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MOBILE SYSTEMS

The Effect of Screen Size on Mobile Phone User Comprehension of Health Information and Application Structure: An Experimental Approach

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Abstract This research analyzes the impact of mobile phone screen size on user comprehension of health information and application structure. Applying experimental approach, we asked randomly selected users to read content and conduct tasks on a commonly used diabetes mobile application using three different mobile phone screen sizes. We timed and tracked a number of parameters, including correctness, effectiveness of completing tasks, content ease of reading, clarity of information organization, and comprehension. The impact of screen size on user comprehension/retention, clarity of information organization, and reading time were mixed. It is assumed on first glance that mobile screen size would affect all qualities of information reading and comprehension, including clarity of displayed information organization, reading time and user comprehension/retention of displayed information, but actually the screen size, in this experimental research, did not have significant impact on user comprehension/retention of the content or on understanding the application structure. However, it did have significant impact on clarity of information organization and reading time. Participants with larger screen size took shorter time reading the content with a significant difference in the ease of reading. While there was no significant difference in the comprehension of information or the application structures, there were a higher task completion rate and a lower number of errors with the bigger screen size. Screen size does not directly affect user comprehension of health information. However, it does affect clarity of information organization, reading time and user's ability to recall information.

Keywords Mobile phones · Screen size · Comprehension · Usability · Retention

Introduction

With more than 1 billion smartphones and 100 million tablets around the globe, the adoption of mobile technologies continues to grow at an accelerated rate. [1]. Within healthcare, Mobile health (mHealth) is a growing field that enables applications, sensors, electronic resources and remote monitoring devices to improve healthcare delivery [2]. Different mobile technologies can be used among clinicians, payers, life sciences companies, and consumers. Hospitals can utilize mobile technology to improve communication and information exchange among staff, referring physicians, patients and visitors. In addition, health professionals can use mHealth in diagnostics and decision support. Moreover, mHealth can improve billing services, scheduling, asset management, and clinical trial enrollment [3]. Although mHealth studies and evaluations continue to grow, little is known about the impact of mHealth technologies on how users process health information.

This paper examines the impact of mobile phone screen size on user comprehension of health information and application structure. The motivation for this research is that downloadable health applications for mobile devices have been rapidly growing as an important and robust component

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of mHealth. According to a report from research2guidance, there are nearly two million mobile phone applications available across multiple operating system platforms in 2013, 97,000 of them are m-Health applications [4]. The number of mHealth applications has grown over the years; this growth is predicted to exceed 23 % annually over the next 5 years [5]. This research is also motivated by the recognition of a growing concern about the benefits and harms mHealth might cause and the fact that the use of mHealth applications by consumers have not been tested for efficacy, efficiency or credibility, of patient safety, accuracy and quality. Additionally, this study is motivated by the paucity of research on the effect of the mobile phone screen size on user comprehension of the health information content and structure.

These recent developments and motivations in mHealth applications raise the question: What is the impact of screen size on how health information is processed by the user? Usability of mHealth mobile applications, especially in terms of the comprehension of information based on screen size has garnered interest over the years. However, the literature is both limited and inconclusive on the benefits and harms of these applications. On one hand, health professionals and patients alike appreciate the technology. On the other hand, the efficacy, efficiency and the credibility of the information provided, particularly how the user processes health information is unknown as this is affected by many factors, including screen size.

Specifically, we ask the questions: (1) Does mobile phone screen size affect user comprehension of information and the application structure? (2) Which phone size (small, medium or large) allows the user to focus more on the content, collect more information and read easily, display an appropriate amount of the information at the same time and helps the users effectively recognize and navigate different elements of the application? Thus, the specific aims of this paper are to examine whether there is a difference between small, medium and large screens of mobile phones that affect the usability regarding the comprehension of the content and the application structure. We also examine the relationship between phone screen size and user focus on the content, readability, ease of display of information and effective recognition and navigation of different elements of the application. Thus, this paper contributes to the literature on the effect of the mobile phone screen size on the user comprehension of the content and structure of health mobile applications.

Background

Today, mobile health technologies, including mobile phones, play a significant role in the delivery of healthcare services. The use of mobile phones offers great opportunities to enhance patient self-management by delivering education,

monitoring, and feedback between patient and healthcare providers. A systematic review was conducted to assess the effect of mobile phone interventions in raising patients' health outcomes. The study focused on improving patients' knowledge and management of their disease. The study presented 18 studies that measured health outcomes for persons with diabetes such as improvement in health status, change in behavioral and clinical development. It was found that there were improvements in patient health outcomes because of the mobile phone intervention by enhancing patients' knowledge and self-efficacy which improved self-management of health behaviors [6].

