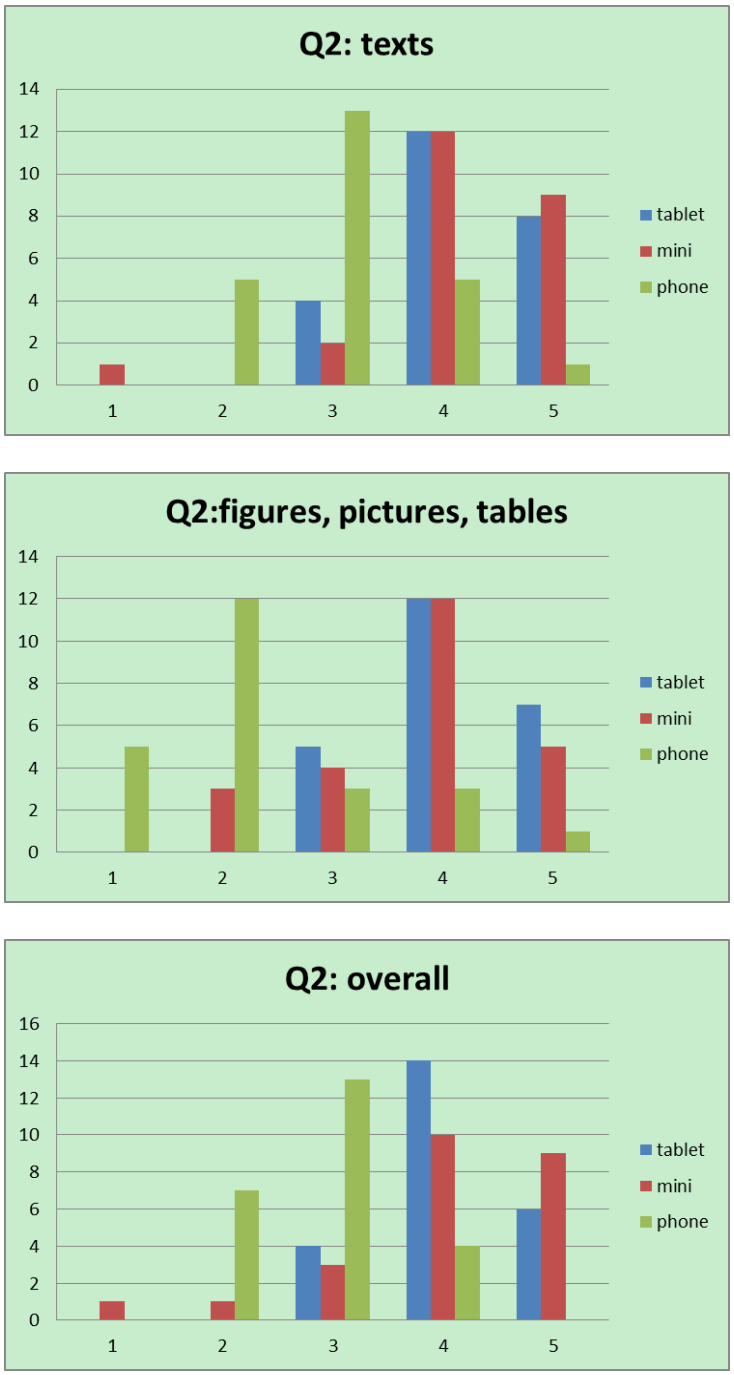


Figure 6: Effective performance of three devices

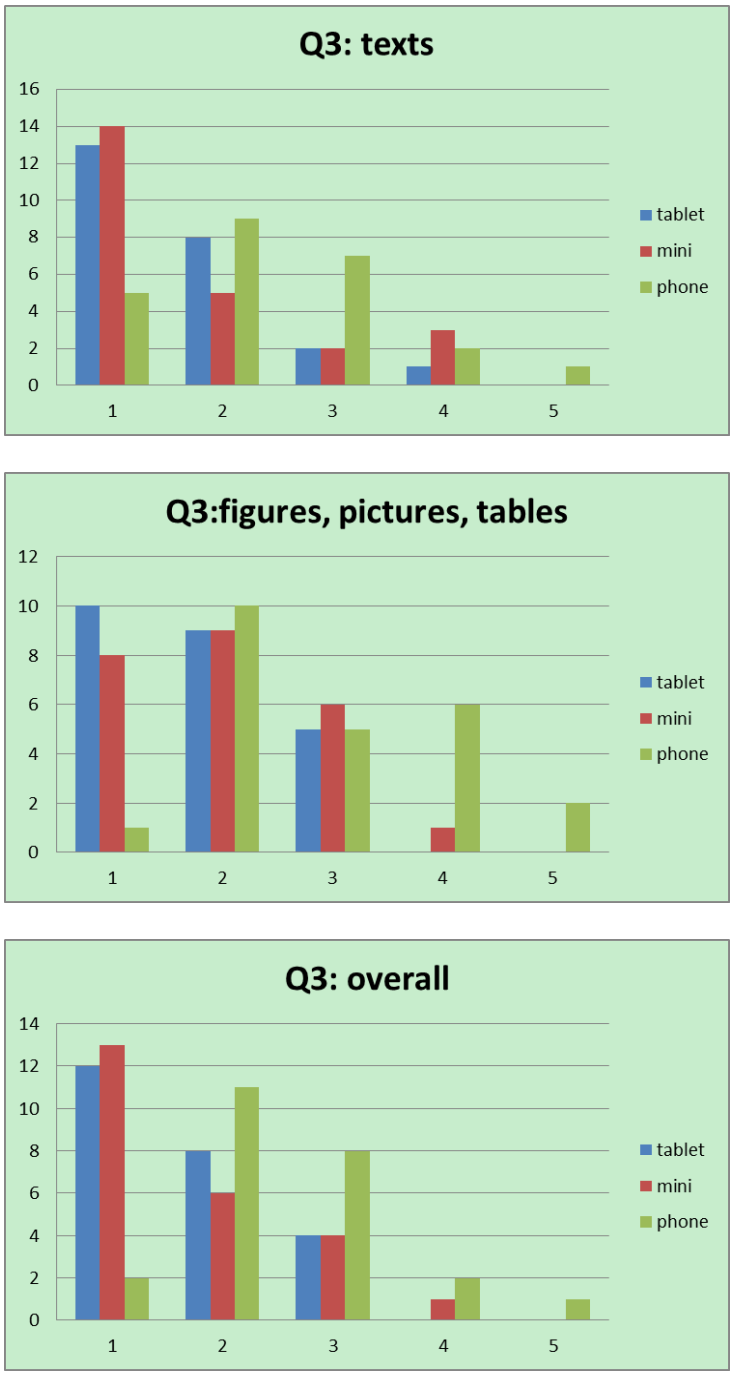


Figure 7: Required mental efforts during reading on three devices

Some participants conducted some operations that they did not intend to do when they read on iPhone, such as accidentally zooming the pages or flipping the pages while

intending to tap the screen to see the navigation bar, mistakenly skipping several pages when sliding the screen for flipping, etc. It was frequently commented that since the contents per page on iPhone seemed much less than the other two, flipping the pages a lot will distract from their understanding of the article, hence hindering the reading effectiveness. About 2/3 of the participants believed the effectiveness of iPad and iPad Mini was similar due to reasons which include enough texts display each page for both devices and proper display sizes of figures, pictures or tables.

Six participants mentioned that due to iPhone's small screen size and easy portability, they had the perceptions that it is only good for light reading or activities during travelling, instead of heavy tasks such as reading a scholarly article. Also, it was almost impossible to make annotations, which should be another essential function for devices which support scholarly reading. One participant said that even if the usage of iPhone was way better than what she expected, she still did not think it is a good device for scholarly reading because she had gotten used to reading on larger screens. Therefore, she would still take using iPhone as the last choice.

(4) User expectation changes

Eleven participants got a better impression towards the usage of iPad Mini after the reading tasks. They thought the overall performance of iPad mini was better than their prior expectations. It was commented that prior the reading task, the participants thought iPad mini's performance will be more similar to small devices like iPhone because of its small sizes and easy portability, and it should be more suitable for light and leisure reading. However after the actual usage, they believed that this device had the equal or

even better performance to iPad, and it was even more convenient to take and read compared with iPad because of its light size and thinness.

Five participants held a slightly more positive impression towards iPhone after the reading tasks. To answer the question "Would you use iPhone to read journal articles in the future?", four changed the answer of "no" to "maybe, depends on situation" after the experiment, and one changed to "yes". Most of them said that they thought it would be impossible to read scholarly articles on iPhone prior to the experiment, but after that they felt using iPhone can accomplish the reading tasks but it was still less desirable than tablets. The rest participants still had a negative impression of iPhone, and answered this question as "no" or "maybe" both before and after the experiment.

