Determining the Effect of Menu Element Size on Usability of Mobile Applications

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Abstract. As smartphones gain more and more prominence in the life of the public and are increasingly used for daily tasks, the usability of mobile applications accessed through smartphones becomes a growing concern. This two-part study looks at the usability of such applications, focusing on how the size of menu elements affects the usability of mobile applications. In the first study, users were asked to complete an online questionnaire regarding their preferences in relation to smartphone use and mobile applications. In the second study, a non-parametric t-test was used to identify how the size of menu elements affects the usability of mobile applications. Users were asked to complete a specific task navigating two different prototype mobile applications by clicking specific menu options and answering questionnaires to document their experiences. The results of this study found increased element size does increase user preference and overall usability.

Keywords: Fitts's law, usability, navigation, smartphones, design, human factors, performance.

1 Introduction

Mobile computing is still a growing field, evolving with other technological advancements. As the popularity of mobile technology grows, determining the size of menu elements in mobile applications need to adapt quickly to ensure effective usability and findability for users. Many of the devices popular today involve touch-screen navigability, thus it has become vital that menu designs are easily accessible to users of these devices. Because the process of navigating through touch is a different experience from navigating through traditional user interfaces such as mice and/or keyboards input, there is a growing need to adjust menu elements in order to make touch navigation easier and more accurate. Designing optimal touch navigation requires taking into account multiple variables that switch from traditional computing to mobile computing. One of the variables that has gained prominent importance for touch navigation is the size of menu elements, which can affect the findability of the elements. The findability can be defined as the degree to which a user can find a specific object along with how well the environment in question supports navigation and the retrieval of information [12]. Findability is crucial to determining the usability of

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the factors in this study because limited screen size can make in more difficult to navigate through larger amounts of information [1, 4, 5, 6, 9], especially given contextual and cognitive [13] limits on the user, when navigating in a mobile platform.

This paper introduces an experimental study investigating on determining the effect of menu element size on mobile applications. The goal of the study is to determine how menu size affects both findability of a mobile application and how it can be optimized to increase effectiveness and efficiency in users' task performance and perceived usability.

2 Background

Much research has been done regarding the relationship between the size of menu element and user performance that includes response time and accuracy [1, 4, 6, 19, 20]. Many of these studies [10, 15] take into account Fitts' law as a basis for analyzing and understanding user performance. Fitts' law is a theoretical model that explains the relationship between speed and accuracy in aimed movements [7]. This model predicts what is called the index of difficulty (ID), which determines how difficult a task will be to achieve [7]. This model has been used as a platform for additional studies in the HCI field [8, 10, 15] in order to identify and explain the relationships between user tasks, interface designs and usability.

Hall et. al. conducted a study on the factors affecting performance on touch-entry systems [8], which built off of Fitt's law. They sought to determine the effect of size on accuracy for both seated and standing subjects. Their results found that the highest potential for target selection accuracy was with targets sized 26mm for seated subjects and 30mm for standing subjects.

Similarly, a study investigating pen-based selection strategies was conducted [15]. The study sought to find which of six two-state transition models were the best. Although the study found no significant different in selection rate or error time between the six strategies, they found target size did have an affect. After analyzing their results using Fitt's law, they determined the smallest maximum size to be 5 pixels (1.80 mm diameter circle) because "the difference in the ID (here, we consider error rates) will disappear" [15]. However, in almost all cases they found a significant effect on subject preference versus selection time and error rate, which there were no significant differences. This goes to show that both target size and perceived ease of use may have a greater effect on the overall success of a design than initial perceived.

In both studies [8, 15], it was determined that the proximity of targets may affect the accuracy of subject target selection. Although this is not a factor being analyzed in this study, it is important to note that it can be an important factor affecting the usability of touch-based interface designs.

Further research on mobile applications [16] has found location context and physical context are both extremely helpful when dealing with mobile design. As seen in the previous research by Hall et. al., physical context (i.e. seated or standing users), does have an effect on the usability of mobile applications [8]. Furthermore, the unique aspects of mobile devices allow for a design of mobile applications with consideration of the users' location context, in this case a "free" and "mobile" smartphone [8].

