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Accessible Button Arrangements of Touchscreen Interfaces for Visually Impaired Users

Takahiro Miura, Takashi Ohashi, Masatsugu Sakajiri, Junji Onishi, Tsukasa Ono
Institute of Gerontology, the University of Tokyo, Japan.
Graduate School of Technology and Science, Tsukuba University of Technology, Japan.
miu@.iog.u-tokyo.ac.jp, ot153202@cc, sakajiri@cs, ohnishi@cs, ono@cs .k.tsukuba-tech.ac.jp

Abstract

Regardless of the improvements of accessibility functions on touchscreen computers, they have some problems using touchscreen interfaces including smartphones and tablets. The reason includes the arrangements of accessible objects may differ in users' visual conditions because the manipulations under screen readers are different from those without screen readers, the characteristics of object arrangements on the touchscreen computers for the visually impaired remain unclear. In this paper, our objective is to clarify the accessible button arrangement features in smartphones for users with visual impairments. We studied these characteristics by evaluating reaction times and error rates in a memory experiment of a single button from some arranged buttons in a smartphone for visually impaired people under a screen reader condition. As a result, the performance of reaction time on a button selecting task with a single button increased as the number of buttons increased; buttons aligned more two-dimensional than one-dimensional allocations.

Keywords

Visually impaired people, touchscreen computers, accessible button arrangements.

Introduction

Touchscreen interfaces, such as smartphones and tablets, have recently become popular in the sighted people because of intuitive manipulation and high customizability. Most of these interfaces ensure accessibility for people with visual impairments via screen magnification software and screen reader functions such as VoiceOver (Apple iOS) and TalkBack (Google Android). As a result of the improvement of the accessibility functions, the accessibility environment for visually impaired people is gradually improving.

Regardless of these improvements, individuals with visual impairments have problems using touchscreen computers, since the manipulations with accessibility software differ from those of manipulation by sighted people. As a result, specialized learning materials and lecture courses for touchscreen computers are insufficient. The reasons include insufficient accessibility support of third-party applications, as with non-compliant screen reading and non-optimized buttons and these arrangements. These situations result from inadequate touchscreen application design guidelines for visually impaired people and a lack of clarity regarding of the conditions of touchscreen computer usage and a spatiotemporal manipulation. To ensure that accessible touchscreen computers for the visually impaired will become prevalent, it is necessary to investigate the specific interaction conditions between users with visual impairments and touchscreen computers.

In this study, our final objective is to embody the application guideline of touchscreen interfaces, such as smartphones and tablet computers. We mainly aim in this paper to clarify the accessible button arrangement characteristics in smartphones for visually impaired users. Our hypothesis is that the usability of 1- and 2-dimensional button arrangements under screen readers' conditions are not different in the case of a small number of buttons, but different in the case of a large number of buttons in visually impaired users.

Related work

The improvement of accessibility for the visually impaired is due to the researches and improvements in user interface (UI) designs. Recently, studies on the UIs of touchscreen computers for visually impaired people have been increasing. These studies can be classified into three main types: presentation methods to users, manipulation methods for users, and investigations of usage conditions. The presentation methods include auditory and/or tactile presentments for sensory substitution and display of additional information, using sound or speech (Ferati, Mannheimer, and Bolchini 9-16; Kennel, 51-56; Ross, and Blasch 193-200) stable guided tactile feedback (El-Glaly et al. 245-253; McGookin, Brewster, and Jiang 298-307) and dynamic tactile feedback (Benedito et al. 379-380; Yatani and Truong, 111-120; Yatani, Gergle, and Truong 661-670). The manipulation methods include pie menu applications tuned for easily browsing and selecting objects (Banovic et al. 120-129) and a slide rule that allows a user to select and input by a combination of continuous slide gestures (Kane, Bigham, and Wobbrock 73-80). The investigations include usability evaluations of objects such as buttons and icons as well as gestures for interacting with a touchscreen computer while using accessibility applications (Bragdon et al. 403-412; Kane et al. 273-282; Kane, Wobbrock, and Ladner 413-422). In addition to these investigations, some researchers have evaluated text input methods for screen readers (Bonner et al. 409-426; Southern et al. 317-326). Some of these results may now be reflected in touchscreen computer screen readers such as VoiceOver.