The majority of participants had an equally positive or slightly better impression to the usage of iPad. Thirteen participants said they would definitely choose iPad for reading scholarly articles, and 10 said they would use it depending on situations. Two participants who did not have experience of reading on tablets before said that after this experiment, they thought reading on iPad was so good an experience that they may choose to change their previous reading behaviors from reading on computers to reading on tablets in the future.

(5) Differences between the display of texts and figures, pictures, tables

As mentioned above, significant differences have been found of the display of both texts and images (including figures, pictures and tables) between iPhone and the rest two. The qualitative results also revealed that for each device, the differences between the texts and images display on iPad and iPad mini was not statistically significant. It means

that participants believed the performances of showing texts and images are really similar when they use these two devices. However, they found that the display of images had a significantly lower performance than the display of texts when they used iPhone in terms of reading speed, reading effectiveness and ease of navigation. It was frequently commented that the images shown on iPhone were too short to be seen without zooming. They also mentioned that though the zooming action was not particularly distracting, the enlarged images cannot be shown as a whole on the screen. In this case, they had to move the images back and forth to read their details, which required more mental effort. In addition, shrinking the images back to their original sizes would often lead to mistakes like accidentally flipping the current page, or opening the navigation bar tool. Five participants had the similar behaviors when they zoomed and shrank the images shown on iPhone.

Such results were probably due to technical limitations using the k2pdfopt tool to convert and reflow the articles from their original PDF format into formats appropriate for the mobile devices, which did not allow for an easy way to handle modifying the original formats of images, especially figures or diagrams. That is why when they displayed on small screens like iPhone, the captions on the images became much smaller, which would require the readers to zoom in order to see them clearly.