As demand for mobile applications continues to grow, it becomes increasingly useful to understand the key factors affecting their use and adoption. For example, Sarker and Wells describe their "Input, Process, and Output" model, which investigates a social analysis of how and why individuals accept and use mobile devices [18].

Models such as the Technology Acceptance Model (TAM) [22] and Diffusion of Innovation [17] describe how usability and findability have a significant impact on how users perceive mobile devices. This model also describes how changes to location and physical context can have a major impact. The TAM demonstrates how factors such as "Perceived Usefulness" and "Perceived Ease of Use" effect how and when a user will use a system [22]. The Diffusion of Innovation framework describes innovation is communicated to different types of users [17]. This framework is made up of five stages and five adopter categories. The concept suggests members in different adopter categories will react more or less favorably to an innovation than others based on their rate of adoption [17].

These concepts are tied to the users' experience of mobile navigation and directly affect research focusing on aesthetic variables in usability design. Research has shown aesthetic variables can either increase or decrease the perceived usability of mobile applications [2, 21]. For example, systems with higher aesthetic were perceived to be more usable than systems with less aesthetic [21].

Users' perception of the usability of data organization has also been shown to increase with increased aesthetics. Research has shown data organized in more aesthetically pleasing formats "performs relatively high in metrics of effectiveness, rate of task abandonment, and latency of erroneous response," showing aesthetics should not be merely an afterthought, but a direct factor in the perceived functionality of a site [2]. Additionally, as seen by Cyr, Head, and Ivanov, design aesthetics do "have a significant impact on perceived usefulness, ease of use, and enjoyment" [3].

While, as discussed, aesthetics have a positive effect on functionality for traditional websites, when applied to mobile applications, these effects can be greatly magnified. Therefore, significant factors in creating efficient menu elements as well as efficient and effective mobile applications are the size of the elements and perceived usability of the mobile application.

3 Objectives and Research Questions

The objective of this study was to discover how different menu element sizes affects the user's overall usability. The purpose of this study was to not only understand the effects on usability, but also understand how and why the users' perceived ease of use might change when specific menu element factors were manipulated. This research asked the following questions:

- How does the size affect the speed of findability on a mobile application?
- How does the size affect the perceived ease of usability of the overall site effectiveness on a mobile application?

4 Research Design

Two studies were designed in order to determine the effect of menu elements on the user's overall usability. Each study is described below.

4.1 Study One

Study One was designed to determine user preferences in regards to mobile device types and applications. A web-based questionnaire was created to collect qualitative data, in which users answered questions online. The questionnaires were formulated using a Likert scale. In the study, questions regarding participants' frequencies of use and task preference in regards to the access of mobile applications on a touch-based mobile device were conducted. The results of Study One were used in Study Two.

4.2 Study Two

Study Two was an empirical study and a lab-based experiment was conducted in this phase, in which all subjects participated in different tasks experiencing two different prototypes. A one factor within-subject design was used where the independent variable was a menu element size, and dependent variables were reaction time and accuracy. A total of three tasks were asked to participants in this study after taking into consideration the results of Study One:

Task 1: Finding the sign-in link
Task 2: Finding the link to news stories
Task 3: Finding the link to mail

When the user selected the link for each task, a brightly colored screen, coordinated for each task, was presented as a visual marker for future data collection. For instance, as each link was pressed, the screen on the phone would turn a specific color: purple for sign-in (Task 1), orange for news (Task 2), and red for mail (Task 3). This allowed for efficient determination of user task completion. All three tasks were counter balanced to remove bias from ordering.

Two questionnaires were used to determine participants' reactions to the tasks, and video recordings of each session were taken, showing each participant using the two prototypes. Time of completion was recorded from (1) when the user looked at the mobile device screen for each task to (2) when the screen of the phone changed to the appropriate color. Although this method of recording time completion may not be as accurate as other more advanced methods, it was chosen in order to not only show quantitative data, such as time completion and posture, but also qualitative data, such as body language and verbal feedback during each task.