Physicians too can use mHealth to monitor patients remotely and engage patients in preventive health. Patients in turn use mHealth applications to manage chronic diseases or improve access to healthcare services. As the possibilities of using mHealth applications continue to expand, more focus on studying the usability of mHealth products is needed [7].

In 1989, Richardson, Dillon, and McKnight conducted a usability study to measure how the user will interact with the mobile device system based on a the variety of variables such as interface design, application performance measures, as well as ease-of-use and user attitude. The study found that one of the significant challenges for evaluating usability of the mobile application was the small screen size, which significantly impacted the visibility of data in the application [8].

As the use of small devices become more widespread, screen size of mobile phones can affect text display, making it difficult for users to conduct tasks. In the 1980s and early 1990s, much of research work was focused on the number of text lines that were done to test the usability, the readability and the comprehension of information displayed on small screens. Richardson, Dillon, and McKnight, for instance conducted two separate experiments one of which used 3500 texts that were displayed on a 20 and 60 line display window. Participants were asked to read the texts and then summarize the main ideas from which comprehension scores were measured. The other experiment was conducted to measure the user performance of navigating the text and searching for text words on the screen sizes of 20 and 40 lines. Both experiments found that the performance and comprehension rates in the smaller screens were as good as in the larger screens [8]. This result agrees with Duchnicky and Kolers study that also focused on text readability. The study concluded that reading text from a large screen was 25 % faster than a smaller screen. They also found that the comprehension rate of the text did not vary based on different screen sizes [9].

Another study focused on investigating the impact of text size on reader comprehension. Three font sizes (12, 20, and 28-point) were used to measure its effect on reader comprehension. The study indicated that text size did not significantly affect reading comprehension although there were significant factors in terms of the reading comprehension such as speed

and displaying methods that impacted comprehension [10, 11].

In an experimental study conducted by Sanchez and Goolsbee examined text size and screen size on reader retention. The participants were divided into two groups: Participants in the large desktop group and another read from a virtual small screen. They were given three separate expository texts. They completed a recall test to measure their retention of each text that was measured. The study concluded that the small devices negatively affect retention of information [12]. In another study, Maniar et al explored objective performance of using different mobile screen size in video based learning. The study was conducted by using different screen size of non-touch mobile phones to teach university students by measuring the amount of information learned. The study showed that the large screen device was rated significantly higher than the small screen device. Similarly, the medium screen device was rated significantly higher than the small screen device and there was no significant difference between large and medium screen devices ratings [13].

Previous research has been done to explore the usability of small screen display and how those screens impact user comprehension regarding readability, visibility of text or gaining information. Comprehension of the content can be decided by reading speed, ease of reading character, comprehension and retention scores [14].

The conceptual framework for analyzing the impact of mobile phone screen size on user comprehension of health information comes from the literature that links usability of mHealth applications in terms of performance and comprehension of the health information and application structures to varied screen sizes [7, 10]. The conceptual framework also comes from the literature that link mHealth applications to usability in terms of minimizing efforts of use [5], enhancing health professionals communications and decision making [3, 6], enhancing patients' knowledge and self-efficacy that improve self-management behaviors [15], and assisting in preventive health and management of diseases [3, 16, 17].

Materials and methods

Our method involved designing and conducting an experiment by enrolling forty-five (45) female English translation students from the college of English Translation department who had already finished their medical terminology course to capture the impact of mobile phone screen size on user comprehension of health information and application structure. Ethical and scientific approval was recieved from King Abdullah International Medical Research Center Research Protocal Number RC12/065.

Specifically, we measured comprehension and retention of information, reading time, efficacy of completing the required

tasks, ease of finding the content through navigation with the window and from one window to another, clarity of information organization to check users understanding the application structure when conducting the tasks. In addition, errors score measurement was conducted for navigating to a wrong section or going out of the application to check the effectiveness of completing the tasks.

We randomly selected and divided the participants into three groups, each consisting of 15 members ($n=15$). In order to assign each participant to one of the three groups, we selected integer between 1 and 3 for each participant from the list. We used MathBook software (a random number generating program) that gave each participant a numerical sequence 1, 2 or 3, to divide them randomly to the three groups; each group consisted of 15 members. Then we selected from each group one participant to participate in one session of the experiment. Group 1 was given a large mobile screen size; group 2 was given a medium mobile screen size and group 3 was given the smallest mobile screen size. In the intervention, three different screen sizes of mobile phones similar in all technical characteristics were selected. The same technical features were used: Touch screen, operating systems capabilities and similar level of screen resolution (Samsung Note 10, Samsung Note 2 and Samsung Galaxy III mini) with an Android operating system.

