Effects of Touchscreen Device Size on Non-Visual Icon Search

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SUMMARY The purpose of this study is to investigate the effects of device size on non-visual icon search using a touch interface with voice output. We conducted an experiment in which twelve participants searched for the target icons with four different-sized touchscreen devices. We analyzed the search time, search strategies and subjective evaluations. As a result, mobile devices with a screen size of 4.7 inches had the shortest search time and obtained the highest subjective evaluation among the four devices.

key words: blind people, touchscreen, icon search, screen reader, user interface

1. Introduction

Smartphones are becoming more popular not only among sighted people [1] but also among blind and visually impaired people [2]. For blind people to use a touch interface device with no tangible key on its top, screen reader software that gives speech output of what is touched and the system’s response is installed by default. Devices with the iOS have the VoiceOver screen reader and those with the Android OS have the TalkBack screen reader. When a screen reader is turned on, it changes the gestures to control the device [3]. For example, touching or single tapping a key, button, etc. only leads to reading that object without activating it. The following double tap or split tap gesture activates the object.

In 2013, we conducted a blind ICT user survey to identify the problems in using touchscreen devices [2]. In the responses to the questionnaire, there were interesting comments from two respondents that the tablet was too large to use for a blind person (their devices were iPads). Concerning device size or key size, some researches have reported that smaller key sizes on software/virtual keyboards reduce the data entry speed and accuracy [4]–[6]. Although the above researches targeted sighted people, the same tendency may be derived from blind users, or touching small objects may become more difficult for them.

Now we have two propositions. One is that smaller key sizes on smaller devices lead to slow data entry, so these devices are less usable. The other is that large touchscreen devices are less usable for blind people. Thus, we hypothesized that there is an optimal device size for blind users to use devices effectively, i.e. to be able to touch the keys and buttons quickly and accurately.

Researches that deal with this relationship between device size or key size and usability for sighted persons do exist as cited before. However, to the best of our knowledge, there is no research that deals with device size and usability for blind people. Thus, we decided to address this issue. In the present study, we focus on the usability of icon search because this is the core action when using smartphones. We carried out an experiment in which participants searched for target icons on four different-sized touchscreen devices with the use of a screen reader (without seeing the screen). The usability was evaluated with the activity indices, i.e. search time and search strategies, and subjective rating.

2. Experiment

2.1 Participants

Twelve undergraduate and graduate students aged between 21 and 25, eleven males and one female, participated in the experiment. Sighted students were selected because this experiment was regarded as a preliminary experiment before having blind people as participants. They used smartphones in their daily lives; seven used iPhones, and five used Android devices. The sizes of their devices varied from 4 inches to 5.2 inches with a mean of 4.7 inches. They were paid for their participation.

This experiment was reviewed by the Research Ethics Committee, Faculty of Engineering, Niigata University and conducted with the permission of the Dean of the Faculty of Engineering.

2.2 Devices

Since iPhones are the most popular smartphones among blind users [2], we used four iOS devices: iPhone 5c, iPhone 6, iPhone 6 Plus, and iPad mini 2. Their display sizes are 4, 4.7, 5.5, and 7.9 inches, respectively.

2.3 Arrangement of Icons

For the iPhone 5c, iPhone 6, and iPad mini 2, 24 icons in total were arranged in four columns and six rows, excluding the four icons in the dock that is located at the bottom of the
only for the iPhone 6 Plus, 28 icons were arranged in four columns and seven rows. The location of each icon is represented by the vertical position followed by the horizontal position, with the top left icon as (1, 1) (Fig. 1). For the experiment, all the icons were named after fruits and vegetables. The arrangement of icons was randomized trial by trial.

2.4 Procedure

The experiment was conducted in a quiet room where the participant sat at a table. The devices to be tested were handed to the participant with the VoiceOver screen reader turned on. It was up to the participant whether to hold the device or to place it on the table and whether to use it either with one hand or both hands. Icon search tasks were performed in a fabric diffuser box (Photo Cube mini, Setworks Japan) so that the participant could not see the touchscreen. During the experiment, the hand movements of the participants were videoed. These videos were used to check the data recorded during the experiment and to analyze the participants’ search strategies.

The experiment consisted of four sessions. In each session, a different-sized device was presented. The number of presenting orders of the four devices, that is the number of permutations of four, is 24. To reduce order effects, the 12 participants were allotted to 12 out of 24 permutations in which four devices were presented in the first and second sessions three times each.

Each session consists of five sets. In each session for iPhone 5c, iPhone 6, and iPad mini 2, the user searched for 24 icons in one set and undertook 120 trials in five sets in total. In the session for iPhone 6 plus, 28 icons were searched for in one set, which amounted to 140 trials in five sets in total.

At the start of each session, a few icon search trials were performed as a warm-up. The strategies for searching for the target icons were not provided by the experimenter and were left to the participant. In each trial, the name and the coordinates of the target icon was read by the experimenter. This was done to simulate everyday smartphone usage; the user was supposed to remember the arrangement of icons that they use every day and know the location of the target icon. The time from the announcement of the target icon to the end of the search was measured by a stopwatch and recorded as the searching time.