In terms of procedure, participants in the study completed a preliminary questionnaire via a desktop computer. Participants then were asked to complete three navigation tasks on the mobile device. All participants used the same mobile device, in this case an iPhone. This phone was chosen based on the results of the first study. After the tasks were concluded, participants completed a second questionnaire via desktop

computer concerning the two prototypes and their subsequent menu elements. The video and audio for all sessions were recorded and participants' actions, comments, and suggestions were documented.

4.3 Participants' Criteria

The source of participants for both Study One and Study Two were males and females ages 18-25. Participants were required to have the following characteristics for both studies:

- Own or have used touch-based Internet enabled mobile device/s,
- Have at least a working knowledge of how to access and navigate websites from a touch-based mobile device, and
- Be able to read the English language fluently.

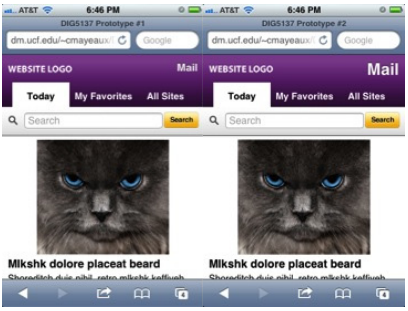

Fig. 1. Prototype A *(left)* Prototype B *(right)*. Screenshots of the main page of both prototypes used during this research.

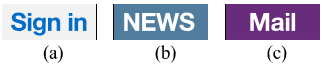

Fig. 2. Levels of Menu Element Aesthetic Treatments used in Study Two: *(a)* through *(c)* show colors of menu element fonts and background colors used in Prototype A through B. Font sizes varied between Prototype A and B; differences in size are not depicted or shown to scale.

4.4 Prototype

Two prototypes were created for use during Study Two, as shown in Figure 1. Both prototypes were modeled after the main page of an identical mobile application. The reason for this is to maintain consistency on other elements.

Overall color selections varied, and were selected purely for aesthetic purposes, as seen in Figure 2. Background color varied for all three menu elements: off-white for sign-in (Task 1), blue for news (Task 2), and purple for (Task 3). Font color also varied between menu elements: white for news (Task 2) and mail (Task 3), and blue for sign-in (Task 1). All menu elements were the same font style.

Prototype A was created first, then Prototype B was created as a replication of the same page but with the mail and sign-in link font size increased by 50%. The news link was the control and kept the same size. The levels of menu element treatments were also measured, as seen in Figure 3, which depicts the height and width of each menu element as well as the total area.

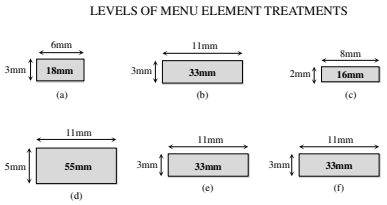

Fig. 3. Levels of Menu Element Treatments used in Study Two: (a) through (c) show dimensions of menu elements used in Prototype A; (e) through (f) show dimensions of menu elements used in Prototype B

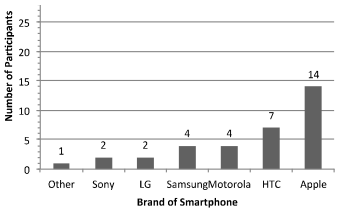

Fig. 4. Brand Smartphone used by Sample Population

5 Results and Discussion

5.1 Study One

A total of 51 participants participated in Study One. Their age ranged between 18 to 25. Data for mean (m) and standard deviation (sd) was not collected for Study One. The results showed 70.6% (36 out of 51) of participants owned a touch-based smartphone. Of the participants who owned a touch-based smartphone and choose to respond with additional comments in the questionnaire, 41.2% (14 out of 34) owned or used an iPhone regularly shown in Figure 4. This aided in determining the mobile device used in Study Two.