In addition, we selected one prevention and learning diabetes application, Diabetes 101 by WAGmob [18] and downloaded it on the three mobile phones. We selected the most common used diabetes application due to the user friendliness of the interface and the plain language that can help users understand information about the disease easily. Moreover, the application displays the material in an organized manner that helps users to find what they are looking for easily with a clear and simple navigation model. Further, the application is compatible with all selected devices. Finally, we downloaded a screen recorder application on each mobile phone to capture audio (which is used in analyzing participants questions and comments) and on-screen activity to measure the time and number of errors.

A scenario was provided to participants to give them background on how to complete the tasks, why they are doing the tasks and introductory information they may need to complete the task. Then, the participants were given the same simple and short tasks consisting of selecting from the main menu the basic subject and then selecting from different options from the second level of the menu to go to a different window. Each window had a separate topic that can be navigated and paged. The participants were asked to find and search for five reading sets. Two of the selected reading sets contained a bullet point, two sets contained short passages (90 and 100 words), and the last set had longer passage (150 words) and consisted of numbers and terminologies.

After completing the tasks, participants completed a follow-up survey questionnaire, which consisted of rating their opinion regarding completing the tasks effectively, ease of reading characters, information organization, their knowledge and understanding of the content. The last step was ten multiple choice questions which were given to participants to measure comprehension and retention of the content: Five multiple choice were comprehension type of questions that consisted of definitions and some treatment steps and the other five multiple choice were retention type questions that contained numbers and terminologies.

We analyzed the results of the experiment using SPSS. In general, all tests were conducted at 95 % level of confidence, and 5 % margin error. Descriptive analysis summarized the data collected by the survey. Correlation tests were conducted to find the strength of the relationship between every two variables, dependent and independent. Kruskal-Wallis test was used to compare means for the three samples for small, medium and large screen size.

Results

General characteristics of participants

All participants were aged 29 years or less and they were all females. Approximately 73 % had no visual problem, approximately 76 % and 64 % of the participants had used the same screen size (that was randomly given to them in this study) and the same phone operating system before respectively.

Table 1 gives the socio-demographic and mobile phone-related characteristics of the study participants by phone screen sizes. As is highlighted, most of the characteristics did not vary significantly among the participants with different screen sizes ($p > 0.05$). Only the prior use of the same screen size was borderline significant ($p = 0.05$), where 87 % of participants in both the small and large screen size group had used the same size before while 53 % in the medium screen size group had experience of using the medium screen size before the study. Accordingly, the familiarity of using the screen size prior to this study can affect the usability of the screen size. This relationship is analyzed later in the report.

Perceptions of effect of screen size on various usability features

Approximately 67 % of participants who used the large screen size, 47 % from the medium screen size group, and 53 % from the small screen size groups strongly agreed that they were able to complete the tasks effectively. On the contrary, 6.6 % of the participants from the medium screen size group and 13 % from the large screen size group strongly disagreed on the question of finding the content easily by scrolling and

navigation. In adition, 60 % of participants who used the small screen, 33.3 % from medium screen size group and 46.6 % from large screen size group strongly agreed on finding the content easily.

Moreover, 80 % from the large screen size group, 93.3 % from the medium screen size group and 33.3 % from the small screen size group strongly agree on the ease of reading character, implying that the characters on the small screen size are less readable than other devices. In addition, 80 % of participants from the large screen size group, 60 % of participants from the medium screen size group and 66.6 % from the small screen size group strongly agreed on understanding the meaning of the content. Furthermore, 53.3 % from the large screen size group, 73.3 % from the medium screen size group and 86.6 % from the small screen size group strongly agreed on the organization of information of the application, implying that organization of information decereases with device screen size.

Next, we report the summary statistics of the difference of five domains (Effectively completing the task, Ease of finding the contents/navigation, Ease of reading characters, Ease of understanding the contents, Clarity of information organization) across the three group participants (large, medium and small screen users). Ease of reading characters was the only domain that was statistically significant. Ease of reading characters was better in the medium screen size group which had the highest mean rank score of 28.13. This difference was statistically significant ($p = 0.002$). The rest of the domains did not show any mean difference across screen size groups.

Comprehension and retention abilities

Data (for total score of participants, reading time, comprehension score, retention score, and number of errors) were analyzed by using Kruskal-Wallis Test. The results showed a significant difference between the three mobile screen sizes regarding the mean reading time ($p < 0.05$), with the lowest mean rank for the group with the large screen size. This indicates that the participants were able to read faster from the larger screen size and the reading time gradually increased as the screen size became smaller. The rest of the domains of learning abilities did not indicate any statistically significant meanigful results.