(6) Overall preferences

The study result indicated that participants had similar positive impressions with respect to the iPad and iPad mini for reading scholarly articles. In an interview question which asked the users to rate the three devices from most negative to positive impressions,

14 users rated iPad Mini as the favorite mobile device, and 9 users believed iPad is the most desirable one. However, in the question which let users to rate the three mobile device from 1(least desirable) to 10(most desirable), iPad got an average score of 8.5, which was significantly higher than iPad mini whose score was 6.9, and iPhone whose score was 4.4.

The reasons that contributed to the different results in terms of the rating and score are probably because that the users who rated iPad mini as the most desirable device also had similarly positive impression towards iPad. They rated iPad mini as the first normally due to some issues which did not impact their reading experience to a large extent, such as light weight, convenient portability, etc. On the contrary, most iPad lovers believed there exist significant advantages of iPad over iPad mini, and there is no way that the reading experience using iPad Mini can be comparable to that of iPad. That is why they rated the score for iPad Mini as much lower than iPad, which resulted in a general lower score of iPad mini.

In all aspects, the iPhone remained the least desirable mobile device for scholarly reading as shown from both interview results.

Table 2 and Table 3 is a list of summary of participants overall likes and dislikes for each device. The number following each category is the total number of participants who mentioned this point. Each list is sorted based on the frequency of comments.

iPad	**iPad Mini**	**iPhone**
Large screen size(7) Good presentation of images(4) Suitable for intense reading(3) Comfortable weight which	Suitable screen size (19) Light weight(16) Enough content each page (3) Thinness(1) Easy to convert scholarly	Light weight(4) Easy portability(2) Small screen (1)

feels safer (2) Easy interaction (2) Feel like an actual book(1) Nice edge design(1)	article into iPad Mini readable version(1) Good presentation of images (1) Feel like an actual book(1)	

Table 2: overall likes of three devices

iPad	**iPad Mini**	**iPhone**
Cumbersome and heavy (5) Thickness (3)	Small screen size (2) Uncomfortable to use due to habits(2) Glare(1) Thinness(1)	Small screen size (6) Flip or zoom page frequently(5) Bad presentation of images (3) Not suitable for scholarly reading (2) Section broken into several pages(2)

Table 3: Overall dislikes of three devices

(7) Major factors that cause user preferences

Twenty-two participants believed that screen size is the most important factor that impacts their preferences and the usability of mobile devices for scholarly reading; one thought the weight is the essential factor and one thought the physical design of the mobile devices matters most. However, participants held different opinions about what kind of screen size is the most desirable one.

The 9 participants who favored iPad most thought the screen size is the major factor. They believed that the large the screen size is, the better the usability for reading scholarly articles will be. They illustrated the following reasons: First, the large screen size is able to present more contents in each page. As scholarly articles often require intensive reading and consist of several continuous content blocks, displaying a complete large block in one page will improve the general understanding of the articles. Second,

tables and pictures can be displayed more clearly on the large screen, especially for tables with intensive statistics. Third, the large screen size can support annotation functionality better, which is another essential requirement for scholarly reading.

As for the 5 participants who preferred iPad mini, they believed screen size should be the major factor, but other factors also exist which impact their preferences. They listed the following major reasons: First, iPad mini is in the middle way compared with iPad and iPhone. It is neither too small to display enough contents, nor too large to be overwhelming. They believed that when the screen size is large to certain extent (in this experiment, to the size of iPad Mini), the smaller screen size the better. Second, most of them also treated the weight of the device as another major factor. That is to say, even under the circumstances which both iPad and iPad mini have similar reading experience, they would still favor iPad mini because of its light weight and thinness.

One participant who believed weight was the major factor preferred to use iPhone most. She thought mobile devices should better be used while travelling; otherwise she could just use her laptop for reading papers. Because of the portability and light weight of iPhone, she rated weight as the most important factor. Another participant thought the physical design should be the essential factor because he was really disturbed by the thin edge surrounding the display screen of iPad Mini. He couldn't find a proper way to hold the device so that his fingers wouldn't touch the screen and he can hold the device firmly at the same time. However, he also believed that the reason that he liked iPad and iPad mini more than iPhone is because of the large screen size.

Other factors that impact the usability also include light weight, thinness, portability, resolution, screen glare, or use habits.

Detailed statistical results of the raw data using Kruskal-Wallis test in this section can be found in Appendix I, as shown at the end of this paper.

Discussions

Screen size as the major factor

The study results indicate that screen size is a major factor which impacts the usability of mobile devices for scholarly reading when the screen size is below certain level (in this study, when the screen size is smaller than iPad Mini). A majority of participants did not enjoy reading scholarly work on the device with a similar size of iPhone, due to few contents shown in each page, frequent page flipping, small text and picture sizes, and less desirable reading effectiveness. Comparatively, the tablets (iPad Mini and iPad) were able to display enough texts which did not interfere with readers' continuous reading frequently; also the presentation of texts and particularly pictures are more optimal than iPhone.

Another point which was raised by participants is related to the difference between leisure reading and scholarly reading. Generally speaking, scholarly articles have denser contents which required intensive attention. Sometimes, readers need to move to the previously read sections to correlate with the current sections, make annotations, or keep track of table of contents frequently. However, because of the small screen size of iPhone, a journal article with a normal length of 10 -12 pages will be divided into about 50 pages when displaying on iPhone, which made it particularly hard for the readers to move the pages back and forth and find the contents they wanted to

read. Besides, readers can hardly make annotations using such a small touch screen with fingers and no external equipment like keyboard or mouse.