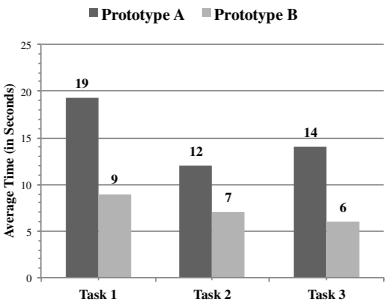

Fig. 5. Average completion time (in seconds) for Prototypes A and B on Tasks 1 through 3

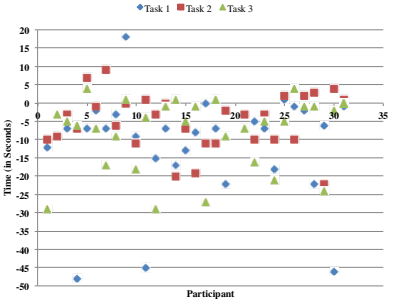

Fig. 6. Difference in time completion between Prototype A and Prototype B for Tasks 1 through 3. A decrease in completion time is depicted by negative values, and an increase in completion time is depicted by positive values.

The results of Study One also determined, 71% of the sample population owned a touch-based smartphone, 53% accessed a mobile application on their smartphone, and 39% accessed a web portal site through their smartphone on a daily basis.

The top five tasks accessed on web portal sites were "internet searches" (average rating of 3.53 out of 5), "sending an e-mail" (average rating of 2.71 out of 5), "checking the news" (average rating of 2.08 out of 5, "getting driving directions" (average rating of 2.06 out of 5), and "signing in to a personalized version of the site" (average rating of 1.94 out of 5). Of those five most popular tasks, three of them were also in the top five tasks never accessed. Those three tasks were "Signing into a personalized version of the site" (30 out of 51 participants never accessed), "Checking the news" (25 out of 51 participants never accessed), and "sending mail" (20 out of 51 participants never accessed).

5.2 Study Two

There were a total of 31 participants in Study Two. Their age ranged from 18 to 25 (m = 22, sd = 1). The size increase utilized in the Study Two's prototype design was determined by analyzing criteria utilized in several previous studies [3, 8, 15]. From this analysis, it was determined on average users spent more time completing the tasks on Prototype A (small menu element) and less time completing the tasks on Prototype B (large menu element). Average times decreased from 9 seconds to 19 seconds on finding the sign-in link (Task 1), 7 seconds to 12 seconds on finding the link to news stories (Task 2), and 6 seconds to 14 seconds on finding the link to mail (Task 3). Figure 5 and Figure 6 are visual representation of the results.

The most difficult task for participants was finding the sign-in link (Task 1) on the page with smaller menu elements (Prototype A). Out of 31 total participants, 13 participants (42%) said finding Task 1 was "somewhat hard" on Prototype A, as opposed to 12 (39%) who said Task 1 was "very easy" on Prototype B.

The second most difficult task for participants was Task 3, finding the link to mail on Prototype A. A total of 14 participants (45%) said Task 3 was "somewhat easy" on Prototype A, as opposed to 24 participants (77%) who said Task 3 was "very easy" on Prototype B. Task 2, finding the link to news stories, was similar on both Prototypes A and B with the majority of participants finding Task 2 "very easy" on both sites.

Although the news links did not change between sites, more participants found Task 2 easier on Prototype B. In addition, 20 participants (65%) found Task 2 "very easy" on Prototype B, while only 14 participants (45%) found it "very easy" on Prototype A. There was also a 20% increase in participants who felt Prototype B was "Very Easy", versus Prototype A. Finally, when asked which site participants preferred overall, 28 participants (90%) said they preferred Prototype B, and only 3 (10%) said they preferred Prototype A.

The average time of completion decreased by an average of 8 seconds with a 50% increase in font size. In addition, qualitative data collected in the form of two questionnaires shows a definite increase in user preference as well. The data in the table clearly supports previous research in association with the TAM, which describes how perceived usefulness and ease of use effect users [3, 22].