Association of screen size with other study variables

Strength and direction of association between various study variables and the screen size were also tested. There was a statistically significant and positive correlation between ease of reading characters and the mobile screen size ($r = 0.42$, $p = 0.01$), implying that the larger the size of the screen the easier the reading of the characters. However, there was a negative correlation between clarity of information organization and the mobile screen size ($r = -0.31$, $p < 0.05$), showing that the

Table 1   Socio-demographic and mobile phone-related characteristics of the participants (*N*=45) by screen sizes

Characteristics		Screen size, n (%)			
		Small (*n*=15)	Medium (*n*=15)	Large (*n*=15)	*p*-value
GPA in last qualification	<3.0	2 (4.4)	0	1 (2.2)	0.38
	3.0 – 3.75	2 (4.4)	0	1 (2.2)	
	3.75 – 4.5	9 (20)	9 (20)	10 (22.2)	
	4.5 – 5.0	2 (4.4)	6 (13.3)	3 (6.7)	
Presence of vision problems	Yes	4 (8.9)	5 (11.1)	3 (6.7)	0.71
	No	11 (24.4)	10 (22.2)	12 (26.6)	
Have used the same screen size as was given in study	Yes	13 (28.9)	8 (17.8)	13 (28.9)	0.05
	No	2 (4.4)	7 (15.6)	2 (4.4)	
Have used the same smart phone operating system as was used in the study	Yes	11 (24.4)	10 (22.2)	8 (17.8)	0.51
	No	4 (8.9)	5 (11.1)	7 (15.6)	

smaller the screen size, the more organized the information appeared. In addition, there was a negative correlation between reading time and the mobile screen size ($r=-0.36$, $p<0.05$) showing that the reading time was faster for the larger screen size group.

Discussion

The results of this experiment demonstrate that there is no major impact of mobile phone screen size on user comprehension of information which is consistent with the finding of Richardson, Dillon, and McKnight which indicated that there is no significant impact of screen size on user comprehension of information [8]. From Table 3 we observe that the mean of comprehension score was highest in small screen size. Furthermore, our results in Tables 3 and 4 indicate that there is a significant difference and negative moderate correlation between the three screen sizes and information reading speed. The fastest reading was in the large size screen, and the slowest reading speed was in the small group. This indicates that the reading speed is improved when a screen size becomes larger. In the results of Dyson study, which was very similar to our findings, the researcher concluded that reading from small font size was significantly slower than the larger one. However the author reported, "fonts that were read faster were generally read less accurately" [19]. Overall, our results, which are consistent with previous studies, reveal that reading speed is affected by screen size but information comprehension is not.

From the results, comprehension scores were highest for small screen size and lowest for large one. This might be explained by the slower reading speed in the small screen which might have given users more time to understand information better. There was no significant impact on user retention of information. However, the study gave opposite results than those shown in the comprehension. These results partially match the Sanchez and Goolsbee study which aimed to investigate the effect of text size and how information would be recalled with different display sizes [12]. Another interesting finding was observed from Table 2 regarding the readability attribute which is known as user ability to read comfortably and easily. Our study concludes that there is a significant impact of ease of reading characters. Reading characters was hardest in a small screen and the best reading was in the medium screen size.

Table 2 Summary statistics for questionnaire items by screen size

Questionnaire item	Mean rank score			*p*-value
	Small	Medium	Large	
Effectively completing the task	21.93	21.40	25.67	0.56
Easily finding the contents / navigation	26.70	20.70	21.60	0.35
Ease of reading characters	15.07	28.13	25.80	0.002
Ease of understanding the contents	22.70	21.33	24.97	0.64
Clarity of organization of information	26.70	23.43	18.87	0.12

Note. Minimum score was 11.8 and maximum score was 32.2

We observed that ease of reading characters was highest in the medium screen and reading speed was highest in the large screen. However, when familiarity with the content was taken into consideration, it improved reading proficiency as was shown in a previous study [20]. The clarity is another attribute of usability that we tested in this study. We investigated the clarity of the structure of the application in the three screen sizes to check if this affects the usability of the application. All the participants reported experiencing the application as user-friendly. We also investigated the participants' views regarding the organization of the health information. The results showed that there is a significant difference between the three devices with a moderate negative correlation between clarity of information, organization and screen size. Small screen size had the most clarity structure and the large one had the least. A previous study showed that a smaller screen size helped viewers focus more on content than larger screen sizes [21].