Apple provides an application design guideline for visually impaired iOS users (iOS Human Interface Guidelines). Applications developed along this guideline are accessible to visually impaired people using VoiceOver. Leporini et al. and Wong et al. reported on the usage situations for Italian and American visually impaired users using VoiceOver, respectively (Leporini, Buzzi and Buzzi 339-348; Wong and Tan, 646-650). Montague et al. investigated user situations for those with visual and motor impairments (Montague, Hanson, and Cobley 151-158). Kane reported preferable gestures in some cases by American visually impaired people (Kane, Wobbrock, and Ladner 413-422). They proposed guidelines for touchscreen interfaces for visually impaired users based on their results. Oliveira et al. presented the different demands about the various text entry methods of touchscreen display in visually impaired people (Oliveira et al. 179-186).Miura et al. investigated touchscreen computers usage and interaction situations for the Japanese visually impaired population (Miura et al. “Usages and Needs of Current Touchscreen Interfaces in Japanese Visually Impaired People” 2,927-2,932; Miura et al. Accessible Single Button Characteristics of Touchscreen Interfaces Under Screen readers in People with Visual Impairments” 369-376).

In summary, the application design guidelines and usage conditions for visually impaired users are being clarified and are now more specific. However, quantitative evidence for creating accessible interfaces are not sufficient, and particularly there is little knowledge regarding accessible button arrangements for visually impaired people. Clarifying these arrangements can enable UI developers to design accessible interfaces for beginners and experts with visual impairments.

Experiment

Participants

Ten visually impaired people (mean age: 24.6 ± 5.3) comprising five and five individuals with congenital total and partial visual impairments participated in this experiment. Nine of them had their own smartphones and used them over a year. Eight of the owners started to trace from the edge of the upper left while one of them from the edge of the upper right. All of the participants with total visual impairment had manipulated under screen reader functions including VoiceOver over three years while one of the participants with partial visual impairment had used a screen reader, but three of them had experienced to use VoiceOver over two years. Seven of them were right-handed while others were left-handed.