Between sessions, there was a short break. After the four sessions, the participant was asked to rank the usability of the four devices subjectively and asked for comments on each device’s usability.

3. Results and Discussion

In all the trials, participants were able to complete the icon search task.

The participants’ device holding styles were classified into three categories: two-handed, one-handed, and on-the-desk. Five participants used two-handed holding style. With this style, icons were touched with one thumb on iPhone 5c, 6, and 6 Plus and with two thumbs on iPad mini (the thumb nearer to the target icon was used). Four participants used one-handed holding style. With this style, icons were touched with either the index finger, middle finger, or thumb of the other hand. Three participants placed the device on the desk and used their index finger(s) to touch the target icon.

3.1 Search Time

The average search time for 120 or 140 trials with one participant and on one device was calculated and treated as the participant’s search time datum.

Figure 2 shows the average search time across 12 participants by device. The error bars represent standard deviations. With any device, the search for the target icons took around 4–5 s on average. The average search time was the shortest with iPhone 6 and became longer as the display size became either larger or smaller. However, a non-parametric Friedman test did not show significant difference in search time ($S = 2.50, p > 0.05$).

3.2 Search Strategy

To understand the reason for the difference in search time by device, the videos were analyzed. As a result, the participants’ icon search strategies were classified into two basic types: “direct search” and “one-by-one search.” With the
direct search strategy, participants estimated the location of the target icon on the screen and moved their finger directly to that location. On the other hand, with the one-by-one search strategy, they moved their finger icon by icon, probably counting the number of icons, until they reached the target icon.

Both search strategies can be broken down into sub-strategies. The direct search strategy can be broken down into two substrategies based on whether the participant hit the target icon with the first touch or not. If he/she did so, the trial was categorized in “direct-hit search.” Otherwise, trials were categorized in “vicinity search” because the participants had to move their finger in the vicinity of the first touched icon for the target icon. The one-by-one search can be broken down into three substrategies based on the search starting point. In the “from-origin search,” the participant first placed their finger at the origin (1, 1) coordinate, that is the upper left icon. In the “half-direct search,” either of the row or the column of the target icon was touched directly, and then the participant moved their finger icon by icon along the row or column. In the “between-targets search,” the participant started the search from the previous icon’s location. These search strategies are illustrated in Fig. 3.

The proportion of each search strategy in each device is shown in Fig. 4. For all devices, direct-hit and vicinity search strategies occupied approximately 70%. This is likely to be due to the fact that sighted smartphone users tend to select icons directly in their everyday usage. For iPhone 6, the proportion of direct search strategies was larger than with other devices. In order to confirm this, the numbers of the direct and one-by-one search trials were put to a Chi-square test. It showed a significant difference in the number of each strategy ($\chi^2(3) = 9.13, p < 0.05$). However, a multiple comparison (a Chi-square test using the Ryans’ method) showed no significant difference between any pair of the devices. Then, the numbers of the direct-hit and vicinity search trials were put to a Chi-square test, too. It showed a significant difference in the number of each strategy ($\chi^2(3) = 14.47, p < 0.05$). A multiple comparison (a Chi-square test using the Ryans’ method) revealed that the number of the direct-hit search trials with iPhone 6 was significantly larger than with iPhone 5c and with iPad mini 2. That means that the success rate of direct search with iPhone 6 was higher than with iPhone 5c and with iPad mini 2.

Figure 5 shows the average search time calculated by strategy across the four devices. It illustrates that the direct-hit search strategy trials are the fastest. Therefore, the iPhone 6 device in which the proportion of direct-hit search is larger than other devices has shorter search time on average (Fig. 2).

3.3 Subjective Evaluation

Figure 6 shows the results of subjective evaluation of usabil-
ity. Each bar shows the number of participants who evaluated the usability of the device as either most usable, usable, less usable, or least usable. The iPhone 6 gained the most “most usable” and “usable” comments followed by iPhone 5c. The iPad mini 2 gained the most “least usable” comments. Interestingly, all devices gained both the most usable and the least usable rating.

This two-sided evaluation is explained by the 23 comments on the usability of the devices. Three of these comments were a comparison with the participants’ devices that they used everyday, and the other 20 comments were evaluations based on the size and weight of the devices. All the devices had both positive and negative comments (Fig. 7). This means the preference differs from user to user, and it is hard to draw one conclusion. Nevertheless, the number of comments concerning each device demonstrates that the iPhone 6 is the most usable and the iPad mini 2 is the least usable.

4. Conclusion

To explore the optimal device size for blind touchscreen users, we carried out an experiment in which participants searched non-visualy for target icons on four different-sized iOS devices. The results show that the iPhone 6, which has a 4.7-inch display, had the shortest search time, enabled the most direct search trials, and gained the highest subjective evaluation. This finding is useful for blind people and their supporters in choosing smartphone devices.

The present study with sighted students as participants was a preliminary one, and a new experiment with blind people as participants is under way. Its experimental results are expected to be more practical.

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References