Our study also shows that more clarity of organization gives better results when searching for content. This result is in contrast to a study that found it was difficult for user to find information or to gain a general overview of the search result when using a small screen size [22]. In addition, this finding is consistent with another study where different line windows were used (12 and 24 line windows). They found that, there was no significant effect on hierarchical menu search times with the smaller screen [23]. These studies might suggest that with a simple tasks and clear structure there is no evidence of a negative impact of the small screen.

Other results, in Tables 2 and 3 show effectiveness of performing tasks. Effectiveness was measured through effectively completing the required tasks including navigation within windows to read the content as well as the number of errors. The results showed that there is no significant impact of the screen size. Nevertheless, the highest score was better in the large screen size, a result consistent with previous studies showing statistically significant differences in a task's completion time for reordering the scrambled text between large and small windows [24]. In addition, the error score showed

Table 3 Learning abilities for diabetes application based on screen sizes

Features	Mean rank			p-value
	Small	Medium	Large	
Total score of the participants	22.43	20.93	25.63	0.59
Comprehension score	25.00	22.37	21.63	0.75
Retention score	20.61	21.47	26.93	0.34
Error score	24.07	21.60	23.33	0.87
Reading time (minutes)	29.83	20.73	18.43	0.04

Table 4 Association of screen size with questionnaire items and learning parameters

Variables	Correlation with screen size	
	r_s	p-value
Effectively completing the task	0.13	0.39
Easily finding the contents / scrolling	−0.17	0.26
Ease of reading characters	0.42	0.01
Ease of understanding the contents	0.09	0.57
Clarity of information organization	−0.31	0.04
Total score of the participants	0.10	0.50
Comprehension score	−0.11	0.48
Retention score	0.21	0.18
Error score	−0.02	0.88
Reading time	−0.36	0.02

that there was no significant difference, which was reported in a previous study [25].

We also studied the familiarity to check if this attribute can affect the usability regardless of screen size especially ease of reading characters, effectively completing tasks and easily finding the content and clarity of information organization. There was a significant difference in the familiarity of the screen size. The lowest familiarity was for the participants of medium screen size, the small and large screens gave the same familiarity results. Ease of reading characters was highest in a medium screen size where this relation shows that the familiarity does not affect the readability. In addition, there was no impact of familiarity on other usability attributes. But this finding is contradicting to another study that was conducted on mobile learning and confirmed that users' familiarity with their mobile phone keep them from many potential usability problems [26].

Consistent with trends in the data, these findings raise several points. The reading speed is affected by screen size and it improves when the text size is increased and screen size becomes larger. Completing the tasks and understanding the application elements could be better in a large screen size. In addition, large screen help more in remembering and recalling information. Moreover, searching and navigating is not affected by screen size, but using a large screen size may improve the total performance of conducting the tasks. It seems therefore, that mobile phone screen size does not significantly affect user comprehension of information or application structure and our findings suggest that the screen size should not be the main concern of mobile phone usability. However, small screens lead to higher reading time and low tasks completion rate but it doesn't affect navigating simple menus or conducting easy tasks.

Conclusion

In conclusion, we revisited our original queries. Does mobile phone screen size affect user comprehension of information and application structure? Which phone size (small, medium, large) allows users to focus more on the content, collect more information and read easily? Which phone size displays an appropriate amount of the information and at the same time helps users effectively recognize and navigate different elements of the application? We considered these questions using an experiment and we found that the impact of screen size on user comprehension/retention, clarity of information organization, and reading time were mixed. We found that while screen size does not have a significant impact on user comprehension/retention of the content or the understanding of the application structure, it does indeed have significant impact on the clarity of information organization and reading time. Participants with a small screen size took longer time in reading the content. In addition, there was a significant difference in ease of characters reading which impact the user readability. There was no significant difference in comprehension of the application structures, but there were a low tasks completion rate and a high number of errors with small screen size.

We recommend conducting another experiment on application with many entry choices and more detailed and complex tasks to check on the impact of screen size on the user understanding of the application elements, which build on our previous work [27–33]. Also, a few of usability studies have been conducted on a multimedia application and there is a need to study the impact of screen size on multimedia applications. One major limitation of the study is that it included only one type of population, a university group, while an extended experiment that includes different groups and ages should provide better generalization of the study findings. Another limitation of the study is that male participants were not considered, as accessibility was an issue. We recommend the consideration of male participants to explore variation or difference with results from our experiment. One more limitation is that the language of the tested application was in English while the mother tongue of the study group participants is Arabic, a fact which could have a some influence on the results, especially text readability and information comprehension.

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