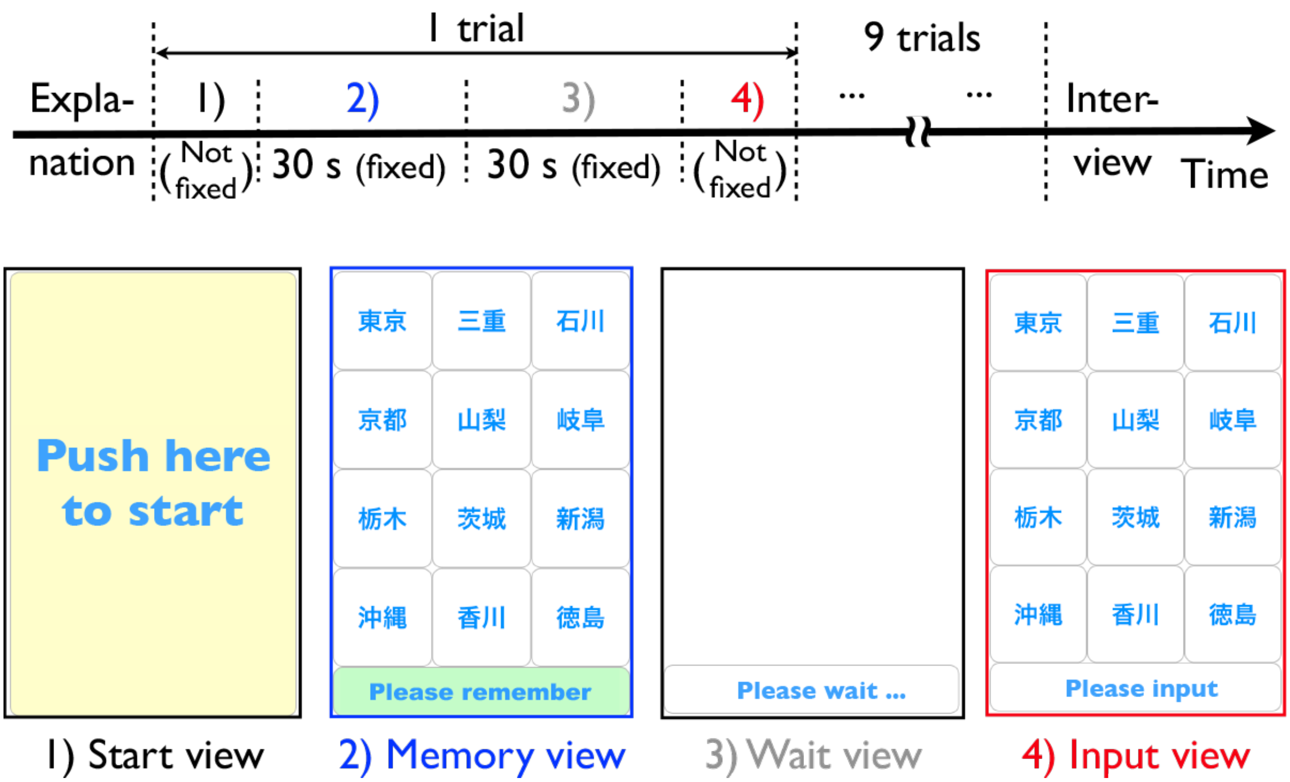

Fig. 1. Upper: Time protocol of the experiment. Lower: Overview of the experimental application.

Method

Experimental application

In this experiment, we developed an experimental application for a smartphone, and then discussed the differences of reaction time and error rate by the number of buttons and these arrangements. The experimental time protocol and overview of the application are shown in the upper and lower part of Fig. 1, respectively. This application presents 1) start view, 2) memory view, 3) wait view, and 4) input view successively. The development environment was Xcode 5.1.1 on Mac OS X 10.8.5, and we implemented to Apple iPhone 5s (OS: iOS 7.1 or 8.1). The contents of buttons were randomly generated from 47 prefectures in Japan (these are common in Japanese adults), and were read aurally by VoiceOver function when a user traces on the surface of a button. The application also presented the view transitions with implemented voices and sounds to a user for informing them to the transitions.

Procedure

The experimental procedure is explained along with the time protocol shown in the upper part of Fig. 1. First, the participants asked to hold the smartphone with their non-dominant hand and manipulate with their dominant hand. In this smartphone, the VoiceOver function was activated. Second, they were asked to tap the surface of 1) start view, and then watch 2) memory view 30 seconds. In this case, "tap" means double tap or split tap after tracing the touchscreen surface; these gestures correspond to a single tap, and are mainly used in the manipulation mode under screen readers including VoiceOver. At that time, the participants were asked to remember button arrangements. The condition of button arrangements were fifteen: three conditions of four buttons (4 × 1, 2 × 2, and 1 × 4 (vertically × horizontally)), six conditions of twelve buttons (12 × 1, 6 × 2, 4 × 3, 3 × 4, 2 × 6, and 1 × 12), and six conditions of twenty buttons (20 × 1, 10 × 2, 5 × 4, 4 × 5, 2 × 10, and 1 × 20), respectively. The reason that we selected these numbers of buttons is that four is the least square number that can check the difference of one- and two-dimensional arrangements, twelve and twenty are the number of buttons presented in Japanese character input methods.

In 3) wait view that was presented 30 seconds to the participants, they were asked to leave their manipulation hands from the screen. After the transition to 4) input view, they entered the recalled button as quick as they could. This procedure repeated ten times for each button arrangement. The participants did this task 200 times, and then were interviewed the difficult condition to memory and the strategy to memory and manipulate.