Moreover, most participants had never read scholarly articles using iPhone before. Some said that even if they thought the performance of iPhone was better than they expected and this device was able to satisfy the needs for reading, they still wouldn't treat it as a preferable tool due to its small screen size. They would lose the sense of their reading speed when they use iPhone, since even when they flipped the pages frequently which made them feel they were reading fast, actually they were not. To solve this problem, one possible way is to provide them with specific table of contents, so that they can get a better sense of which section they are reading and how many are still left for them.

However, when the screen size is equal to or larger than iPad Mini, no significant usability difference was found. Few participants thought that their preferences between the iPad Mini and iPad were directly related to the screen size factor, for example, whether the contents each page were too short or too overwhelming. Instead, other factors become more important, among which the most frequently mentioned one is the weight of the devices.

In this case, one assumption based on this study result is that when the screen of the mobile device is smaller than a certain size, screen size is regarded as the essential factor impacting usability for scholarly reading. When it reaches a certain level, it will be no longer a major factor; instead, other factors such as weight, resolution and other physical design will be more essential to impact the device's usability.

However, this study did not extend to the degree to find the exact dimensions of the mobile devices which will lead to the most optimal usability, because most mobile devices which support e-reader functions are of the similar sizes of iPhone, iPad Mini or iPad. Determining exact size thresholds would require the availability of other comparable devices and thus require additional future studies..

Other factors

The study shows some other factors that impact the usability of mobile devices for scholarly reading, one most prominent of which is the device weight. It is inevitable that with the growth of the screen size, the weight will increase correspondingly. Some participants mentioned that when the screen size is large enough and does not affect their reading workflow, the portability and convenience, distinguishes mobile devices from traditional electronic devices such as laptops, becomes more important. For those who favored iPad Mini most, they thought iPad Mini combined the easy reading from iPad with the convenient portability from iPhone, and should be regarded as the most optimal mobile device to use for scholarly reading. In contrast, iPad is more cumbersome. The study's observations on participants' reading behaviors also indicated that they tended to change their postures of holding the iPad more frequently than the other two devices. Also, half participants chose to lean the iPad on external supports, such as their legs or the table, in order to release the pressure of holding the device by hands.

However, there still exist some other participants who claimed that particularly for intensive scholarly reading, the screen size was still the most essential factor and the larger the better.

Other factors that were commented included device thickness, glare of the screen, device edge design, easy interaction, previous use habits and the Kindle App interface. In summary, despite of the light weight and portability of iPad Mini, one thing worth noting is that neither the screen size nor other factors has caused significant differences in terms of the usability of iPad and iPad Mini. Users held different opinions about their preferences towards both devices, though they all had a negative feedback towards the usage of iPhone.

Recommendations for possible improvements

(1) Adding table of contents and page numbers

Looking at overall picture (based on the interview and survey results), a majority of participants were aware of the difference between leisure reading and scholarly reading. Compared with articles for leisure reading such as novels or short stories, scholarly articles often call for more users' attentions, easier interaction with e-book devices, and aids from external functionalities such as annotation tool and navigation bar. Participants were also willing to see a continuous block of content shown on the same page, so that they did not need to flip the page back and forth for searching or verifying. In this regard, the smaller amount of content per page and the larger number of pages for each article on iPhone make this device a less desirable one particularly for scholarly reading.

Two improvements were mentioned by the participants to address this issue – adding table of contents and page number. Adding these might help mitigate these issues by providing readers a clearer sense of the overall article structure, how much content

they have read and how much is left to read. They could also better estimate their reading progress if provided the current page number along with the navigation bar. The table of contents can also allow readers to quickly and directly move to arbitrary sections they are interested by clicking that particular section links in the table of contents, instead of flipping linearly through the pages.

(2) Developing advanced tools to fit texts and images on small screens

The author used the open-source software called “k2pdfopt” as well as manual work to convert the PDF formatted articles into e-book device readable versions. However, three disadvantages still exist using this method: First, this method managed to reflow the texts to fit into devices with different screen size with appropriate font sizes and formats. However, no way has been found to reflow the display of images, tables and figures other than manually changing their original formats. In this study, the author reserved the original image formats for all three devices to control this factor, and as a result the display of images on iPhone received the most negative feedbacks compared with that of iPad and iPad mini, and the display of texts on iPhone.

Second, the software did not support generating new versions of article format from two-column PDF files. It would regard all files as single column and the multiple column articles’ contents will be broken and unreadable while converting. This significantly hindered the real usage of converting scholarly articles for reading on mobile devices, as a large proportion of scholarly articles are in two-column formats.

Third, the current development version of this software still couldn’t guarantee one hundred percent accuracy. After converting the articles, the users will need to reread

it again to ensure it has been formatted correctly. Under this circumstance, it is almost impossible to apply this version into read life due to those current issues that need to be solved immediately.

An intermediate solution would be to have available more advanced tools to enable the optimal display of texts and images of scholarly articles on mobile devices. The better and longer term solution is to use formats such as XML that properly separate content from presentation formatting and allow reflowing the content to different presentations through style sheet type formatting. Otherwise, using currently available software, it is difficult to process articles for easy robust viewing on smartphones.