There are several potential reasons why user times decreased. One theory is that menu element size directly affected the users' speed of findability, and the quantitative data does support this showing a consistent decrease in completion time on all Prototype B tasks. This theory is supported by previous research, as described by Hall et. al. [8], Ren, et. al. [15], and many other researchers who seek to prove element size does have an effect on usability [10, 14].

Another theory is that because the tasks chosen were based user preference as described in the first study, the increased contrast in size between more frequently accessed links and less frequently accessed links increased the perception of ease of use. This theory is also supported by previous research, which states that the proximity between and number of elements on smaller mobile screens can have an effect on usability [8, 15].

Although we did not conduct research or testing specifically on the usability of different element locations, many participants commented on the location of the sign-in link. These participants comment that it was "unnecessarily hard" to find due to the unexpected location. This suggests that additional testing may be required to determine the effect of menu element placement on usability. The following are quotes from three different participants taken from the concluding questionnaire:

- "I would prefer the sign in button to be at the top,"
- "I think that the sign in link should be at the top of the page. Normally that is the first thing people would do on a website due to the fact that it is their own personal pages that most likely contain the information relevant to them,"
- "Increasing the size of the sign in link made it much [easier] to find but personally I think the sign in option should be near the top so frequent users can quickly get to it."

One participant even suggested commented: "It took me a minute or so to find [the link] in the [Prototype A], and it could be difficult for someone with very little experience with a iPhone," which suggests that the mobile device used may also have adversely affected their usability.

In addition, some users suggested that their increased times on Prototype B may have been a result of the use of Prototype A beforehand. Thus, additional testing may also be required to rule out the affect of repeated tasks on within-subject testing. The following are quotes taken from the concluding questionnaire in the second study regarding potential testing redundancy affecting their usability:

- "I did enjoy the larger font on the links that you had to find, but once you know where to look, it really doesn't matter the size of the font,"
- "It's easy to find things after you have already seen them,"
- "Once the steps were completed an initial time, it made it easier to repeat with a different prototype."

In addition, although all participants were seated during testing, video data collected did show participants using different selection methods. For example, some participants placed the mobile device on the table during use, while others held the device in their secondary hand. Some participants used their index finger to select menu elements and others used their thumb. Therefore, although one can compare previous

research and find that different methods of selection (i.e. thumb-based, pen-based, etc.) does indeed have some kind of effect on usability [8, 10, 11, 14, 15], additional testing may be required to rule out selection method as a determining factor in this particular study.

A specific sample population was selected for this study in order to eliminate any unnecessary confounding variables. The specific sample population requirements used in this study was chosen order to increase the possibility of finding a wide range of participants who already have a working knowledge of touch-based smartphones. As referenced in Rogers' Diffusion of Innovations model, this study was designed in order to narrow our research to a specific range of "adopter categories" in order to find a group of participants who would react favorably to the task of navigating mobile applications on touch-based mobile devices [17]. Furthermore, limiting the participants in this way allowed this study to have fewer confounding variables as well as some consistency in reference to the context of the participants (i.e. economic factors, social factors, etc.). These factors could inadvertently affect how the participants conceptualized and carried out presented tasks, as visualized in Sarker and Wells' "Input, Process, and Output" model, and affect the results in ways that are not being analyzed in this study [18]. For example, only one out of 31 participants voiced any concerns about using a mobile device they were unfamiliar with. This suggests that the other 30 participants were not affected enough by the specific mobile device used for it to affect their usability or perceived ease of use. However, additional testing is needed to verify whether specific sample populations and/or specific models of mobile devices used have an effect on usability.

6 Conclusion

This study has determined the effect of menu element size on usability of mobile applications in that the element size has a direct correlation to increased user preference and usability. Although additional information collected during the concluding questionnaire suggests supplementary factors such as menu element placement, proximity to other menu elements, reactive testing, mobile device model or brand, and sample population may come to play in determining overall usability, further research is needed to determine the effects of these factors on usability of mobile applications. As technology develops and the popularity of touch-based mobile devices increases, it is imperative that the mobile applications running on them take into consideration any changes to user's findability and perceived ease of use.

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