The experiment was carried out in a silent room for suppressing acoustic noise level and making the participants listen to VoiceOver's voices correctly. In addition, for checking the memorability without visual information, screen curtain mode was used to prevent some participants from watching the button arrangements.

Evaluation items

Regarding evaluations, the application was implemented to log a user's manipulations, including the reaction time to select a button, the positions touched by fingers, and the kinds of touch events. The interview items after the experiment were comprised by followings:

- <u>Usual manipulation method (5 items)</u>: Holding and manipulating hands of a smartphone. Whether hold or put on the device while using it. Use experiences (years) of touchscreen computers and screen readers installed on them. Current smartphones used. Familiar gestures.

- Manipulation in this experiment (6 items): Easy and difficult button arrangements in each number of buttons. The easy-to-tap shape of a button. Strategy to trace and find buttons. Method to remember buttons. Subjective strains in each number of buttons. Free answers.

Results and Discussion

Figures 2 and 3 show the reaction time and the error rates of the button selections by partially and totally visually impaired participants in each button arrangement condition, respectively. The error bars in Fig. 2 represents standard errors. According to the result of 3-way analyses of variance (ANOVA), there were significant main effects of participants' visual conditions, numbers of buttons, and button arrangements ($p < .01$). The results of Tukey honestly significant differences (HSD) test indicated that there were significant differences in all combinations of numbers of buttons, in the totally visually impaired group ($p < .01$). However, in the partially visually impaired group, though there were also significance in 4 and 12, 4 and 20 button conditions ($p < .01$), no significant difference were observed between 12 and 20 button conditions ($p = .49$). According to the interview comments by the participants, they felt mentally overloaded as buttons increased, and these overloads were reported by mainly the participants who liked two-dimensional button allocations and mainly included people with partial visual impairments. Moreover, as the buttons increased, some of them changed the style to remember buttons, from linguistically to spatially or the reverse order. These strategy changes were mainly observed in the participants with partially visual impairments. This difference may be because they usually get information from screen reader and visual cues, and they are accustomed to switching which they rely on, visual or auditory senses. On the other hand, according to the results of 2-way ANOVA for combinations of the years of experience in touchscreen computers with the reaction time or the correct rates, there were no significant main effects and interactions between these two combinations ($p >.10$).