(3) Rotating screen when displaying on small screen sizes

Apart from building advanced tools for better automatic conversion of scholarly articles, another possible solution for displaying images and tables on iPhone is to rotate the screen and read in a landscape mode. As shown in Figure 8, the first and the second pictures are the rotated display effects, whereas the third one is the original horizontal mode of the same contents. More than half of the participants prefer the landscape mode because the text and image sizes are larger which allows faster and more effective reading. However, they still believed the performance is still less desirable than iPad and iPad Mini. Two participants thought rotating the screen on iPhone did not improve the device usability too much, because although the text and image sizes became larger, the contents each page were even less, which made them harder to understand the articles with enough contexts for once.

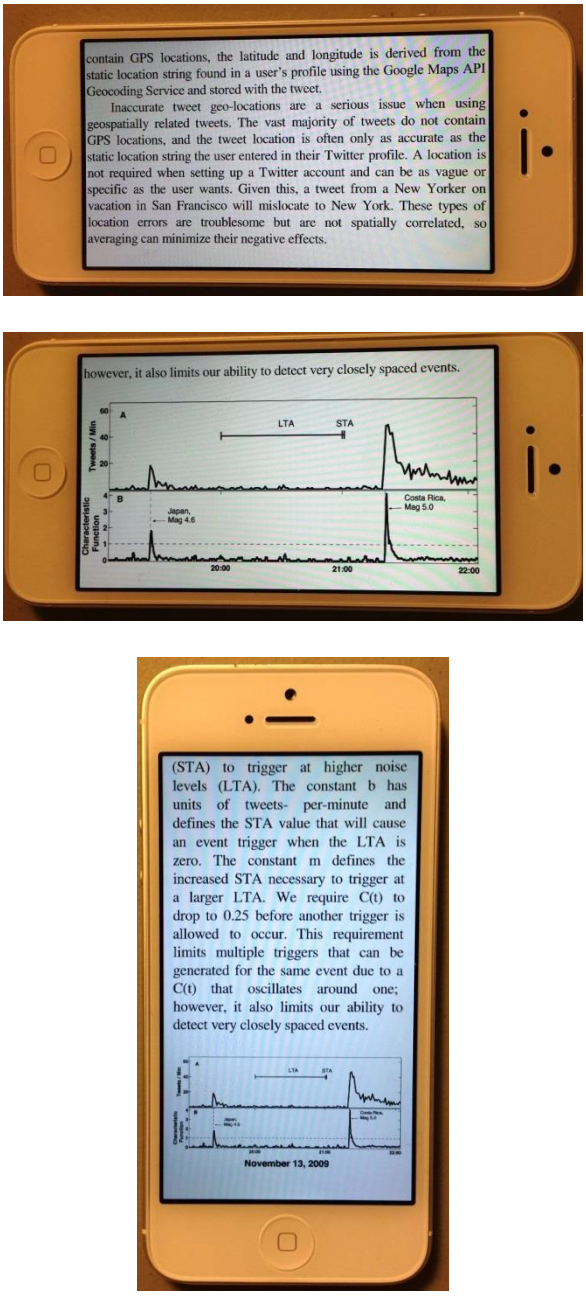


Figure 8: Comparison between landscape and portrait mode on iPhone

It is interesting to note that 8 participants believed that the landscape mode was worse than the portrait one due to the following commented reasons: 1. They were not used to reading on landscape mode, which was dramatically different from reading an actual book. 2. Reading on landscape mode would normally require the readers to hold

the device with two hands because of its longer width. It decreased the portability of the small device and made it even less desirable to use.

Therefore, it is still hard to determine whether reading scholarly articles in landscape mode on iPhone will significantly increase its usability. It should be regarded as a feasible way to enlarge the size of texts and images on small screen, but its real effects on usability still remain unknown.

(4) Physical design improvements

Another technical issue arises from the physical design of the mobile devices, i.e. the weight and the thickness. Obviously, these two factors often grow proportionally with the increase of screen size for mobile devices. Yet, one thing worth noting is whether the decrease of weight and thickness of iPad will lead to its better usability than iPad Mini. For instance, this study chose to use iPad 1st generation and iPad Mini 1 as the mobile devices for usability test. Will the results significantly differ if the study used iPad Air instead? The weight and thickness of iPad Air (469g, 0.30 inch) are only about 2/3 of those of iPad 1st generation (680g, 0.50 inch), but iPad Air is still thicker and heavier than iPad Mini. Further research may be conducted to investigate whether differences in weight and thickness affect these results for a given screen size.

(5) Adding annotation functionality with high performance

This study did not test the annotation functionality used on mobile devices for scholarly reading; yet, about half participants mentioned this issue as related to their preferences towards the mobile devices. It has also been regarded as another reason that

mobile devices may not suitable for scholarly reading. They all believed that the larger screen size is, the more suitable the device is for making annotations. Also, some of them mentioned that typing comments using touch screen with fingers is really slow, and it will be better if external equipment such as keyboard and mouse is supported for annotation.

Based on the author's preliminary research, no reading Apps have been found which specifically support full annotation functionality. Some of them can recognize texts on pdf file and support highlight, but seldom can allow intense annotations. Therefore, another possible recommendation to increase the usability of mobile devices for scholarly reading is to develop Apps with high performance of annotation functionality.

Conclusions

This study reveals the usability of e-book mobile devices for scholarly reading, with a particular focus on the impact of screen sizes. The devices used in this study include iPad 1st generation, iPad Mini and iPhone 5. A set of issues related to usability and user preferences was uncovered, and recommendations for responding to these issues through good design were derived.