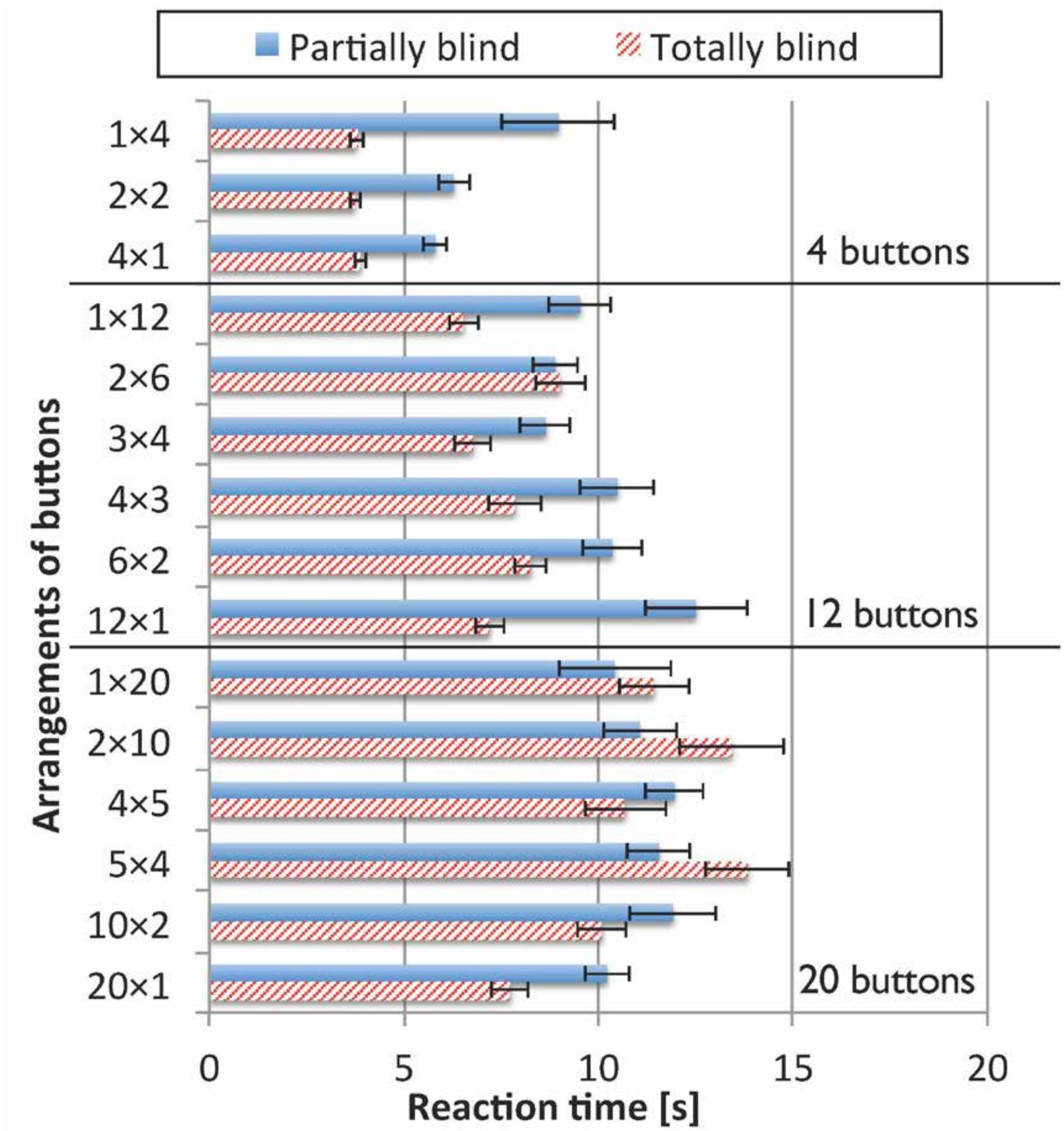

Fig. 2. Reaction time of button selection in each button arrangement condition.

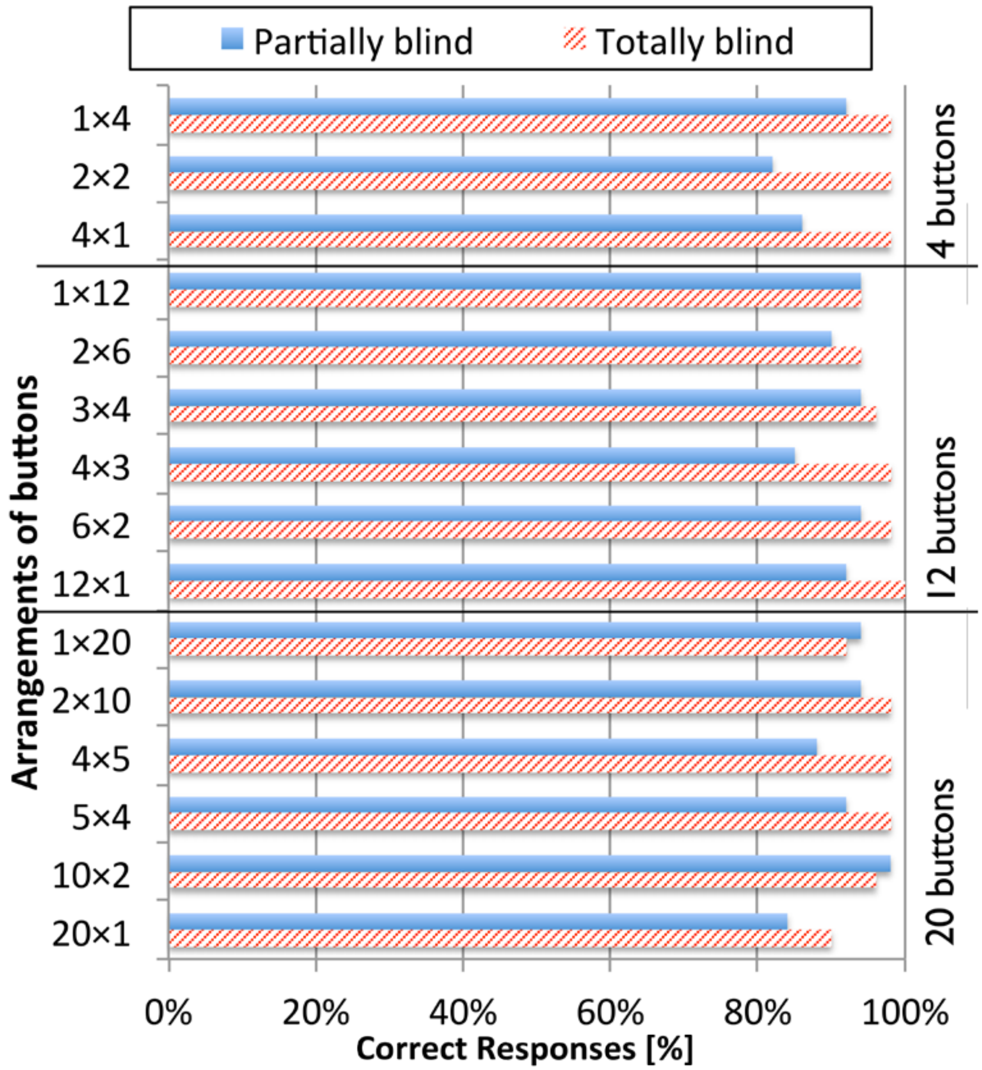

Fig. 3. Correct rates of button selection in each button arrangement condition.

In the button arrangements of 1 × 4, 1 × 12, 12 × 1, and 20 × 1, the participants with total visual impairments reacted significantly faster (Tukey HSD: $p < 0.05$). However, in the other conditions, no significant difference was observed between the two. These results may be because of the participants with partial visual impairments were less used to tracing buttons that were allocated vertically or horizontally. According to the comments of the participants with partial visual impairments, they sometimes confused to remember the button locations in these button arrangements conditions and often felt the difficulty trace the target button, particularly in the 20 × 1 condition. Besides, the results of subjective strains in each button arrangements indicated that the number of the participants who preferred two-dimensional button arrangements increased as the number of buttons increased. These results show the opposite tendency from the reaction time, but the similar tendency to the error rates.

From these results, the guideline of button arrangements in this study can be summarized as follows:

- One-dimensional button arrangements bring a user with visual impairments, particularly totally visually impaired users to a speedy manipulation experience.
- Two-dimensional button arrangements enable a user with visual impairments, especially partially visually impaired users, to robust manipulation experience.

This tendency becomes stronger as the number of buttons increases. Also, even individuals with total blindness also feel troublesome to use 1-D button arrangement with large number of buttons.

Conclusions

In order to clarify the accessible button arrangement characteristics in smartphones under a screen reader condition for visually impaired users, we qualitatively evaluated reaction times and error rates in a memory experiment of a single button from some arranged buttons. The results indicated that performance of reaction time on the button selecting task with a single button increased as the number of buttons increased; buttons aligned more similar to two-dimensional than one-dimensional allocations. However, error rates were generally lower in the case of two-dimensional button arrangements, especially in partially visual impaired users.

From these results, we summarized a design implication of button arrangement for visually impaired touchscreen users like one-dimensional button arrangements bring users with total blindness to a fast manipulation experience while two-dimensional button arrangements enable users with partial visual impairments to robust manipulation experience.

Our future work includes an evaluation of button arrangements with more numbers of buttons whose size are varied, and a proposal of a comprehensive design guideline of touchscreen interface for visually impaired users.

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