The study concludes that the usability of iPad and iPad Mini to display both texts and pictures for scholarly articles does not have significant difference; however, their usability is significantly better than that of iPhone. The screen size is a major and essential factor affecting usability when it is smaller than a certain level (in this study, the

size of iPad Mini), but becomes less significant compared with other factors like weight and thickness when it is larger than this level.

Such results reveal that some concerns are difficult to resolve adequately with current technology. Users would like screens that are large enough to read from comfortably, but do not want the associated bulk and weight. They want to read from screens as effortlessly as they do from paper, making notes and marks anywhere they like, and flicking through the pages naturally, browsing and glancing, etc. Continuing development in mobile technologies (lighter weight tablets, larger display smartphones) may improve performance and user satisfaction when using these devices for scholarly reading.

Several recommendations for possible future improvements have been derived from this study, most of which aims to increase the usability for devices with small screen size such as iPhone. They include but are not limited to:

- Adding table of contents and page numbers
- Developing advanced tools to fit texts and images on small screens
- Rotating screen when displaying on small screen sizes
- Physical design improvements
- Adding annotation functionality with high performance

This study aims to draw greater attention to the impact of screen size of mobile device in academia and industry, and contribute to possible future improvements of e-book mobile device's design. This study also aims to raise awareness of the necessity of investigating the potentials of using mobile devices for scholarly reading.

Limitations

The foreseeable limitation for this study is that the screen resolutions on three mobile devices are not fully controlled to be exactly the same, which may impose slight bias on the study result. Due to the equipment limitation, the mobile devices that this study would use are first generation iPad (released 2010), first generation iPad mini (released 2012) and iPhone 5 (released 2012). Although three of them are all using LED display technology of their screens, the display resolutions are different due to their release date. Besides, the first generation iPad will be 0.5cm thicker than the other two devices. The slight physical difference of the three devices may have some impact on usability results. It may be subject to further investigation.

Another limitation is the selection of sample subjects in this study. This author chooses to recruit graduate students as the study subjects. Although this group is the foreseeable frequent users of e-book reader and needs to read intense research articles, the result of this study is not generalized to other groups.

What's more, another limitation is the technical limitations using the k2pdfopt tool to convert and reflow the articles from their original PDF format into formats appropriate for the mobile devices, which did not allow for an easy way to handle modifying the original formats of images, especially figures or diagrams.

Bibliography

Aaltonen, M., Mannonen, P., Nieminen, S. & Nieminen, M (2011). Usability and compatibility of e-book readers in an academic environment: A collaborative study. *IFLA Journal 2011* 37: 16. DOI: 10.1177/0340035210396775

Allmang, N.A. & Bruss, S.M. (2010), "What customers want from Kindle books", Online, Vol. 34 No. 1, p36-9.

Connell, C; Bayliss, L & Farmer, W. (2012). Effects of eBook Readers and Tablet Computers on Reading Comprehension. *Int'l J of instructional Media*. Vol. 39(2)

Cox, J. (2004). E-book: challenges and opportunities, *D-Lib Magazine*. 10(10) 1082–9873 (ISSN 1092-9873).

Dillman, D. A. (2007). *Mail and Internet Surveys: The Tailored Design Method* (2nd ed.) Hoboken, NJ: John Wiley.

Gibson, C; Gibb F (2010) An evaluation of second-generation ebook readers. *The Electronic Library* Vol. 29 No. 3, 2011. p303-319

Gupta, S.; Gullett-Scaggs, C. (2010). Would Students Benefit From Using eBook eReaders in Academic Program? *Proceedings of the Southern Association for Information Systems Conference, Atlanta, GA, USA*

Heikkilä, Harri (2011). eReading User Experiences: eBook Devices, Reading Software & Contents. *eReading Media Use, Experience & Adoption*. p13.

Herther, N.K. (2009), "Kindle DX: Amazon's latest eBook reader", Information Today, Vol. 26 No. 9, p26-27.

Kang, Y.; Wang, M.; Lin, R. (2009). Usability evaluation of E-books. *Displays*. 30 (2009) p49-52

Kim, R. (2009) E-books read well on smart phones. *San Francisco Chronicle*.

Lam P., Lam S.L., Lam J., & McNaught C. (2009). Usability and usefulness eBooks on PPCs: How students' opinions vary over time. *Australasian Journal of Educational Technology*, 25(1), 30-44.

Landoni, M. & Hanlon, G. (2007), "E-book reading groups: interacting with e-books in public libraries", *The Electronic Library*, Vol. 25 No. 5, pp. 599-612.

Li, C., Poe, F., Potter, M., Quigley, B. & Wilson, J (2011). UC Libraries Academic e-Book Usage Survey. University of California, Springer, California Digital Libraries.

McNamara, Carter (2006). Overview of Methods to Collect Information. Retrieved from http://managementhelp.org/businessresearch/methods.htm

Marcial, Laura (2011). Moving beyond the desktop: Searching for information with limited display size and interaction techniques. Ph.D dissertations. Retrieved from http://ils.unc.edu/~wildem/ASIST2011/Marcial-proposal.pdf

Mentch, M. (2010), "Amazon Kindle DX pilot results", available at: www.case.edu/its/itac/content/assessment/images/kindle%20pilot%20white%20paper.pdf (accessed 19 October 2011).

MobiThinking (2013). Global mobile statistics 2012 Part D: Consumer mobile behavior. MobiThinking.com. http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats/d#mobilebehavior

Pattuelli, M.C. & Rabina, D. (2010), "Forms, effects, function: LIS students' attitudes towards portable e-book readers", Aslib Proceedings, Vol. 62 No. 3, p228-244.

Princeton University (2010), "The e-reader pilot at Princeton", available at: www.princeton.edu/ereaderpilot/eReaderFinalReportLong.pdf (accessed 19 October 2011).

Rauch, M. (2011). Mobile Documentation: Usability Guidelines, and Considerations for Providing Documentation on Kindle, Tablets, and Smartphones. *IEEE*. 9778-1-612-84- 779-5/11

Richardson, J. (2011). E-book readers: user satisfaction and usability issues. *Library Hi Tech*. 30(1) 2012. p170-185.

Rowlands, I., Nicholas, D., Jamali, H. R. & Huntington, P (2007). What do faculty and students really think about ebooks? *Aslib Proceedings* 59, 6, p489-511.

Thayer, A; Charlotte P. Lee; Linda H. Hwang; Heidi Sales; Pausali Sen; and Ninad Dalal (2011). The Imposition and Superimposition of Digital Reading Technology: The Academic Potential of E-readers. *CHI 2011*.Vancouver, BC, Canada

Wildemuth, B. M. (2009). Application of social research methods to questions in information and library science. Westport, CT: Libraries Unlimited Press.

Wilson, R. & Landoni, M. (2001) Evaluating electronic textbooks: a methodology. In: *Research and advanced technology for digital librairies* :5th European conference, ECDL 2001, Darmstadt, Germany, September 2001 proceedings.

Wilson, R. (2002). The "Look and Feel" of an Ebook: Considerations in Interface Design. SAC 2002, Macirid, Spain.

Wilson, R. (2003) E-book readers in higher education. *Educational Technology and Society*, 6 (4). ISSN 1436-4522

Appendix I: Kruskal-Wallis test on survey questions(1-5) results

Did this device enable the QUICK (speedy) performance for reading journal articles?						
	Ipad vs. iPad mini		iPad vs iPhone		iPad mini vs iPhone	
texts	H	0.321535	H	6.537415	H	7.921875
	D	0.803626	D	0.90317	D	0.914188
	adjusted H:	0.400105	adjusted H:	7.238301	adjusted H:	8.665477
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.527035	P value:	0.007136	P value:	0.003243
Figures, pictures, tables	H	1.965986	H	23.78072	H	17.86777
	D	0.898393	D	0.955221	D	0.952399
	adjusted H:	2.188336	adjusted H:	24.8955	adjusted H:	18.7608
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.139059	P value:	6.05E-07	P value:	1.48E-05
Overall	H	0.089392	H	14.70918	H	11.22715
	D	0.866967	D	0.916576	D	0.927323
	adjusted H:	0.103109	adjusted H:	16.04797	adjusted H:	12.10705
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.74813	P value:	6.18E-05	P value:	0.000502
Does interacting with this device for reading journal articles require a lot of mental effort?						
Texts	H	0.002657	H	6.380208	H	4.642963
	D	0.801346	D	0.896385	D	0.905829
	adjusted H:	0.003316	adjusted H:	7.117709	adjusted H:	5.125649
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.954079	P value:	0.007633	P value:	0.023575
Figures, pictures, tables	H	0.535821	H	11.08939	H	7.185374
	D	0.88287	D	0.915274	D	0.916576
	adjusted H:	0.606908	adjusted H:	12.11593	adjusted H:	7.839364
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.435955	P value:	0.0005	P value:	0.005112
Overall	H	0.001701	H	9.312925	H	8.333333
	D	0.829624	D	0.897851	D	0.909574
	adjusted H:	0.00205	adjusted H:	10.37247	adjusted H:	9.161793
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.963887	P value:	0.001279	P value:	0.002471
Was it easy to navigate through the text and figures when reading the journal article?						
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.177407	P value:	2.09E-05	P value:	0.000914
Overall	H	0.000957	H	10.14892	H	9.566327
	D	0.778875	D	0.890686	D	0.901324
	adjusted H:	0.001228	adjusted H:	11.39449	adjusted H:	10.61363
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.972043	P value:	0.000737	P value:	0.001123

Overall	H	0.122874	H	20.20578	H	15.67347
	D	0.841728	D	0.898176	D	0.927323
	adjusted H:	0.145978	adjusted H:	22.49645	adjusted H:	16.90184
	d.f.:	1	d.f.:	1	d.f.:	1
	P value:	0.702409	P value:	2.11E-06	P value:	3.94E-05

Appendix II: Consent Form

The Impact of Screen Size:
A Usability Evaluation of Mobile Devices for Scholarly Reading

You are being asked to participate in a research study investigating the user preferences of scholarly reading to three popular mobile devices with different screen sizes: iPad, iPad Mini and iPhone 5. You are invited to participate because you are an adult above 18 with experience using multi-touch enabled devices. If you agree to participate, you will be one of the 20 participants in this study. Your participation in this study is completely voluntary. Your participation will be anonymous.

- WHAT THE STUDY IS ABOUT: The purpose of this study is to learn how the screen size of mobile devices affects people's preferences and interactive behaviors.
- WHAT WE WILL ASK YOU TO DO: You will be asked to read three scholarly articles on the following mobile devices: iPad, iPad Mini and iPhone 5. It will take you about 2.5 hours to complete the study. You will have regular breaks.
- RISKS AND BENEFITS: We do not anticipate any risks to you for participating in this study other than those encountered in day-to-day life. There are also no specific benefits to you, but you may become more accomplished at reading scholarly articles at different types of mobile interfaces.
- COMPENSATION: You will be compensated $25 for participating in this study.
- YOUR PARTICIPATION WILL BE CONFIDENTIAL: The records of this study will be kept private. In any sort of report we make public we will not include any information that will make it possible to identify you. Research records will be kept in a locked file/on a secure server; only the researchers will have access to the records.
- TAKING PART IS VOLUNTARY: Taking part in this study is completely voluntary. You may skip any questions that you do not want to answer. If you decide not to take part or to skip some of the questions, it will not affect your current or future relationship with University of North Carolina. If you decide to take part, you are free to withdraw at any time.
- IF YOU HAVE QUESTIONS: The IRB number for this study is 12-2544. The researchers conducting this study are Shumeng Gu and Bradley M. Hemminger. Please ask any questions you have now. If you have questions later, you may contact Shumeng Gu at shumengg@live.unc.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the University of North Carolina at Chapel Hill (UNC-CH) Behavioral Institutional Review Board, IRB_subjects@unc.edu, Tel: 919-966-3113. You may be given a copy of this form to keep for your records. This consent form will be kept by the researcher for at least three years beyond the end of the study.

STATEMENT OF CONSENT: I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Name:_____

Signature: _____

Appendix III: Questionnaire Survey

1. Demographic Information
1) What is your age?
2) What is your gender?
3) Are you experienced with multi-touch based mobile devices?

2. Usability survey

- Did this device enable the QUICK (speedy) performance for reading journal articles?

	Not at all	Slightly	Moderately	Very	Extremely
Texts					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Figures, Pictures, Tables					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Overall experience					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐

- Does this device enable the EFFECTIVE (successful) performance for reading a journal articles?

	Not at all	Slightly	Moderately	Very	Extremely
Texts					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Figures, Pictures, Tables					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Overall experience					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐

- Does interacting with this device for reading journal articles require a lot of mental (cognitive)

effort?

	Not at all	Slightly	Moderately	Very	Extremely
Texts					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Figures, Pictures, Tables					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Overall experience					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐

- Was it easy to navigate through the text and figures when reading the journal article?

	Not at all	Slightly	Moderately	Very	Extremely
Texts					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Figures, Pictures, Tables					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Overall experience					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐

- Has using these devices in this experiment changed your mind about whether you would use them for reading journal articles? (Note reverse scale)

	Not at all	Slightly	Moderately	Very	Extremely
Texts					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Figures, Pictures, Tables					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐
Overall experience					
iPad	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐

- Would you use this device to read journal articles in the future?

	Before Experiment			After Experiment		
	No	Maybe, depends on situation	Yes	No	Maybe, depends on situation	Yes
iPad	☐	☐	☐	☐	☐	☐
iPad Mini	☐	☐	☐	☐	☐	☐
iPhone 5	☐	☐	☐	☐	☐	☐

Appendix IV: Semi-structured Interview

1. Do you currently read articles on {iPhone, iPad-mini, iPad)? Explain which ones, and in what conditions do you use to read on them?

2. Which would be your favorite device to read on and why?

3. Did you think screen size was a major factor in your impression of device?

4. Are there any qualitative differences between the different displays when reading with respect to
   - Texts
   - Tables
   - Images/Figures

   and under what conditions make using this device difficult?

5. What is your overall impression of interacting with the three devices? Please rank them from them from most desirable to least, and also rate them from 1 to 10 (1=worst, 10=best), and explain why.

6. If the articles were formatted to be easy to read on these devices (reflowed single column) and you had good interface annotation etc , and you already had all three devices, would you read on the devices {iPhone, iPad-mini, iPad)? (be sure to take **out** the considerations of cost etc).

7. Summarize your overall likes and dislikes in performing the reading tasks. (and/or is there anything else you'd like to share about using the devices?).

Appendix V Article Assignment Table (11 articles in total)

Subject #	Device1	Device2	Device3	Paper1	Paper2	Paper3
1	iPad	mini	phone	10	9	8
2	phone	mini	ipad	1	2	3
3	phone	ipad	mini	5	7	6
4	mini	iPad	phone	10	11	9
5	mini	phone	iPad	8	7	9
6	iPad	phone	mini	11	9	10
7	phone	mini	ipad	7	5	6
8	phone	mini	ipad	4	8	9
9	phone	mini	ipad	10	11	1
10	phone	mini	ipad	2	4	3
11	phone	ipad	mini	8	10	9
12	phone	ipad	mini	11	2	1
13	mini	iPad	phone	4	5	3
14	mini	iPad	phone	7	8	6
15	mini	iPad	phone	2	3	1
16	mini	phone	iPad	5	4	6
17	mini	phone	iPad	11	10	1
18	mini	phone	iPad	3	2	4
19	iPad	mini	phone	7	6	5
20	iPad	mini	phone	5	4	3
21	iPad	mini	phone	2	1	11
22	iPad	phone	mini	8	6	7
23	iPad	phone	mini	3	1	2
24	iPad	phone	mini	9	7	8